Expert knowledge elicitation in the firefighting domain and the implications for training novices

by

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Abstract

Background/Purpose: Experienced fireground commanders are often required to make important decisions in time-pressured and dynamic environments that are characterized by a wide range of task constraints**.** The nature of these environments is such that firefighters are sometimes faced with novel situations that seek to challenge their expertise and therefore necessitate making knowledge-based as opposed to rule-based decisions. The purpose of this study is to elicit the tacitly held knowledge which largely underpinned expert competence when managing non-routine fire incidents.

Design/Methodology/Approach: The study utilized a formal knowledge elicitation tool known as the critical decision method (CDM). The CDM method was preferred to other cognitive task analysis (CTA) methods as it is specifically designed to probe the cognitive strategies of domain experts with reference to a single incident that was both challenging and memorable. Thirty experienced firefighters and one staff development officer were interviewed in-depth across different fire stations in the UK and Nigeria (UK=15, Nigeria=16). The interview transcripts were analyzed using the emergent themes analysis (ETA) approach.

Findings: Findings from the study revealed 42 salient cues that were sought by experts at each decision point. A critical cue inventory (CCI) was developed and cues were categorized into five distinct types based on the type of information each cue generated to an incident commander. The study also developed a decision making model — information filtering and intuitive decision making model (IFID), which describes how the experienced firefighters were able to make difficult fireground decisions amidst multiple informational sources without having to deliberate on their courses of action. The study also compiled and indexed the elicited tacit knowledge into a competence assessment framework (CAF) with which the competence of future incident commanders could potentially be assessed.

Practical Implications: Through the knowledge elicitation process, training needs were identified, and the practical implications for transferring the elicited experts' knowledge to novice firefighters were also discussed. The four component instructional design model aided the conceptualization of the CDM outputs for training purposes.

Originality/Value: Although it is widely believed that experts perform exceptionally well in their domains of practice, the difficulty still lies in finding how best to unmask expert (tacit) knowledge, particularly when it is intended for training purposes. Since tacit knowledge operates in the unconscious realm, articulating and describing it has been shown to be challenging even for experts themselves. This study is therefore timely since its outputs can facilitate the development of training curricula for novices, who then will not have to wait for real fires to occur before learning new skills. This statement holds true particularly in this era where the rate of real fires and therefore the opportunity to gain experience has been on a decline. The current study also presents and discusses insights based on the cultural differences that were observed between the UK and the Nigerian fire service.

Keywords: *experts, tacit knowledge, decision making, decision points, critical decision method, firefighters, cues, training, and four component instructional design (4C/ID)*

Dedication

I dedicate this PhD thesis to the Almighty God, the maker of Heaven and earth, my refuge and strength and the redeemer of my soul. No one can replace you in my life and I owe all I am today entirely to you. You supplied Grace in difficult moments and provided for my needs, ensuring I did not lack throughout this journey. You became my wisdom in times of imbroglio and my focus amidst distractions. Now I can say it loud and clear that “You have won again”!

Thank you my Father, I will love and serve you all my life.

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time you call me Prof, you constantly reminded me of the journey ahead. Thank you sir. To my wonderful JCC choir, I will never forget you guys for all the love you showed me.

To everything that has a beginning there must surely be an end. I make a shout out to my notable PhD colleagues with whom I started this journey together: Natasha and Khadijah. I'm glad we made this to the end and best wishes for the future

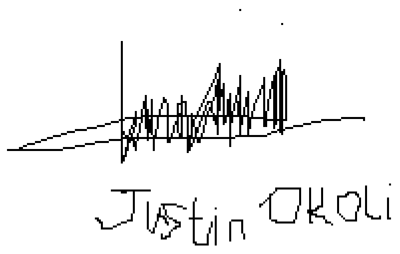
Thank you one, Thank you All!

Declaration

I declare that this work is entirely the result of my investigation and independent research and has not been submitted elsewhere for any other degree or examination.

This work is being submitted in partial fulfilment of the requirements for a Doctor of Philosophy Degree at Middlesex University

I hereby give consent for my work to be made available at Middlesex University's library repository for research purposes



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CHAPTER 1

1.0 INTRODUCTION AND BACKGROUND OF STUDY

It has been widely reported that the outcome of managing any major incident will much more depend on the way proceedings were handled on-scene and less on the possible causes or scale of the incident (Flin, 1996; Tissington and Flin, 2005; MacLennan *et al*., 2006; Lipschitz *et al*., 2007; Boin and Hart, 2007; Klein *et al*., 2010; Clancy, 2011). Hence, managing any major incident will undoubtedly require making good and timely decisions, often supported by sound domain knowledge.

Prior research has shown that firefighters typically operate in an environment that is characterized by a number of task constraints (Burke and Hendry, 1997; Omodei *et al*., 2005; Lipschitz *et al*., 2007; Kahneman and Klein, 2009; Ingham, 2008; Frye and Wearing, 2011) which include:

- Uncertainty, ambiguity and missing data
- Shifting and competing goals
- Dynamic and continually changing conditions
- Action feedback loops (distance between real time reactions and changed conditions)
- Time pressure (having to make crucial decisions in seconds)
- High stakes involved
- Multiple players/team factors that need to be effectively coordinated
- Organizational goals and norms that could negatively impact decision making

However, despite these task constraints, civilians whose lives and properties are at stake often expect a lot from fire crews. In fact, it has been shown that members of the public mainly judge the effectiveness of any response effort based on the amount of valuable properties response crews were able to salvage (Tissington and Flin, 2005; Ingham, 2008; Okoli *et al*., 2014). Thus, considering such huge expectations on fire crews, it becomes logical to expect that managing more dangerous and unpredictable fires will require the skills and knowledge of the more experienced officers.

The field of cognitive psychology has been broadly divided into two schools of thought. The first comprises scholars who believe experts are themselves vulnerable to some of the cognitive biases that are common with novices (Caverni, 2001; Gilovich, Griffin and Kahneman, 2002). This community of scholars are mainly concerned with questioning the extent to which experts' competence can/should be trusted (see Kahneman and Klein, 2009 for a review). The second school of thought consists of a body of research that explores "cognition in the wild", for which scholars are particularly interested in studying what experts know and do in the real world, and how they use their experience to solve difficult domain tasks (Hutchins, 1995; Lipschitz *et al*., 2001; Salas and Klein, 2001; McLennan, Omodei, Holgate and Wearing, 2004; Gore *et al*., 2006; Klein, 2008; Salas *et al*. 2010). The phrase "naturalistic decision making" (NDM) is widely used to describe this body of knowledge since most NDM studies are conducted in valid environments where tasks are "real" and "natural". The early study that led to this approach that is now called NDM was an attempt by Klein and his colleagues to describe the decision making approaches that were used by some group of fireground commanders (Klein, Calderwood and Clinton-Cirocco, 1986)

In contrast to the normative decision model that *prescribes* how decisions should be made, the naturalistic decision making (NDM) *describes* how people actually make decisions using their experience. In this way, NDM researchers try to learn from expert professionals by identifying the cues experts use to arrive at their judgments, even if those cues involve tacit knowledge that is difficult to articulate (Wong, 2000; Kahneman and Klein, 2009; Okoli *et al*., 2014). Thus researchers in this field, amongst other things, strive to make prescriptions based on what they learn from experts (Yates, Veinott and Patalano, 2003; Montgomery *et al*., 2005). According to Lipshitz and Ben Shaul (1996), a common feature of the NDM domain is that it uses both the intuitive and deliberative modes, which are both happening in an ongoing simultaneous cycle of thinking and acting. As Orasanu and Connolly (1993, p.19) put it: “people think a little, act a little and then evaluate the outcomes and think and act some more”. The focus of a decision maker in such domains is thus not on a single decision point or a choice dilemma, but in solving sets of dynamic and interrelated problems extremely rapidly (Burke and Miller, 1999; Wong and Blandford, 2002). A number of scholars have suggested that experts are likely to approach problems using both intuition and analysis, switching between both decision styles as conditions warrant (Goldstein and Gigerenzer, 2002; Klein, 2003; Evans, 2008; Dane and Pratt, 2009; Gigerenzer and Gaissmaier, 2011), but it still remains unclear how such sequence is followed. Do experts draw on intuition and analysis as separate ‘inputs’ when making critical decisions, or do they allow their intuition to guide their analysis, or do they make intuitive decisions first and then deliberate a bit? These questions form part of the underlying issues to be addressed in the current study. It is hoped that more insights are gained into when/how expert firefighters (both in the UK and Nigeria) utilize their intuitive knowledge while performing fireground tasks.

Prior research, starting from the seminal work of Polanyi (1962) has shown that experts are able to spot certain cues just like others do, but act upon such cues differently, and most times in ways that seem inexplicable. This is exactly the type of knowledge driving the interest of the current study ─ tacit knowledge. Tacit knowledge in this context represents the type of knowledge that comes to mind without any necessary explicit awareness of how the decision maker arrived at their judgment. This type of knowledge includes, for example, a firefighter’s decision to withdraw his firemen after sensing the potential for a building to collapse (Klein *et al*., 2010); an experienced nurse sensing the need to place a newly born baby under a closer surveillance even when the baby is not showing any visible sign of illness (Crandall and Gretchell-Leiter, 1993); a chess master seeing promising moves that are hidden from other novice players (Chase and Simon, 1973); and a qualified geneticist that is able to find out the gender of about 2,000 newly hatched chickens in one hour, with 98% rate of accuracy (Biederman and Shiffrar, 1987).

Furthermore, the study aims to compare and contrast the decision making strategies of the UK and Nigerian firefighters across both cognitive (mental processes and decision making strategies) and non-cognitive (e.g. organizational and cultural factors) dimensions. The Nigerian fire service has been accused of being highly disorganized based on evidence from their work ethics when responding to fire calls (Adedoyin and Olanrewaju, 2006; Alinnor, 2007; Esinwoke, 2011). For example, in his study covering the economic implications of fire incidents in Lagos state (the largest commercial city in Nigeria), Cobin (2013) explained that properties worth millions of dollars (and sometimes human lives) are often lost when a serious fire breaks out in the state. The author claimed serious gaps exist in the operational procedures and approaches to firefighting across some major states in Nigeria. The saddest part of the story relates to the helplessness surrounding these Nigerian firefighters when managing major fire incidents. In fairness to the firefighters, however, a few have argued that the moribund state of the fire service in the country is mainly due to the gross neglect of the institution by the Nigerian government (Esinwoke, 2011; Angus Fire, 2011; Cobin, 2013). The lackadaisical attitude of the firemen, including their late arrival to fire scenes has been attributed to the weak infrastructural and technological advancement in the fire service. What remains unclear and therefore worthy of investigation is whether or not these conditions affect the overall performance of the Nigerian fire service, and to what extent.

How do the Nigerian firefighters cope despite all the challenges they are plagued with? Would the Nigerian fire service become more effective if it were to be provided with better equipment? Would they be better-off if provided with more advanced training? What cultural differences exist from the cognitive and non-cognitive aspects of fire-fighting between the UK and the Nigerian fire service? What can the two groups learn from each other, if anything? These important questions also form part of the issues this study aims to address. It is therefore hypothesised that culture will play a significant role in the decision making process since it is one element that shapes people's beliefs, values, attitudes and work ethics.

In order to enhance the process of knowledge elicitation and contribute to existing knowledge on fireground decision making, the current study will employ a formal knowledge elicitation tool known as the critical decision method (CDM). Klein *et al*.

(1989, p.464) defined the critical decision method as “a retrospective interview strategy that applies a set of cognitive probes to actual non-routine incidents that required expert judgment or decision making”. Current evidence, based on comparison between pre-training and post-training performances of learners, suggests that the CDM when utilized for instructional design is able to increase the amount of gained knowledge by about 30% (Clark, 2014). In addition, the CDM method being a qualitative method, is hoped to provide more detailed information regarding the basis of expert competence — something NDM proponents believe is often difficult to achieve with the use of quantitative or experimental approaches (Lipshitz *et al*., 2001; Tsoukas, 2003; Lipshitz and Cohen, 2005; Klein, 2008; Nonaka and Krogh, 2009).

1.1. AIM OF STUDY

The overall aim of this study is to investigate, using the critical decision method, how expert firefighters in the UK and Nigeria make important fireground decisions and to discuss the implications of transferring elicited expert knowledge to novices.

1.2. RESEARCH OBJECTIVES

- ❑ To investigate how experienced firefighters in the UK and Nigeria make difficult decisions under various task constraints on the fireground and to capture the (tacit) knowledge that underpins experts’ judgment

- ❑ To design a conceptual model that describes the decision making strategies used by expert firefighters and to evaluate the model against other existing models in the field of cognitive psychology

- ❑ To compare and contrast the various approaches to firefighting between the UK and Nigerian firefighters, with particular interest on the cultural differences that exist between both groups.

- ❑ To discuss the implications of knowledge transfer from experts to novices using information generated from objectives 1 & 2 above.

1.2.1. RESEARCH QUESTION

The overarching question this study aims to answer is stated thus:

How can tacit knowledge best be elicited from expert firefighters particularly when it is needed to enhance instructional design for training novice firefighters?

In the attempt to provide answers to the above question, the following subsidiary questions will be addressed:

- ❑ How do experts utilize their tacit skills when managing complex non-routine incidents?
- ❑ How can elicited expert knowledge be transformed into useful knowledge outputs that will facilitate learning for potential incident commanders?
- ❑ What cognitive and contextual (cultural) differences exist between the UK and Nigerian firefighters, and what/how can the two groups possibly learn from each other?

1.3. PROBLEM STATEMENT: WHY BOTHER WITH UNDERSTANDING HOW EXPERIENCED FIREFIGHTERS MAKE FIREGROUND DECISIONS?

Research involving expert knowledge elicitation has in more recent years continued to gain prominence across a wide range of domains (Shadbolt and Burton, 1990;

Zsambok, 1997; Wong, 2000; Pliske, McCloskey and Klein, 2001; Ericsson *et al*. 2007; Sarfo and Elen, 2007). Scholars are increasingly becoming aware of the importance of examining how top managers make difficult and vital decisions while performing tasks under varying degrees of task constraints (See Hoffman, Crandall and Shadbolt, 1998 for a review). By so doing, a number of models and frameworks have been developed to describe how experts translate what they know into useful actions (e.g. Hammond *et al*., 1987; Endsley, 1995; Freeman, Cohen and Thompson, 1998; Wong, 2000; Lipshitz *et al*., 2007; Lamb *et al*., 2014). For example, in their study with urban fire-fighters Klein, Calderwood and Clinton-Cirocco (1988) showed that experienced fire-ground commanders are able to rely on their previous experiences to recognise cues in the current environment, and then deploy strategies that had been successful in the past. This insight eventually inspired the development of the now known “recognition primed decision making model” (Klein, 1997). Similarly Cohen, Freeman and Wolf (1996) in their study with active duty naval officers also developed a naturalistic decision-making framework known as the Recognition/Metacognition model. The model suggests that in high novel situations where recognizing patterns might prove slightly difficult, experienced officers tend to rely more on their metacognitive skill. In such circumstances experienced officers are more likely to employ a story building strategy — developing useful “stories” from several unrelated events to make a workable action plan.

However, despite burgeoning research in the aspect of expert knowledge elicitation, the emergence of decision making models that are particular to the domain of firefighting remain relatively rare. Yet developing useful expert models that attempt to describe what experienced firefighters know and do arguably remains one of the most crucial tasks for both current and future research. This is even more true in this present era where the rate of fires has been on a decline particularly in the UK, meaning the less experienced officers have even less chances of gaining real life experience (Lamb *et al*., 2014). This further underlines the need to develop more useful decision making models that will aid demystifying the complexity associated with fireground decision making. The model proposed in this study is deemed useful for training purposes since: (i) it was developed directly from high ranked operational commanders in the fire service (ii) it emerged from non-routine incidents that challenged experts’ skills.

The current research is further necessitated from compelling evidence that experts are not fully aware of about 70% of their own decisions and mental analysis of tasks and are therefore unable to explain them explicitly, particularly when such explanation is needed to support the design of training, assessment or job descriptions (Clark and Elen, 2006; Feldon and Clark, 2006). Hence, although experts possess extensive domain and procedural knowledge than novices (c/f Ericsson *et al*., 2007), they often still find it difficult to express what they both know and do. This difficulty provides a useful opportunity to explore more effective strategies for capturing tacit knowledge — which has been regarded as the most important type of knowledge (Polanyi, 1962; Redding, 1992; Alavi and Leidner, 2001; Clark *et al*., 2006; Feldon, 2007; Grant, 2007; Spender, 2008). The current study is therefore largely inspired by the fact that although tacit knowledge dwells in the unconscious and hence difficult to verbalize, eliciting it seems not only realistic but also worthwhile if the right knowledge elicitation tool is employed (Hoffman et al., 1995; Hoffman *et al*., 1998; Bontis, 2001; Klein *et al*., 2010; Horberry & Cooke, 2010; Okoli *et al*., 2014).

Finally, despite growing evidence suggesting that decision making within the naturalistic setting involves more than one reasoning strategy in practice, there is still ongoing debate about what the dominant thinking mode is (Dane and Pratt, 2009; Hodgkinson *et al*., 2009). There is currently little or no research agreement concerning the preferred sequence by which individuals should employ these thinking modes. It thus still remains unclear whether people should take stock of their intuition first and then engage in analysis, or whether deliberative thinking should come first before invoking the intuitive mind?

1.4. JUSTIFICATION OF STUDY: INTENDED CONTRIBUTIONS FROM THE STUDY

A few instances have been reported where subjects were seen to rate themselves as experts even when their records indicated the contrary (Kruger and Dunning, 1999; Dunning *et al*., 2003; Ericsson *et al*., 2007). These self-acclaimed experts have been termed *pseudo-experts* (Kahneman & Klein, 2009) who might not be aware “they actually do not know what they thought they knew”. Since the current study is focused on investigating what expert firefighters know and do, it is expected that the products that emerge from it will serve as a useful framework in defining who true experts are. It is also expected that a competence assessment framework (CAF) that will be developed in the study, which is a compilation of tacit knowledge that underpinned experts’ judgment, will serve as a useful tool for designing training curriculum for novices.

Secondly, the study will contribute to the body of knowledge by comparing and contrasting the decision making and problem solving strategies employed by the UK and Nigerian firefighters. Most of the existing expert studies have been conducted either within a particular geographical region or across different countries with similar cultural characteristics (Klein *et al*., 1988; Calderwood, Crandall and Baynes, 1990; Burke and Hendry, 1997; Omodei *et al*., 2005; McLennan *et al*., 2006; Lipshitz *et al*., 2007; Ingham, 2008). Rarely was any study found that compared the cognitive process of experts from two or more countries with distinct cultural orientations. For example, could it be that the competence of the UK firefighters is largely influenced by the advanced level of firefighting technology in place? Would the Nigerian firefighters be able to perform better if they had the same level of technology? “Does smart technology actually make people stupid?” Following the dearth of knowledge in this area, this study hypothesises that cultural differences in the aspect of technology would likely influence decision outcomes.

Thirdly, following Winterton, Delamare-LeDeist and Stringfellow’s (2005) definition of knowledge as the interaction between intelligence (capacity to learn) and situation (opportunity to learn), this study is designed not only to understand how expert firefighters make decisions, but also to elucidate how knowledge elicited from these firefighters can best be utilized for training purposes. This means that people must first be given the opportunity to learn before making attempts to assess their level of competence. Hannabuss (2000) identified four “states of knowing” and explained how each relates to competence (see Fig 1.1). The framework starts from a state where people show a complete lack of awareness of how little they know (unconscious incompetence) to a state where people know so much without realizing how much they actually know (unconscious competence). The current study aims to advance the competence framework by providing useful insights through which knowledge gathered from the “conscious competence” group (the expert firefighters) can be applied as a potential recipe for equipping the “conscious incompetence” group (the potential incident commanders).

Figure 1:1 Four levels of competence (Hannabuss, 2000)

1.5. ORGANIZATION OF THE THESIS

The next chapter will present a review of the literature, which will cover a wide range of themes/concepts specific to the study. Key theories, models and frameworks such as cognitive continuum theory, recognition primed decision model, recognition/metacognition model and tacit knowledge will be explored. Evidence will also be provided from theoretical, empirical and experimental studies and some of the main debates surrounding topics such as tacit knowledge, implicit learning, intuition and expertise will be evaluated.

Chapter three will discuss the research design as well as the methods employed in achieving the study aim. It will address the epistemological and ontological stance of the researcher and provide adequate justifications regarding the various tools and instruments that were employed in the study. Drawing on the research methods literature, the sampling strategy, sample size, as well as the quality control process from data collection to data analysis will all be discussed.

Chapter four will be dedicated to explaining the knowledge elicitation tool that was utilized in the study — the critical decision method. The method will be introduced and discussed in relation to its role in eliciting expert knowledge. A conscious effort will made to justify why the method was preferred to other available methods in the cognitive task analysis family. Issues of validity and reliability of the critical decision method will be discussed and some of the limitations associated with the methods will also be outlined.

Chapter five will present and discuss the results and key findings from the study. The outputs from the knowledge elicitation protocol, which include an intuitive decision making model, a competence assessment framework, a critical cue inventory, a goal decomposition table will also be presented and discussed. For ease of understanding, presentation of the findings will be done alongside with their discussion.

Chapter six will discuss the implications for learning the elicited knowledge, and suggest how such could be taught to novices. In doing so, the four component instructional design (4C/ID) will be adopted to show the breakdown of skill hierarchies, learning tasks, cognitive rules, procedural information and the pre-requisite knowledge used by the various experts. This chapter will specifically address the issue of knowledge transfer

Chapter seven will conclude the entire thesis, with relevant recommendations for the UK fire service, the Nigerian fire service and for researchers in the areas of expert studies, educational psychology, knowledge management and judgment and decision making. Possible areas for future research will also be identified and discussed.

CHAPTER 2
LITERATURE REVIEW

2.1. AN OVERVIEW OF THE FIRE-FIGHTING DOMAIN

> *Fire is a complex object in itself, and in a threatening context such as the engulfment of an inhabited building, it can create a complex environment which might in turn require a complex method of inquiry (Ingham, 2007:Para 9).*

A building on fire poses serious threats to human lives, properties, livestock, communities, local economies, natural resources and the environment at large (McLennan, Holgate, Omodei and Wearing, 2006). The complexity of managing fire incidents mainly stems from the need to manage uncertainties, ensure the safety of crew members, rescue trapped victims, manage members of the public, adhere to some of the statutory obligations binding fire fighters and verify media perceptions (Ingham, 2007). The dynamic and extremely dramatic environment where such events occur further increases the possibility of exposing firefighters to all sorts of risks and dangers (Grimwood, 2003; HSE, 1997). The unpredictable nature of the firefighting job therefore explains why firefighters still encounter novel and difficult situations that sometimes shock them, despite being equipped with advanced equipment and gadgets such as breathing apparatus, fire resistant clothing and all sorts of hose-lines (Tissington and Flin, 2005; Ingham, 2008).

Arguably, one of the main tests of character for incident commanders is that of finding possible solutions to current problems amidst uncertainty, yet finding a way to act as quickly as possible (Marold, Wagner, Schobel, and Manzey, 2012; Mitroff, 1988; Riabacke, 2006; Lipshitz *et al*., 2007). Since uncertainty in this context is defined as a sense of doubt that inhibits or delays action (Lipshitz *et al*., 2001), the dilemma therefore remains that making quick decisions on the fireground can become quite challenging as key information are sometimes not just available. As a result, decision makers find themselves in situations where they have to “think and act at the same time” (Orasanu and Connolly, 1993; Fink, 2002; Boin and Hart, 2007; Milasinovic, Kesetovic and Nadic, 2010).

The following excerpt from the work of Flin (1996) sheds more light on some of the complexities associated with firefighting, including the web of decisions that confront firefighters mostly under time pressure:

> “*On arrival at the scene of a fire, officers are bombarded with a mass of visual and other information relating to the incident, its progress and its context. On a short time scale, often under great pressure, the officer in charge must grasp the situation, understand the problem being faced, prioritize fire service actions on the basis of reasonable strategy, deploy available resources, know when to ask for reinforcements and what these should be” (*Flin, 1996, p.140*)*

2.1.1 Complex fires as a form of crisis

According to Boin and Lagadec (2000), there is no such thing as a routine crisis. Every crisis confronts decision-makers with hard dilemmas that must somehow be negotiated. An event or a series of events is therefore referred to as a crisis precisely because something out of the ordinary happened which in turn necessitates some form of intervention (Smith, 2000). Essentially, a crisis differs from other related terms such as hazard or incident in that successful decisions are not usually based on documented procedures and appropriate pre-defined responses may not exist, and even if they do, they may have conflicting meaning in practice. Those responsible for managing crises must therefore think through a situation and respond in more creative and flexible ways (Borodzicz and van Haperen, 2002). This further justifies why high cognitive demands are usually placed on operational firefighters in terms of being creative, flexible and adaptive to changing conditions (Orasanu and Connolly, 1993; Cokely, 2007). Therefore considering the level of uncertainty and unpredictability associated with complex fires, their scale and impacts, it appears logical to place such fires into the category of a crisis (Turner, 1976; Wallace, 1981;

Smith, 1990; Fink, 2002; Vakalis *et al*., 2004; Elliot & Smith, 2006; Wales and Thompson, 2013; Cobin, 2013).

Interestingly, and in line with the context of the current study, the terms “crisis” and “decision-making” have been viewed as two inseparable entities i.e. two sides of the same coin (Shrivastava, 1992; Fink, 2002; Shaluf, Ahmadun and Said, 2003). This relationship is evident from the crisis definitions reviewed below:

Table 2.1 A review of crisis definitions

Crisis definition	Author (s)
“…a serious threat to the basic structure or the fundamental values and norms of a social system, which—under time pressure and highly uncertain circumstances—necessitates making critical decisions”	**(Rosenthal, ‘t Hart and Charles, 1989)**
“…a situation that threatens high-priority goals of the decision-making unit, restricts the amount of time available for response before the decision is transformed and surprises the members of the decision-making unit by its occurrence”	**(Herman, 1997)**
….. a point of indecision; the moment when uncertainty looms at the same time as disruption.	**Ogrizek and Guillery (1997)**
a turning point for better or worse; a decisive moment, a crucial time	**(Fink, 1982, 2002)**
“A fit of uncertainty and distress where everything is in suspense.......in anticipation of imminent resolution. A sort of moment of truth and choice where everything changes fast and irreversibly”	**Boin and t’Hart (2007)**

A dominant emerging theme from the above crisis definitions is that almost all crisis situations require swift and rapid decisions. Having sound domain knowledge or understanding the cognitive rules associated with various tasks may be insufficient if officers are in the end unable to act intuitively under time pressure.

2.1.2. Dynamic Risk Assessment on the Fireground

As with many other work practices, the firefighting domain is usually characterized by a number of standard operating procedures (SOPs) that guide safe performance at the incident ground (Calderwood, Crandall and Klein, 1987). These SOPs are a combination of technical procedures (e.g. using the right type of equipment such as hose reels, main jets, ladder, fireman's axe etc.) as well as the *modus operandi* of managing incidents (e.g. splitting crews between the front and rear of a building).

In the UK, for instance, one of the philosophical rules or tenets guiding the decision making process of incident commanders is that:

- *"Firefighters will take 'some' risk to save saveable lives*
- *Firefighters will take 'a little' risk to save saveable property*
- *Firefighters will 'not take any risk at all' to try to save lives or property that are already lost"*

*(*HM Fire Service Inspectorate, 1999b, p.30)

While it is worth acknowledging that rules and philosophical principles of these sorts are useful in most high risk domains as they help establish risk tolerance levels for task operators, what remains a challenge is finding an appropriate way of interpreting phrases such as 'some risk', 'a little risk' and 'any risk at all' (Grimwood 2003; Tissington and Flin 2005; HM Government 2008). Previous studies have shown that making decisions about what is/not risky on the fireground tends be more subjective than objective (Shanteau 1992; Adams 2003; Perry and Wiggins 2008; Okoli *et al*. 2013). For example, the fact that a particular procedure is marked "high risk" in a training manual does not necessarily imply that officers must take a defensive position when faced with a similar situation in real-life. Some level of risk must be accepted and managed on the fireground. Evidence from empirical studies has shown that solving certain fire ground tasks by strictly following domain rules could sometimes be counter-productive (Burke, 1997; McLennan *et al*. 2006; Ingham 2008; Klein, Calderwood, and Clinton-Cirocco 2010)

What then is dynamic risk assessment? The DRA model as proposed by several authors (e.g. Clancy, 2011; Tissington and Flin 2005; HM Government, 2008) requires that fire-ground commanders:

- Continuously monitor and evaluate a situation, the tasks, the people and properties at risk
- Select the most appropriate systems of operation
- Assess and re-assess the chosen systems of operation
- Introduce additional controls if required
- Modify and implement action plans as events unfold

The strength of the DRA model lies in the fact that it gives decision makers the opportunity to use their experience to select the most appropriate strategy that would achieve desired response goals. Commanders are allowed to decide whether to follow the “bog standard” ways of doing things or make some level of adjustments to existing rules. Contrary to claims by the classical theorists, the model advocates that decision making is not static or linear, but highly dependent on current environmental and informational cues (Reimer and Hoffrage, 2006; Katsikopoulos, 2010).

However, since the DRA model does not indicate, for example, the precise amount of risk that should be tolerated by a commander, the experience of the decision maker therefore becomes a critical component of the model (Ericsson, Prietula and Cokely, 2007). In other words, the accuracy of the subjective interpretations that an officer would potentially make regarding an incident, as well as the decisions accruing from such interpretations depends largely on the officer’s level of expertise (Klein, 2003; Shanteau, 1992; Ericsson *et al*, 2007). Experience is vital in making critical fire ground decisions such as whether to employ an offensive attack or to go defensive, whether to commit crews into a building or become more precautionary, whether to allocate more resources at the beginning of an incident or wait till a later stage when more information must have been obtained (Liptschitz *et al*., 2007; McLennan *et al*., 2004; Omodei *et al*., 2005).

Experienced fire fighters always strive to draw from their rich base of mental model, which helps them describe, explain and predict events better (Phillips, Klein and Sieck, 2003). Since the commanders are aware that generating and evaluating a large set of options will likely cause a fire to grow out of control and then become impossible to manage, they use their experience to generate a workable option, which is usually the first, and possibly the only option they might have to consider (Johnson and Raab, 2003). These themes are discussed further in section 2.7.1

2.2. THE NATURE OF EXPERTISE IN CRISIS DECISION MAKING

It has been shown that studies within the naturalistic decision making environment are somewhat incomplete in the absence of domain experts (Shanteau, 1992; Elliot, 2005; Hoffman *et al*., 1998; Ericsson, Prietula and Cokely, 2007; Klein, Calderwood and Clinton-Cirocco, 2010). However, what remains unclear from most of the previous studies is how the cognitive functioning of experts differs from that of novices. This lack of clarity continues to generate questions in the expertise literature as researchers are becoming increasingly curious to gain a better understanding of the cognitive functioning of experts and novices (see Elliot, 2005; Phillips, Klein and Sieck, 2004). One of the fundamental challenges yet to overcome in this regard lies in defining who an expert actually is (Crandall, Klein and Hoffman, 2006; Kahneman and Klein, 2009; Ericsson, Prietula and Cokely, 2007). It is perceived that most of the confusion in the expertise literature is hinged upon the lack of consensus in agreeing at a universal definition for the term ‘expert’, with definitions varying across a wide range of disciplines and contexts (Shanteau, 1992; Shanteau *et al*., 2002; Hoffman *et al*., 1998). Many criteria for measuring expertise have been reported. For example, Klein *et al*. (1986) in their initial research with firefighters used ‘years of experience’ as a yardstick for defining experts. They suggested that a repertoire of at least 10 years of experience is generally acceptable to qualify a person as expert (Lesgold *et al*., 1988; Klein, Calderwood and Clinton-Cirocco, 1986).

Other scholars, however, argue that it is not enough to solely rely on years of experience in defining experts (Shanteau, 1989; Shanteau *et al*., 2002; Phillips, Klein and Sieck, 2004; Gore, 2006). These authors suggest that the "quality" of people's experience and the nature of the problems they solve should also be considered. In line with this logic, it is believed that experts who are more exposed to complex and non-routine tasks but have 5 years of experience are more likely to be superior to experts with 10 years of experience who mostly perform routine tasks (Hatano and Inagaki, 2000; Tissington and Flin, 2005; Feldon, 2007; Ericsson, Prietula and Cokely, 2007). This also supports the findings of Serfaty *et al*. (1997) who, in their study with battle ground commanders, revealed that good performance on job tasks was neither correlated with the participants' years of experience nor rank.

Other scholars have also defined experts on the basis of peer nomination i.e. by asking colleagues within an organization to identify who they think the experts are (Hoffman, Shadbolt, Burton and Klein, 1995). Defining experts this way seems to suggest that expertise is domain specific and that people who are external to a particular organization might have to rely on the advice of in-house staff to be able to identify individuals with exceptional abilities (Shanteau, 1992; Hoffman, Crandall and Shadbolt, 1998).

In other instances, still, the term "expert" has been defined on the basis of how competent people are in performing domain tasks. For example, Hoffman, Shadbolt, Burton and Klein (1995) reported how college students were used as experts in a wide range of studies focused on football, reading or wedding apparel. In these studies, expertise was strictly defined on the basis of how competent an individual was on any of these tasks (regardless of whether or not they were college students). On this school of thought, Means and Voss (1985) relied on the participation of nursery children who were passionate fans of the "star wars" movies in a study aimed at investigating the performances of school children across different class levels.

Two contrasting paradigms have therefore generally emerged from the expert and expertise literature, depending on the lens with which people decide to view experts. Firstly, researchers within the judgment and decision making (JDM) discipline see experts as people who are similarly prone to making flawed decisions, just like novices (for example see Meehl, 1954; Dawes, 1979; Tversky and Kahneman, 1973; Kahneman, 2003; Evan and Over, 2010; Hilbig, Scholl and Pohl, 2010). Scholars here believe experts are not necessarily immune to the cognitive biases and human factors that affect novices. On the other hand, scholars in the field of cognitive science show a significant level of trust in experts' competence (see Klein, 1993, 2003; Shanteau, 1992; Ericsson, 2004; Baylor, 2001; Philips, Klein and Sieck, 2004; Zsambok, 1997). The naturalistic decision making community which is a sub-unit of cognitive science draw inspiration from the notion that experts make better decisions than novices in all aspects of cognitive functioning (Salas *et al*., 2010; Keller *et al*., 2010; Lipschitz *et al*., 2001; Klein, 2008; Okoli *et al*., 2014)

This divergent view of expertise has perhaps encouraged further disagreement amongst scholars (Meehl, 1986; Dreyfus and Dreyfus, 1986; Driskell, Copper and Moran, 1994; Kahneman, 2003; Falzer, 2004; Gobet, 2005), which has in turn generated more questions for researchers within the field of expert studies. Some such questions include: is expertise synonymous with experience? Do experts rely on their intuition more than novices when solving complex problems? Do experts suffer from the same judgmental biases that have been demonstrated in novices? To what extent do experts display overconfidence when faced with novel situations? How best can people attain expertise?

Nonetheless, two definitions of the term 'expert' have been found to be particularly relevant for the purpose of this study. The first by Shanteau (1992) is that experts are "those who have been recognized within their profession as having the necessary skills and abilities to perform at the highest level" while the second by Kahneman and Klein (2009) used an analogy within the domain of fire-fighting to define expert in the sense that *When colleagues say, "If Person X had been there instead of Person Y, the fire would not have spread so far," then Person X is an expert in that organization.*

Although the first definition relates expertise to acquiring the right skills and knowledge while the second links it to peer nomination, the common ground with both definitions is that experts know and do better than their novice counterparts (see also Elliot, 2005; Shanteau, 1992; Glaser and Chi 1988; Ericsson *et al*., 2007; Gore, 2006; Klein, 1997; Klein, 2003; Chi and Glazer, 1981). This justifies the need to explore both the characteristics and qualities that make experts who they are.

2.3.1. Expert and Novice dichotomy: exploring the skills and strategies used by experts

Since finding a universally accepted definition for the term "expert" has proved quite challenging, some scholars have reverted into comparing the performance of experts with that of novices, using the result from such comparison as the basis for understanding who experts are (see Klein, Calderwood and Clinton-Cirocco, 1988; Crandall & Gretchell-Leiter, 1993; King and Clark, 2002; Dreyfus, 2004). It is however worthy of note that the terms "expert" and "novice" are used as relative terms throughout this thesis to refer to higher and lower levels of skills and experience (Hoffman, Shadbolt, Burton and Klein, 1995).

Experts are not necessarily better than novices because they think faster or possess a wider range of skills; they do mainly because they are able to organize and apply their knowledge and skills better through a schema-based network that makes the process of information retrieval relatively easier and less effortful (Sweller, 1994; Dreyfus and Dreyfus, 1986; Dreyfus, 2004; Calderwood, Crandall and Baynes, 1990; Means and Gott, 1988; Beach and Lipshitz, 1997; Anderson, 1982; Glaser and Chi, 1988; Phillip *et al*., 2003; Hilbig, Scholl and Pohl, 2010). Experts use their existing knowledge to facilitate situation assessment and gain a perceptual advantage as events unfold (Hutton and Klein, 1999). As a result, they are able to see what is invisible to novices such as situation typicality, identification of patterns, relationships and potential consequences of action (Lewandowsky and Kirsner, 2000; Hutton and Klein, 1999; Means *et al*. 1993; Elliot 2005). For instance, in an empirical study aimed at identifying the rules used by experts to assess roof *squishiness* (a term used to measure the structural integrity of a roof), Calderwood *et al*. (1987) discovered rather surprisingly that no visible rule exists for making such a decision. One of the experienced firefighters interviewed by the authors explained that:

"You simply have to stand on enough squishy roofs and enough un-squishy roofs until you know the difference. To a novice, all roofs are squishy". (Calderwood, Crandall and Klein, 1987, p.19).

A summary of some specialized techniques used by experts in gaining these perceptual advantage are briefly discussed below:

- *Information filtering:* Experts are able to systematically sift relevant from irrelevant information, thereby increasing the cognitive capacity of their working memory (Randel *et al*., 1996; Federico, 1995; Hutton and Klein, 1999; Hutchins, Pirolli and Card, 2004). This technique helps to reduce the risk of cognitive overload in experts since there will now be more space to accommodate useful data (Tulving, 2002). Experts organize their schemata such that they are able to ignore *mental noise*, allowing closer attention to be given to the pressing cognitive demands (Klein, 2003; Salas, Rosen and DiazGranados, 2010)

- *Chunking*: this is the ability to condense a complex and problematic task into manageable "chunks" rather than tackle as a whole entity (Dreyfus, 2004; Elliot, 2005, p.29). Managing problems in chunks helps decision makers to more easily apply various treatment strategies to each chunk in their manageable state, exactly what is required for managing complex world problems (Klein, 2003)

- *Rich knowledge base and mental model:* With the ability to organize knowledge using inferences and principles that allows the construction of rich mental model, experts tend to generally possess greater domain knowledge than novices (Crandall, Klein and Hoffman, 2006; Montgomery, Lipshitz and Brehmer, 2005; Zsambok, 1997). A Mental model is defined as a mental representation of how things work, or simply put, an internal representation of the external world (Chi and Glaser, 1981). Experts understand the dynamics of events in their domain and know how tasks and subtasks are supposed to be performed, how equipment is supposed to function, and how teams are supposed to operate (Phillips, Klein and Sieck, 2004). Their wide pool of experience also allows them to understand a situation in terms of the plausible goals, relevant cues, expectancies and typical actions (van Merrienboer, Clark and de Croock, 2002; Klein, 1993). And because experts know what to expect in advance they are then able to free up more energy to respond to the more difficult tasks (Wulf and Shea, 2002; Ingham, 2007)

- *Pattern matching:* this is the ability to address a current situation by recognizing patterns as similar to those previously stored in one's memory (Watkins, 2007; Dane and Pratt, 2007; Hutchinson and Robin, 1998). This characteristic feature of experts has elsewhere been termed recognition-triggered reasoning (Lesgold *et al*., 1988) or recognition primed decision (Klein, 1993, 1997). Experts tend to identify cues collectively (patterns), whereas novices focus more on fragmented cues without having much understanding of how cues link up (Van Merrienboer and Sweller, 2005; Crandall and Gretchell-Leiter, 1993).

- *Finding leverage points:* this is the ability to form effective improvisation strategies when faced with novel (atypical) situations – also known as *creative decision making* (Okoli *et al*., 2014). For example, Klein (1998) reported how a fire ground commander used a belt intended to secure firefighters to a ladder to rescue a woman dangling on a highway sign. According to Klein, the commander was able to mentally simulate a series of approaches aimed at rescuing the woman and eventually determined that the ladder belt would do the trick better. This creative quality is evident in experts because they spend relatively more time to analyze a situation than to deliberate on a course of action (Ericsson, Prietula and Cokely (2007). Novices tend to do it the other way round.

- *Mental simulation:* this is the ability to project the environment's status into the future (Artman, 2008). Once an option is generated, experts use mental simulation to work it through at a deeper level, looking for pitfalls and/or potential opportunities. This process is also known as *progressive deepening* (Gobet, 2005). However, the accuracy of people's mental simulation seems to be influenced by the quality of their mental model. As Salas *et al*. (2010) put it: mental simulation is simply "running a mental model".

If experts are therefore known for exceptional performances, there must likely be something that motivates them to do so. Zimmerman (2006) found a positive correlation between motivation and the development of expertise and identified four themes in the process: (i) experts are mostly propelled to set higher goals for themselves because of their high level of self-efficacy. This self-efficacy in turn increases their level of commitment in achieving their set goals (ii) experts are by default keen on improving their level of performance which explains why they tend to value continuous learning and deliberate practice (iii) experts are particularly motivated by their achievement of success and often build their confidence from their success stories. As confidence grows, the fear of failure continues to get less attention (iv) experts are naturally motivated within their domain of practice, always showing great respect for their job even when extrinsic reward falls short of their input.

The characteristics of experts can therefore be thematically summarized as:

- Expertise is domain specific ─ i.e. experts' skills are diminished outside their area of expertise.
- Experts see patterns.
- Experts are faster in thinking and make fewer errors.
- Experts have superior memory in their domain (environmental cues are an aid to recall).
- Experts see and represent a problem at a deeper level i.e. experts see what is normally invisible to others
- Experts first assess a situation before acting in order to identify the relevant cues and to understand their implications for action.
- Experts have strong self-monitoring skills *(metacognition).*

- Experts have refined perceptual abilities.
- Expertise is acquired through stages of development (e.g. increasing levels of training) and there are no shortcuts to attaining expertise
- Experts produce concrete results and superior performances than their peers
- True expertise can be measured and replicated in the laboratory (e.g. through serious games, role-playing or simulation exercises). This implies that knowledge elicited from experts can be developed into useful forms, which is then utilized for designing learning tasks.

2.4. SKILL ACQUISITION, SKILL DEVELOPMENT AND MEMORY SYSTEMS

A skill, for the purpose of this study, is defined as any combination of mental, physical or behavioral qualities that is useful for task performance and requires a considerable amount of training and practice to be acquired (Winterton, Delamare-LeDeist and Stringfellow, 2005). It can therefore be inferred that (i) skills develop over time, but with continuous practice (Ericsson, Prietula and Cokely, 2007) (ii) skills are goal oriented i.e. they are meant to respond to or address some external environmental demands (Anderson, 1982) (iii) the acquisition of skills is facilitated when components of behaviour are structured into coherent patterns (Rasmussen, 1983), and (iv) the cognitive efforts required for the application and utilization of skills are drastically reduced as skills develop (Proctor and Dutta, 1995).

Four categories of skills have been broadly identified in the cognitive science literature: (i) *perceptual skills* ─ the ability to make clear distinctions and judgments and to discriminate between and within cues (Phillips, Klein and Sieck, 2004; Calderwood, Klein and Crandall, 1988); (ii) *response selection skills/ decision-making skills* ─ the ability to choose the most workable option from the various available alternatives (Klein, 1997; Alberti, 2002; Flin, O'Connor and Crichton, 2008); (iii) *motor skills* ─ concerned with the manual aspects of performance e.g. the speed and accuracy of physical movements (Proctor and Dutta, 1995; Wulf and Shea, 2002; Winterton *et al*. 2005); and (iv) *problem-solving skills* ─ the ability to creatively proffer solutions to novel challenges and atypical problems (Proctor and Dutta, 1995;

Ingham, 2007; Cokely, 2007; Falzer, 2004). Besides the motor skills, which are non-cognitive skills, the other three skill categories are all classified as cognitive skills.

In their book entitled “Safety at the sharp end: a guide to non-technical skills”, Flin, O’Connors & Crichton (2008) used the term *non-technical skills* (NTS) to differentiate between the more “obvious” technical skills and the tacit (soft) skills, and strongly criticized the notion that possessing technical knowledge about a task is sufficient for effective performance. The authors made a strong case to justify why professionals must also possess non-technical skills (NTS) in addition to their technical knowledge. Non-technical skills generally represent the cognitive and social skills of team members, not directly related to the control of a system or standard operating procedures (SOP), but that complement the technical skills and contribute to safe and effective performance of tasks (Crichton and Flin, 2008; Fletcher *et al*., 2003; Flin, O’Connor and Mearns, 2002; Proctor and Dutta, 1995, p.262; Keller *et al*., 2010). The authors identified seven non-technical skills which includes communication, leadership, stress management, fatigue management, situation awareness, teamwork and decision-making (Crichton and Flin, 2004; Flin, O’Connors and Crichton, 2008). In explaining the value of NTS, Endsley and Garland (2000) observed that about 85% of the accidents that occurred in the aviation industry were as a result of pilots losing their situation awareness at critical points on motion despite possessing ample technical skills.

Understanding how skills develop in people over time has been shown to facilitate a better understanding of experts’ cognitive architecture (Elliot, 2005; Shanteau, 1992; Glaser, 1987; Spender, 2008). However this would require that one first understands how skills are committed to the memory (Winterton, Delamare-LeDeist and Stringfellow, 2005). Below is an outline of the basic principles involved in learning, memorizing and utilizing skills, based on the work of Welford (1968) whose early research focused on examining various aspects of skilled performance. Welford posits that all the stages in the framework must have to take place before a skill can be effectively learnt or transferred:

- The actor must understand the task (material must be perceived and comprehended).
- Material must be held in short term memory (STM) until there is time for a more permanent registration to take place.
- A memory trace has to be established and must be able to withstand any form of interference.
- The memory trace must endure (must not be distorted) until time of recall.
- The actor must be able to recognize an appropriate situation to apply the information stored in the memory.
- Material stored in memory must be recovered correctly
- Recalled material should be used to produce a workable action

Consistent with Welford's model of skill acquisition, Shanteau (1992) categorized the process of skill development into three different but inter-related stages. The first stage is what he referred to as the *cognitive stage* where specific facts are committed into memory through rehearsal (Anderson, 1982). The second is the *associative stage* where links are made between facts and attempts are made to reduce interference from the outside environment (Cooper, 1998; Eraut, 2004). Finally, the *automatic stage* is where the links formed in the associative stage become smooth and continuous; where task performance requires only minimal conscious effort (Feldon, 2007; Dane and Pratt, 2009; Klein, 2003; Falzer, 2004).

In essence, before a skill can be used to aid performance, it has to firstly be stored in the memory, retrieved and then converted into behavior (Tulving, 2002). Routinized skills and previous experiences are stored in the memory for ease of recollection (Tulving, 1989).

2.4.1. What is memory?

Although a complicated subject, attempts have been made over many decades to define what it is and how it operates. William James, one of the founders of Psychology defined memory as "the present conscious awareness of an event that has happened in the rememberer's own past" (Williams, 1890; cited in Tulving, 1989). The initial assumption had been that people are able to retrieve useful information from their memory only if they were also able to recollect the key events that took place at the point of information encoding (Tulving, 1985). But over the years, this assumption was debunked as new studies began to reveal that both the knowledge of learned facts and the recollection of past events represent operations of different memory systems (Cooper, 1998; Tulving, 1989, 2002; Anderson and Schooler, 2000). It was also shown that these memory systems are most times independent of each other.

Three memory systems have been distinguished and widely reported in the literature: (i) *Procedural memory* — which enables individuals to retain learned associations and connections between cues and actions so as to avoid learning those associations over again. Simply put, procedural memory is where the knowledge of "how best to do things" is stored. (ii) *Semantic memory* — stores factual knowledge and ensures that individuals are able to construct their own meaning of the external world. It includes such things as types of cars, name of countries, social cultures, functions of equipment, vocabulary, understanding of subjects, etc. (iii) *Episodic memory* — ensures that previous episodes and events are stored such that individuals are able to mentally "travel back" and retrieve particular information from their past experiences.

How then do people manage to access information in their memory when needed? This question refers to the operation of short-term memory (Tulving, 1989; Sweller, 1994; Azuma, Daily and Furmanski, 2006). STM represents a "temporary store" where effortful and conscious internal computations are performed (Cooper, 1998; Cowan, 2008). It is also designed to remind us about facts that have previously been stored in long term memory, for the sake of precision when performing current work tasks e.g. when recalling a specific event (analogue) from among the many episodes that are chunked together in the memory (prototypes). It therefore implies that skills, if not properly learnt or correctly stored in long term memory, may prove difficult or even impossible to recall (Paas and van Merrienboer, 1994).

However, understanding how skills in individuals develop over time does not seem an easy task as other factors other than the characteristics of the skill also influence the learning of skills (Ericsson *et al*., 2006; Dane and Pratt, 2009; Horberry and Cooke, 2010; Ericsson, 2006; Phillips, *et al*., 2004). These include for example, the learning environment, learner's level of engagement and motivation, individual attitude of learners as well as their talent level (c/f Pollock *et al*., 2002). The difficulty in understanding how skills develop in people have led a number of scholars to propose an alternative way of understanding the process of skill development i.e. by examining the various developmental stages of expertise and consciously monitor skill performance at each stage (Dreyfus and Dreyfus, 1986; King and Clark, 2002; Dreyfus, 2004; Ericsson, Prietula and Cokely, 2007; Winterton *et al*., 2005). As opposed to concentrating on the 'ready-made' experts, this approach will provide a clearer assessment of how human cognition develops with expertise.

Studies have attempted to compare the cognitive architectures of novices and experts as a way of understanding skill development (Calderwood, Crandall and Klein, 1987; Dreyfus and Dreyfus, 1986; Chase and Ericsson, 1981; Calderwood, Crandall and Baynes, 1990). Dreyfus (1972) identified six developmental stages along the chain of expertise: *Novice* — *Advanced* — *Beginner* — *Competent* — *Proficient* — *Expert*. Similarly, Hoffman *et al*. (1995) identified seven developmental levels using completely different terminologies from Dreyfus: *Naivette* — *Novice* — *Initiate* — *Apprentice* — *Journeyman* — *Expert* — *Master*.

2.4.2. Skills, Rules and Knowledge

The notion that experts are able to perform recurrent aspects of tasks due to their extensive domain knowledge has been widely reported in the cognitive science literature (Sweller, 1994; Anderson and Schooler, 2000; Paas, 2005; Cowan, 2008; Clark *et al*., 2014). These authors attributed this ability mainly to the efficient functioning of schemas. Schemas contain rules and procedures that can systematically link particular features of a problem to a possible course of action (IF condition, THEN action). In other words, experts use the general knowledge they have about a domain, or the knowledge they are able to recall from concrete cases, or knowledge from both to form action plans and solve new problems (Klein, 1998; 2003). On this note therefore, a direct relationship seems to exist between the *skills* possessed by experts, their *knowledge* of the domain and the domain *rules* that guide their actions.

Ten Berge and Van Hezewijk (1999) identified two major types of knowledge used for task performance: declarative knowledge (knowing-that) and procedural knowledge (knowing-how) and argued that both knowledge types are not competitive but complementary to each other. Declarative knowledge supports performance through conceptual understanding of the procedures and principles that surround particular tasks or domain in general (Anderson, 1983). It is often expressed verbally and explicitly by professionals as it is made up of stored facts and events (Tulving, 1985; Anderson, 2000; Nonaka and Takeuchi, 1995; Nichols, 2000; Cowan, 2008).

The acquisition of declarative knowledge begins by learning skills in hierarchically structured and sequential patterns (Clark *et al*. 2006). As experts acquire more skills and gain more domain knowledge, their declarative knowledge automatically becomes more extensive, thereby requiring a more structured and coherent organization of the various cognitive elements. Such organization takes place in schemas, and it is this schema-based network that makes information retention and recall possible for domain experts with a high degree of accuracy (Orasanu and Connolly, 1993; Elliot, 2005; Lipshitz and Strauss, 1997; Falzer, 2004; Salas, Rosen and DiazGranados, 2010).

The challenge, however, is that declarative knowledge is insufficient for generating skilled performances or for subsequent use in designing training materials (Ritter *et al*., 2007). This is because experts can unintentionally misrepresent the conceptual knowledge upon which their competence is based: a paradox where professionals are able to refer to scientific data, theoretical manuals and SOPs in clear explicit terms, yet use such knowledge in ways that are largely *tacit* (Skriver and Flin, 1996; Nichols, 2000; Tsoukas, 2003; Eraut, 2004). It therefore appears that expert performance is qualified by another type of knowledge other than declarative knowledge, which is procedural or automated knowledge — also known as knowledge of knowing-how (Eraut, 2004; Cooke, 1994; Cooper, 1998). Knowledge of wine tasting, maintaining balance while riding a bicycle or crafting a violin are all typical examples of this type of knowledge (Nonaka and Krogh, 2009)

It is true that experts sometimes apply certain rules and procedures to arrive at their judgments, however, analyzing such rules have only provided limited information regarding how decisions were actually made (Polanyi, 1962; Shanteau *et al*. 2002; Ingham, 2008). At best, “rules” and “methods” are useful in explaining this type of knowledge only after solutions to problems have been proffered, not before (Dörfler and Ackermann, 2012). For example, Cooke and Breedin (1994) found that knowledge elicitors were unable to arrive at the same conclusions with expert physicists even after adopting exactly the same procedures and explanations stipulated by the experts. This therefore implies that procedural knowledge operates outside the conscious awareness of professionals (Reber 1989; Eraut, 2004; Hogarth, 2003) and involves a good understanding of how a system operates (how to do things). This knowledge type is thus a compulsory requirement for all skilled performance and is characterized by both situational and strategic procedural qualities i.e. assessing, deciding, acting and monitoring (Billett, 2010; Wei and Salvendy, 2004).

Without adequate knowledge about a particular procedure, skills cannot be transferred for solving difficult problems (Feldon, 2007). One of the features of higher level competence is that knowledge becomes increasingly ‘proceduralized’ and readily converted into skills (Dörfler & Ackermann, 2012). Simply “knowing that” (declarative knowledge) is not enough for most job tasks in high reliability organizations such as firefighting. Knowing what to do with what is already known and knowing how to combine what is known differently is usually of greater importance in these domains (Shanteau *et al*., 2002).

On this note, one of the main differences between procedural knowledge and declarative knowledge is therefore that the former has more utility over the latter. This means procedural knowledge has already been contextualized and ready for use, whereas the latter is still based on other people’s perspectives and therefore not readily available for use (Ten Berge and Van Hezewijk, 1999; Eraut, 2004).

2.5. TACIT KNOWLEDGE AND TACIT KNOWING: POLANYI'S PERSPECTIVE

> *"Something that we know when no one asks us but no longer know when we are supposed to give account of it is something we need to remind ourselves of"*
>
> *(Wittgenstein, 1958: No 89)*

Michael Polanyi, a chemist turned philosopher, was the first person to use the term *tacit knowledge* — a term that has now become popular in the knowledge management literature (Nonaka and Takeuchi, 1995; Tsoukas, 2003; Grant, 2007). In his article entitled "do we really understand tacit knowledge" Tsoukas (2003) noted that Polanyi is an author who has been heavily referenced, but whose work is actually understood by only a few. Polanyi's main line of thought is that creative acts (or acts of discovery) are imbued with strong personal feelings and commitments, and that knowledge is highly dependent on human action. These assertions were well documented in his early work, specifically in one of his most famous books titled *Personal Knowledge*. In the book, Polanyi (1958, p.3) refuted the then dominant belief that science was value-free, arguing instead that the informed guesses, gut-feelings and intuitions which are part of exploratory acts are motivated by what he called 'passions'. The assumption that codified (or theoretical knowledge) is totally objective was the major bone of contention for Polanyi. He argued that taking a closer look at how the so called codified knowledge is used in practice reveals it is grounded on "personal judgments" and "tacit commitments", implying therefore that theoretical or codified knowledge is not as objective, or explicit, or self-sustaining as it was taken to be at the time (Polanyi, 1962, 1966; Grant, 2007).

All forms of knowledge contain what Polanyi (1962, p.17) termed *personal coefficient*. It is this personal knowledge that makes the interpretation of facts or application of knowledge unique from one individual to another — since individuals acquire and utilize skills differently. To him all knowing is *personal*, to which the knower necessarily participates in all acts of understanding — what was also termed "participation through *indwelling*" (Polanyi and Prosch, 1975, p.44).

To simplify the above, Polanyi presented a map reading scenario. A map, according to him, is an explicit representation of a particular territory which, in logical terms, is not different from a theoretical system or a system of rules (in this case enabling the map user to move from point A to point B). To use a map, Polanyi identified three things the user must do: (i) they must identify their current position on the map ("I am here") (ii) they must find their route on the map (e.g. "I want to get to the train station, which is 2 miles away") and (iii) they must identify the routes on the map using various landmarks that allows them get to their destination (e.g. "I have to get past the clinic and then turn left"). The salient point here is that a map cannot read itself no matter how elaborate or well-designed it seems; it will require some level of judgment and interpretation from its user who will have to relate the map to the outside world through cognitive and sensual means (Polanyi, 1962)

However, since every act of knowing contains a *personal coefficient*, which is evidenced through skilful performance, how much influence then does an actor have on their skilled performance? For Polanyi, an actor actually achieves skilled performance by observing a set of rules they know little or nothing about e.g. a cyclist does not normally know the rule that helps them maintain good balance on the bicycle neither does a swimmer know the rule that keeps them afloat. Interestingly, being ignorant to these rules is not necessarily detrimental to task performance since a rule is effective in guiding actions in the first place only when it has been *assimilated and "lapsed into unconsciousness"* (Polanyi, 1962, p.62). For example, in learning how to drive, one can learn a great deal about how to use the gear box or how to press the accelerator, but to be able to drive, such knowledge has to *lapse into unconsciousness.*

Do individuals actually know how to exercise their skills? Polanyi (1962) believes they usually don't, instead a mental effort is mostly relied upon (along with its accompanying *heuristic effect*). This mental effort captures and incorporates other elements of a situation, provided such elements are related to the task at hand, without the performer knowing them as they would appear in themselves. The features of the elements are *subsidiarily* known by the actor as long as they contribute to the task being performed. Putting it in Polanyi's words:

> "*This is the usual process of unconscious trial and error by which we feel our way to success and may continue to improve on our success without specifiably knowing how we do it" (italics in the original). This is how we invent a method of swimming without knowing that we actually regulate our breath in a particular manner"*
>
> (Polanyi, 1962, p.62)

In exercising one's skills, Polanyi identified two different kinds of awareness; one he called *subsidiary* and the other *focal*. Using the scenario of "hitting a nail with a hammer", he explained that the carpenter, for example, is aware of both the nail and the hammer, but in different ways. The main object of attention for the carpenter is to drive the nail down (which s/he is *focally* aware of), but in doing so, the carpenter is also aware of the feelings of holding the hammer in their palm (*subsidiary awareness*). This feeling is not the object of the decision maker's attention, but an instrument of it. To perform the task well, we can therefore say that the carpenter has a *subsidiary awareness* of the feelings in his hand which is then merged into his *focal awareness* of driving the nail.

If we switch our focal attention to features of which we initially had only subsidiary awareness of, their meaning is lost, which will affect performance negatively. For example, a pianist who shifts their attention away from the musical piece to focus on their finger movement; a public speaker who shifts attention away from the speech to focus on individual phrases that make up each sentence; a carpenter who shifts attention away from hitting the nail to focus on how the hammer was being held, would all struggle to perform at optimum capacity. In order to make skilled performance more effective, actors must therefore rely subsidiarily (tacitly) on some features while attending to the main tasks i.e. knowing a set of features without being able to identify them (Polanyi, 1966).

One of the insights from Polanyi's work relates to how he perceived the relationship between tacit knowledge and explicit knowledge to be. Whilst some scholars (e.g. Nonaka and Takeuchi, 1995; Ten Berge and Van Hezewijk, 1999; Clark *et al*., 2006) have viewed tacit and explicit knowledge as competitive, Polanyi largely believes in their complementarity. He explained that the two systems are mutually inclusive and that knowing is only possible when tacit and explicit knowledge are integrated.

Putting this in his words:

> "*Now we see tacit knowledge opposed to explicit knowledge; but these two are not sharply divided. While tacit knowledge can be possessed by itself, explicit knowledge must rely on being tacitly understood and applied. Hence all knowledge is either tacit or rooted in tacit knowledge. A wholly explicit knowledge is unthinkable"* (Polanyi 1966, p.7 — italics in the original)

Polanyi noted that although these sub-conscious processes (subsidiary awareness) are aimed at discovering 'truth', they are not necessarily in a form that can be expressed formally. In other words, personal judgement cannot be prescribed by rules, they rely essentially on the use of our senses. As Polanyi puts it in what most believes to be one of his most remarkable phrases*:*

> *'We can know more than we can tell*'.
>
> (Polanyi, 1966, p.4)

Drawing on Polanyi's work, Tsoukas (2003) conceptualized tacit knowledge using a triangle, with each of the corners representing *subsidiary features*, *focal target*, and the *knower* who joins the two. No knowledge is therefore possible without integrating subsidiary awareness with focal target ─ an *act* which can only be carried out by the performer. It is in this regard that Polanyi referred to all knowledge as *personal* and all knowing as *action.* For him, there is no significant difference between tangible instruments such as a probe (for a dentist), a map (for a geographer), a hammer (for a carpenter), or a hosereel (for a firefighter) on one hand, and intangible constructions such as linguistics, scientific knowledge, radiological or cultural knowledge on the other hand — they are all *tools* that enable people perform their tasks effectively. Thus, to use a tool effectively we must assimilate it and dwell in it, otherwise our use of the tool will become clumsy and get in the way of getting tasks done. Hence, for a tool to be used effectively it must become an instrument through which we carry out our actions subsidiarily, and not an object of attention. In Polanyi's original words:

> "*We may say that we learn to use language, or a probe, or a tool, and thus make ourselves aware of these things as we are our body, we interiorize these things and make ourselves dwell in them" (Polanyi, 1969, p.148 — italics in the original)*

Polanyi emphasized this notion of *indwelling* in most of his publications (Polanyi, 1958, 1962, 1966). To dwell in a tool, for him, simply means that one *uncritically* accepts the tool and *unconsciously* commits to it. A novice driver, for example, will still be conscious of what to do; he feels the impact of the pedals as he presses his leg on them as well as the impact of the gear lever on his palm. He has not learned to unconsciously integrate the movement of the car with the specific bodily actions he undertakes as a driver. The experienced driver, on the other hand, is unconscious of his driving procedures because they have been *interiorized* (or mastered) and is therefore able to use them automatically for the purpose of driving.

2.6. AUTOMATICITY: IMPLICATIONS FOR INSTRUCTIONAL DESIGN

Automaticity, which is regarded as one of the hallmarks of expertise, has been conceptualized as the act of executing cognitive procedures effortlessly (Ericsson, 2000; Baylor, 2001). It is acquired by consistently and repeatedly mapping stimuli to responses over a given period of time, until such procedures become routinized

(Anderson, 1982; Anderson and Milson, 1989; Sweller, 1994; Wulf and Shea, 2002; Feldon, 2007). Although skill acquisition begins with the learning of procedures, attaining automaticity however requires deliberate and continuous practice of what was learnt (Chase and Ericsson, 1981; Anderson, 1982; Wegner, Erber and Raymond, 1991; Schempp *et al*., 2007). This association gets better through practice and procedures become less effortful over time and eventually takes a 'second nature' position in professionals.

To be able to cope with the inadvertent pressures associated with performing time-pressured tasks in dynamic environments, managers need to develop automated knowledge (Matzler, Bailom and Mooradian, 2007). Automated knowledge helps to relieve the working memory of excessive cognitive load, thereby freeing up mental energy for handling the more difficult problems (Sweller, 1994; Sarfo and Elen, 2007; Clark *et al*., 2014). In effect, when the skills required to perform a particular task become automated, such a task can be performed alongside other tasks with little or no interference.

At the other extreme, however, automaticity has been regarded as the greatest threat to attaining expertise (Ericsson, 2004; Clark and Feldon, 2008). If we take *expertise* to mean successful adaptation to unusual tasks, as opposed to routine tasks, and *automaticity* as the ability to perform a given procedure unconsciously, it then appears the latter contradicts the principle of adaptive and reflexive practice — which are themselves key features of expertise. Furthermore, concerns have been raised regarding the effect of automated knowledge in the design of training curricula e.g. knowledge could become so internalized that experts struggle to explain what they know or do (Tulving, 1989; Hannabuss, 2000; Paas, Renkl and Sweller, 2004; Clark *et al*., 2006; Feldon, 2007; Clark, 2014).

Prior research has identified a negative correlation between people's ability to recount the principles governing task mastery on one hand, and the level of skills they possess on the other hand (Broadbent, 1977; Broadbent, Fitzgerald and Broadbent, 1986; Eraut, 2004). These studies showed that highly skilled individuals struggled more to explicate "what they know" than the less skilled ones. In a particular study, Ericsson and Simon (1993) analysed the "think aloud" protocols of both experts and novices and found that novices were more likely to recall the memory traces surrounding their cognitive processes than their expert counterparts. This was attributed to the fact that novices performed their tasks in ways that were deliberate and stepwise, thereby leaving a memory trace in the process. Experts, in contrast, start to take “shortcuts” unconsciously, owing to their wide domain knowledge (Eraut, 2004). These shortcuts, on the long run, begin to impair the “replicability” of their performance.

The ease of access to memory trace, the ability to recall and/or verbalize pre-stored information and the willingness to deliberately travel back memory lanes have all been shown to have huge implications for instructional design (Wiley, 1998; Tulving, 2002; Pollock, Chandler and Sweller, 2002; Paas *et al*., 2003; Clark *et al*. 2006; Feldon, 2007; Cowan, 2008). Despite compelling evidence that most routine tasks are performed *tacitly* (Polanyi, 1962; Wegner, 2002; Dreyfus, 2004; Grant, 2007; Spender, 2008), experts sometimes deny this fact and instead prefer to attribute most of their actions, if not all, to intentional (deliberative) thinking. This cognitive bias has been termed *doctrine of concordance* (Tulving, 1989). When people fail to acknowledge the link between automaticity and expertise, they can start to fabricate *consciously* reasoned explanations for their *unconscious* actions during knowledge elicitation, albeit, unintentionally (Ericsson and Simon, 1993; Wiley, 1998).

To illustrate the above claims further, Eraut and his colleagues studied a group of nurses and midwives to understand how they utilize scientific knowledge in their domain of practice (Eraut, Alderton, Boylan & Wraight, 1995). The authors focused on six themes from which the respondents were asked to narrate recent incidents that contained any of the themes. Data obtained from the study was analyzed and a series of knowledge maps that had aspects of the scientific knowledge on one hand, and the activities carried out by the participants on the other hand were developed. As expected, the authors found that the experienced nurses had more awareness of the rules and procedures binding their work practice, but were helpless in accounting for this knowledge when required to do so (for details see Eraut, Alderton, Boylan and Wraight, 1995).

2.7. THE CONCEPT OF INTUITION

"The intuitive mind is a sacred gift and the rational mind is a faithful servant. Unfortunately, we have created a society that honours the servant and has forgotten the gift"

(Albert Einstein, 1879–1955*)*

Defining intuition is seemingly a difficult task as it is a concept that deals with *tacitly* held knowledge which is, itself, difficult to verbalize and articulate (Hannabuss, 2000; Hogarth, 2003; Tsoukas, 2003; Nonaka and Von Krogh, 2009). As a process that operates within the sub-conscious realm, intuition has generated a great deal of controversy in the fields of cognitive science and decision making (Gilovich, Griffin, Kahneman, 2002; Hogarth, 2003; Acker, 2008; Waroquier *et al*., 2010). Some scholars perceive intuition and its outcome (intuitive judgment) as a mysterious concept that is far from any scientific measurement (Meehl, 1986; Lamond and Thompson, 2000; Caverni, 2001; Bonabeau, 2003; Maqsood, Finegan and Walker, 2004). Others, though not denying that intuition is an important part of human cognition, remain adamant that the outcome of such process would, more often than not, provide a favourable ground for judgmental bias (Kahneman and Tversky, 1982; Meehl, 1986; English, 1993; Paley, 1996, 2006; Dana and Dawes, 2004; Gigerenzer et al. 2008; Evans and Over, 2010). In the words of Albert Einstein, modern society has been taught to mistrust intuition, preferring explicitly articulated expressions, theoretical or codified knowledge instead (Albert Einstein, 1879–1955).

One of the reasons that has been attributed to most of the controversies surrounding the concept of intuition is that it lacks the monolithic definition and the well-defined qualities that are characterized with the deliberate/analytical/rational strategy (Bargh and Morsella, 2008). For instance, an analytical thinker should typically be able to display some level of intentionality, accessibility to awareness and high mental engagement, and will therefore not to be seen as an analytical thinker in the absence of any of these qualities. In the world of intuition, unfortunately, no such overt "expression" yet exists to assess intuitive thinking. The main bone of contention for sceptics is thus the lack of “transparency” of the so called intuitive knowledge i.e. the fact that the underlying values and beliefs supporting someone’s decisions are only known to the person (Lamond and Thompson, 2000). This lack of explication, according to critics, may also be considered morally reprehensible. According to Pellegrino:

> *“To resort to terms like ‘art’ or ‘intuition’ is to impede explication of a socially significant process. Whatever name we use to subsume the indefinable elements in the process, the effort to explicate them further is a moral as well as an intellectual responsibility” (Pellegrino,1979, p.187)*

Thankfully, the scientific measurement of intuition and how it can be taught is increasingly gaining ground in recent years across disciplines such as management, education, healthcare, military, informatics and firefighting. (Hogarth, 2001; Klein, 2003; Tanner, 2006; Plessner and Czenna, 2008; Dane and Pratt, 2009; Salas, Rosen and DiazGranados, 2010; Dörfler and Ackermann, 2012; Okoli *et al*., 2015). The following reasons have been attributed to the relentless effort shown by scholars who have, over the last two decades, continued in their pursuit to gain a better understanding of intuition and how it can be better utilized at the workplace:

- The limitations of the so called analytical approach in coping with the requirements of dynamic and time-pressured environments
- The feeling that intuition is probably one of the least understood aspects of human cognition
- A belief that gaining a better understanding of intuition and its scientific measurement will go a long way to guide more meaningful conceptualization of human cognition (Khatri and Ng, 2000; Isenman, 1997; Sinclair and Ashkanasy, 2003; Nonaka and Von Krogh, 2009; Salas, Rosen and DiazGranados, 2010).

In his important book entitled “The power of intuition” Klein (2003), who although acknowledged that our intuition can sometimes be flawed, suggested we are all intuitive decision makers and can rarely survive or excel in life without it. Prior research has shown that intuition is an integral part of human decision making and cannot be replaced by any form of data, analysis or rules (Khatri and Ng, 2000; Matzler, Bailom and Mooradian, 2007; Hayashi, 2001; King and Appleton, 1997; Klein 2003; Hogarth, 2003). The work of Waroquier *et al*. (2010) revealed that individuals who often fail to trust their intuition generally come across as the poor decision makers and are likely to remain so. In the study, subjects were first asked to create a first impression, after which they were presented with a decision task (the task of choosing an apartment). Decision mechanisms were then tested against three different conditions. The first set of participants were asked to make their choices immediately they received information about the task was, the second set were given another task before being asked to select their choices (with the aim of distracting them), while the last set of participants were allowed to deliberate and think consciously (for about 4mins) before selecting their choices. Findings from the study showed that participants who responded immediately made the best decisions about the apartment, but only when their first impression was *rich.* In contrast, the last set of participants made the poorest decisions as the subjects were tempted to re-adjust and redefine their first impressions. Subjects in the last group were consciously re-examining their memory in search of attributes that relates to the apartment — a process known as *option deliberation (*Johnson and Raab, 2003).

The main insight that was generated from the above study was that unconscious thought process is superior to the conscious/deliberative strategy, not necessarily because deliberation is in itself a wrong thing to do but because too much deliberation tends to disrupt the naturally flowing first impressions (Phillip, Klein and Sieck, 2004)

If we are to advance the concept of intuition beyond its current state then merely developing our newly gained knowledge into frameworks that are theoretically sound might prove insufficient (Sinclair and Ashkanasy, 2005). The first step to making the concept of intuition less mysterious, as suggested by Sinclair and Ashkanasy (2005), is to refrain from definitions that tend to portray it by what it is not. Definitions such as “anything that does not fit into the category of analysis or rationality” should be discarded as intuition is not the opposite of analysis. Similarly, a number of authors have advised that care must be taken when describing intuition using affective and emotional phrases such as sixth-sense, gut feelings, instinct, foreboding, inner feelings, common sense, premonitions, hunches and presentiment as these could encourage sceptics to continue to question the scientific base of the term (Polanyi, 1962; King and Appleton, 1997; Dane and Pratt, 2009; Burke and Miller, 1999; Khatri and Ng, 2000; Dijksterhuis, 2004; Matzler, Bailom and Mooradian, 2007).

What then is intuition? Dane and Pratt (2007) defined it as ‘affectively charged *judgments* that arise through rapid, non-conscious, and holistic associations, while Sinclair and Ashkanasy (2005) defined it as a non-sequential information processing mode which comprises both cognitive and affective elements and results in direct knowing without any use of conscious reasoning. Regardless of the way it is being defined, a general consensus amongst scholars is that intuitive judgment incurs little or no information processing costs and enables individuals to quickly integrate multiple reasons in their decisions in a compensatory way (Hodgkinson et al., 2009; Hilbig, Scholl and Pohl, 2010; Katsikopoulos, 2010). Intuition therefore supersedes mere emotions; it is not a magical sixth sense neither is it a paranormal process but an integral part of our daily experiences of memory.

In the course of this research, seven distinct characteristics of intuition were identified and compiled across the literature (Isenman, 1997; Gilovich, Griffin and Kahneman, 2002; Sinclair and Ashkanasy, 2005; Kahneman, 2003; Hogarth, 2003; Salas, Rosen and DiazGranados, 2010; Acker, 2008; Dörfler and Ackermann, 2012). The first four relate to the *process* itself i.e. intuiting, while the last three apply to the *outcome* i.e. intuitive knowledge:

Intuiting itself:

- is fast, rapid and instantaneous
- requires *unconscious* processing of information and a minimal mental effort
- is *alogical* i.e. neither logical (does not follow the rules of logic) nor illogical (does not contradict the rules of logic)
- is frequently accompanied by emotion

The outcome of the intuitive process:

- is usually *tacit* i.e. intuitors find it difficult to describe how they arrived at their judgment
- is *holistic* – information is processed holistically i.e. unconnected elements are integrated to generate more meaningful insights.
- is such that the intuitors feel *confident* about their judgment, despite not having a clear evidence to justify their chosen course of action. According to Sinclair and Ashkanasy (2003), intuition is usually accompanied by a sense of assurance, which is what differentiates it from mere guesses.

One of the most recent contributions that have been made on the subject of intuition can be traced to the work of Dörfler and Ackermann (2012). Building upon the work of Polanyi (1962), the authors attempted to categorize intuition into two distinct forms: intuitive judgement and intuitive insight. Although Dörfler and Ackermann (2012) were not the first to categorize intuition, their work was found particularly important in advancing current research on intuition. The motivation of their research stemmed primarily from the fact that most of the studies on intuition seemed to have emphasised its role in judgment/decision making (*intuitive judgment)*, with little or no emphasis on its creative role (*intuitive insight)*. In substantiating their argument, the authors made reference to one of the most influential phrases in the field of psychology:

> *"It is by logic that we prove, but by intuition that we discover"*
>
> (Poincare, 1914, p.129)

The role of mindfulness in gaining and maintaining intuitive insights is also beginning to gain attention in the literature (Herndon, 2008; Dane, 2011; Dörfler and Ackermann, 2012). The term *mindfulness,* which holds a different meaning from deliberative thinking, has been defined as a state of consciousness in which attention – both internally and externally – is focused on present-moment phenomena (Weick and Sutcliffe, 2001). To be mindful, individuals must be strictly attentive to the "here and now" as opposed to being preoccupied by other mind wandering thoughts about the past or future (Herndon, 2008). This thus suggests why revelation mainly occurs when the conscious mind finally exposes what the sub-conscious mind had already known (Klein, Moon, Hoffman, 2006a; Klein, Moon, Hoffman, 2006b; Hayashi, 2011). Mindfulness attunes individuals to the operations going on within the unconscious system thereby shedding more light to intuition ─ discovering new insights (Ackoff, 1989; Dane, 2011; Hogarth, 2001; Yi *et al*., 2008). Unfortunately, not all intuitive thoughts receive adequate attention; some arise and disappear in the absence of any conscious focus from the decision maker.

A good illustration of how intuition can be used to generate creative insights through mindfulness was demonstrated by Doctor Apgar, whose work to date has been credited for the reduction in infant mortality (Apgar, 1953). Before Apgar got her revelation in 1952, the field of medicine was plagued with inconsistencies and a lack of standardized procedures for determining whether or not a new born infant was in distress. Physicians and midwives were allowed to use their clinical judgment to determine how much help a baby that was perceived to be in distress needs. As a result, cues were identified and interpreted differently by various medical officers. But the breakthrough started when a medical resident asked how Apgar would personally assess the health conditions of a new born baby. That's easy, she replied, you would do it like this ─ Apgar listed down five variables (heart rate, respiration, reflex, muscle tone, and colour) against three scores (0, 1, 2, depending on the severity of each of the variables). Following her encounter with the young resident doctor, Apgar herself began rating infants by this rule one minute after they were born. A baby with a total score of eight or above was likely to be pink, crying, squirming, grimacing, with a pulse of 100 or more, and such baby is adjudged to be in good fit. Conversely, a baby with a score of four or below is likely to be bluish, lifeless, passive, with a slow or weak pulse and would likely need an immediate intervention. Apgar's score has, till date, provided a considerable level of consistency to doctors and midwives in determining which babies were in desperate need upon delivery (Adapted from Kahneman, 2011: 227).

2.7.1 Intuition, expertise and memory Systems

Over the last decade or so, cognitive researchers have sought to validate intuition as a scientific discourse, evidenced from the increasing number of theoretical models and frameworks that have been advanced (Khatri and Ng, 2000; Wong, 2000; Hayashi, 2001; Hogarth, 2003; Klein, 2003; Sadler-Smith and Shefy, 2004; Klein *et al*., 2006; Rosen, Shuffler and Salas, 2010; Frye and Wearing, 2011; Dorfler and Ackermann, 2012). The main reason that people, and sceptics in particular, find the concept of intuition less scientific has been attributed to their lack of understanding on how it relates to experiential knowledge or other macro-cognitive processes (Anderson and Schooler, 2000; Tulving, 2002; Horstmann, Ahlgrimm and Glöckner, 2009). In their important article entitled *conditions for intuitive expertise: A failure to disagree,* Kahneman and Klein (2009) argued people will often marvel at the story of a fire fighter who, for instance, had a sudden urge to escape a burning building just before it collapsed (simply because the firefighter knew the danger intuitively "without knowing how he knows"). The authors however explained that the mystery of knowing without knowing is not necessarily a distinctive feature of intuition but the norm of mental life. People learn implicitly on a daily basis without knowing when, how or where learning took place (Tulving, 1989; Dodgson, 1993; Fessey, 2002; Eraut, 2004).

The relationship between intuition and the human memory is demystified from the early works of Simon (1992) who defined intuition as: *the situation has provided a cue; the cue has given the expert access to information stored in the memory, and the information provided the answer*. Dreyfus and Dreyfus (1986) put it more succinctly as: *intuition is nothing more and nothing less than recognition.*

Yet a few scholars still remain sceptical about the validity of some of the information that is recalled from the human memory (Tversky and Kahneman, 1973; Gilovich, Griffin, Kahneman, 2002; Paley, 1996, 2006; Kahneman, 2003). Lamond and Thompson (2000) using the term *falsae memoriae* argued that people are sometimes not able to fully recollect past events from their memory, contrary to claims made by proponents of intuition. The term was also used to explain the act of *deja vu* i.e. a feeling people have that they have been in a situation before, whether true or false. The authors therefore advocated for an analytical way of making high-staked decisions with the notion that people are not always guaranteed to remember their past.

Whilst it is true that people do learn implicitly and from past experiences —whether good or bad — it appears worthwhile, for the purpose of the current study, to examine how the information that supports intuition gets committed into memory and recalled when needed. Klein (2003) defined intuition as *the process of translating our experience into action.* This definition is consistent with the assumption that every individual is embedded in a continuous flow of experience throughout their lifetime, consciously or unconsciously, implying therefore that the quality of people's intuition will only be as good as the experience upon which it was built (Eraut, 2004, Gobet, 2005; Billett, 2010).

One of the simplest ways of describing the *modus operandus* of intuition is by thinking of it as an advanced pattern recognition mechanism. That is, the subconscious mind somehow finds a link between a current situation (e.g. the problem to be solved) and the various "patterns" that had been stored in memory, mainly from past experiences (Eraut, 2004). The sub-conscious mind rapidly projects the new problem onto the pre-stored patterns and then sends a "message of wisdom" to the decision maker. The message often comes as an inner voice and is most times expressed in the language of one's feelings, in the form of calmness or relief, or as a burst of enthusiasm and energy (Khatri and Ng, 2000; Hayashi, 2001; Matzler, Bailom and Mooradian, 2007). The onus is thus on decision makers to understand the best way through which the "voice of wisdom" is conveyed to them. By so doing, they will also be able to differentiate more easily between correct intuitions and other "emotional noise" (Ackoff, 1989; Weick, 1993; Sinclair and Ashkanasy, 2003)

Similar to the notion of intuitive decision making is the concept of phronesis, which originated from Aristotle (2002) in his book titled the "Nicomachean Ethics". Aristotle distinguished between three types of knowledge — episteme, techne, and phronesis. Episteme represents universal truth, objective, scientific (explicit) knowledge that focuses on universal applicability and therefore context-independent. Techne roughly translates to technique, technology and art and is context-dependent, unlike episteme. It is the practical (tacit) knowledge required to solve a problem ("know-how"). Finally, phronesis, which roughly translates today as prudence, ethics, practical wisdom or practical rationality, often encompasses the first two (Von Krogh and Nonaka, 2008). Phronesis is generally understood as the ability to determine and undertake the best action in a specific situation to serve the common good, hence its notion as an intellectual virtue (Eisner, 2002; Nonaka and Toyama, 2007). "*Phronesis is acquired through the effort to perfect one's craft, which makes one a virtuous artisan" (Nonaka and Toyama, 2007:378)*. Phronesis is the synthesizing glue that joins "knowing why" as in scientific evidence, with "knowing how" as in hands-on skill, and "knowing what" as in goal to be realized. It is the ability to synthesize a general, universal knowledge with the particular knowledge of a concrete situation as actions originate from a current environment. Hence, in managing complex incidents phronetic leaders must be able to synthesize contextual knowledge accumulated through real-life experience, with universal knowledge gained through training (Nonaka and Toyama, 2007)

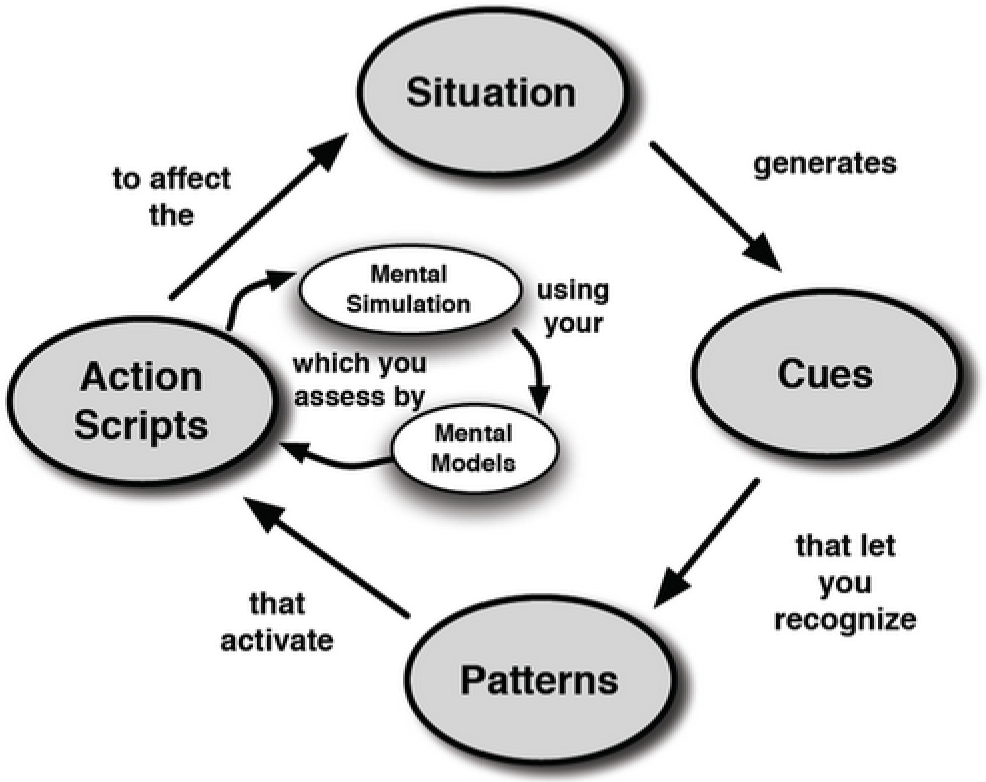

Figure 2:1 The Pattern Recognition Process (Klein, 2003, p.26)

The recognition/metacognition model (Fig. 2.1) shows the relationship between intuitive decision making and experiential knowledge. The model suggests a sense of a situation is potentially gained once a pattern is recognized. Following the pattern recognition process, the decision maker is then able to predict the most important cues to focus on, the goals to pursue, the likely things to expect and more importantly how best to react —*action scripts* (Klein, 1998; 2003). While patterns tell experts what to do, action scripts suggests how things should be done. One important aspect of the model is its inclusion of a "decision check" component where decision makers have the opportunity to mentally simulate, test and validate their action scripts before acting (Klein, 1997; Driskell, Cooper and Moran, 1994; Calderwood, Klein and Crandall, 1988; De Groot, 1978). The model also posits that the quality of experience people have gained over time largely determines the quality of their action scripts. This obviously has implications for training in that individuals with less experience should first be made to enrich their mental models, build sufficient patterns and gain more real life experiences before thrown into tasks that require mental simulation (Cohen, Freeman and Wolf, 1996).

The relationship between pattern recognition and intuitive decision making can therefore be summarized thus:

- Cues let us recognize patterns
- Patterns trigger action scripts
- Action scripts are assessed and refined through mental simulation
- Mental simulation is underpinned by mental models.

It is important to note that not all intuitive judgments come from skills (Dijksterhuis, 2004; Waroquier, Marchiori., Klein, Cleeremans, 2010; Evans and Over, 2010; Doherty, 1993; Gilovich, Griffin and Kahneman, 2002). Hence, although incorrect intuitions just like the valid ones tend to arise from the operations of memory, the mechanisms that produce them only operate in the absence of skills (Lesgold *et al*., 1988; Winterton, Delamare-LeDeist & Stringfellow, 2005; Kahneman, 2011). The difficulty is that people have no clear-cut way of knowing where their intuition originates from, neither is there any subjective marker that distinguishes correct intuition from those produced by highly imperfect heuristics (Kruger and Dunning, 1999; Dunning *et al*., 2003). More so, checking the authenticity of one's intuition is an effortful operation of system 2 (the effortful cognitive mode) and people are sometimes lazy to carry out such mental task.

A distinction has therefore been made between expert-based intuition and the more general intuition, on the basis that the former is built upon extensive domain-specific knowledge. For example, King and Clark (2002) studied how different nurses across four levels of expertise (advanced beginners, competent, proficient and expert nurses) utilized their intuition. Findings from the study showed that all the nurses, regardless of their level of expertise, employed both intuitive and analytical decision making styles. However the rate of use of intuition and the level of confidence associated with intuiting were found to increase as the nurses climbed the ladder of expertise. In another study, Baylor (2001) provided an interesting insight as she attempted to differentiate between mature and immature intuition using a U-shaped curve (see Fig 2.2 below). The X-axis of the curve represents the level of expertise while the Y-axis represents the rate at which intuitive decisions were made. Similar to experts, novices also relied on their intuition to make difficult decisions only that their intuition were found to be *immature* compared to those of experts. Baylor (2001) used the term immature to explain a type of intuitive knowledge that is not built upon extensive-rich-domain knowledge.

According to Baylor, as novices gain more experience and advance along the chain of expertise the rate at which they rely on their intuition decreases. This is because a higher level of expertise consequently increases the scope of task difficulty, thereby placing additional cognitive demands on operators. This additional cognitive demand essentially pushes the “potential experts” to the more analytical end as they will now require more time to process the various task related information. This is shown at the bottom end of the U shaped curve in Fig 2.2. But as individuals approach the upper scale of expertise the use of intuition once again becomes the dominant decision making strategy. At this stage, a minimal mental effort is required to process various task related informational cues. Interestingly, the mature intuition that was described by Baylor (2001) at the upper scale of expertise has also been referred to in the literature as *educated intuition* (Hogarth, 2001); *intuitive expertise* (Kahneman and Klein, 2009); *intuition-as-expertise* (Sadler-Smith and Shefy, 2004) and *expert-based intuition* (Salas *et al*., 2010).

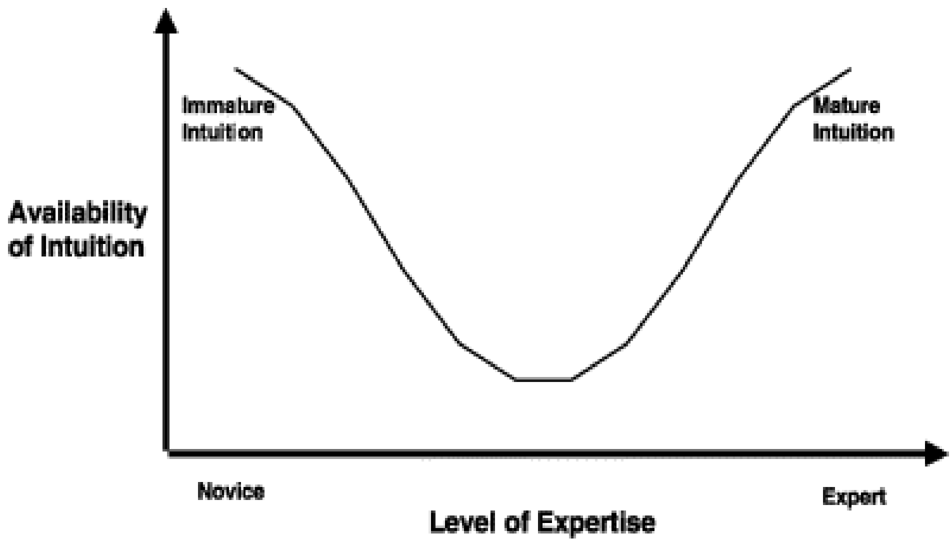

Figure 2.2: A U-shaped model of the development of intuition by level of expertise (Baylor, 2001)

Notwithstanding that expert intuition has generally been perceived to be more trustworthy than that of novices, a few concerns have been raised regarding if and when it should be trusted (e.g. Shynkaruk and Thompson, 2006; Kahneman and Klein, 2009; Kahneman, 2011). For instance, in his book entitled "Thinking fast and slow", Kahneman (2011, p.240) explained that the confidence people attach to their intuition does not necessary correlate with its validity but that people's intuition should only be trusted when the following two conditions have been met:

- the task environment is sufficiently regular to be predictable i.e. an environment that is able to generate valid cues to support action plans

- actors have had the opportunity to learn the regularities in the environment through prolonged practice and training

In the absence of the above two conditions, the author argued that an intuitive judgment will mostly be based on "trial and error". However, since true skills cannot easily develop in irregular or highly unpredictable environments, performers in such environments have to rely more on chance than on experience to make the right decisions (Arkes, 2001). This explains why experts' intuition in unpredictable (or wicked) environments (such as stock markets, nuclear power plants) has been advised to be treated with caution and suspicion (Kahneman, 2011)

2.8. OVERCONFIDENCE IN EXPERTS

In reality, experts need confidence, intelligence, and moral strength to be able to make difficult and complex decisions, such traits, however, must be tempered with prudence, openness and an accurate appraisal of skills so as to avoid overconfidence (Messick and Bazerman, 1996). The act of overconfidence poses a serious threat to decision making, with the real danger lying in people's reluctance to seek additional information to update their knowledge bank (Kruger and Dunning, 1999; Dunning *et al*., 2003; Doherty, 1993; Hallinan, 2009). This reluctance could sometimes be as a result of "failure of success" syndrome i.e. the illusion that solutions will always emerge just as they have done in the past (Kets de Vries, 1991).

Terminologies such as *egocentrism* (Bazerman and Watkins, 2008) and *narcissism* (King III, 2007) have been used to describe certain type of experts who overly pride themselves as infallible. King III (2007) warned that such egocentric behaviour provides a fertile ground for overconfidence to grow if not checked. There is compelling evidence from both theoretical and empirical studies to show that experts do not always have control over all the possible factors that aid effective response (Dawes, 1979; Smith, 1990; Shanteau, 1992; Weick, 1993; Messick and Bazerman, 1996; Wegner, 2002). Some experts ignorantly deny this "uncertainty view" of the world and hold on to the deterministic nature of events, exaggerating the extent to which they can control crisis events. This act has elsewhere been termed *illusion of control* (Messick and Bazerman, 1996) or *illusion of superiority* (Gasaway, 2013). In the firefighting domain for example, some factors (task constraints) have been identified that often exceed the remit of expertise (Grimwood, 1992; Gasaway, 2012). These include extreme adverse weather conditions (e.g. intense wind speed, high external temperature), fire behaviour (backdraft and flashover) and human errors (mistakes, stress).

The concern about overconfidence is not new; early researchers have previously made attempts to challenge the validity of expert judgment (Simon, 1955; 1956; Meehl, 1954; Oskamp, 1965; Tversky and Kahneman, 1971; Dawes, Faust and Meehl, 1989). For example, Meehl (1954) in one of his experimental studies showed that predictions made from statistical computations were found to be superior to experts' predictions. In another study, Oskamp (1965) tested the level of competence displayed by 32 judges using 25 multiple-choice personality judgement questions on a published case. The judges were allowed to read through sections of the case before being assessed and findings revealed that although competence did not necessarily increase as the judges gained more information, the level of confidence increased significantly and steadily as more information was acquired. Simply put, confidence continued to increase as more information was received to the point that judges became overconfident. Unfortunately, overconfidence, on this account did not translate to better performance.

There is evidence to suggest that the judgment of experts is not always accurate. For example, Kahneman and Klein (2009) revealed two conditions in which experts' judgment should be trusted i.e. a valid environment with identifiable cues and a prior experience of events. They argued that trusting experts' judgement solely on the basis of years of experience or the extent of subjective confidence could be misleading. Other authors have also shown that people's account of expertise can sometimes be "over rated" and should therefore not be taken at surface level (Meehl, 1986; Shynkaruk and Thompson, 2006; Dunning *et al*., 2003).

Most of the questions raised by previous scholars have over the years necessitated the need to further investigate overconfidence in experts. Researchers now seem to be interested in knowing how subjects/participants are been recruited for participation in expert studies. This includes, but not limited to, having pre-set criteria to discriminate between 'real' experts and 'pseudo-experts' (Kruger and Dunning, 1999; Ericsson et al. 2007; Shanteau *et al*., 2002). For example, in his paper entitled "competence in experts" Shanteau (1992) warned that knowledge elicitors could easily be cajoled into interviewing self-acclaimed experts rather than real experts.

Kahneman (2011, p.239) described these self-acclaimed experts as ‘pseudo-experts’ who have no idea that they do not know what they think they know.

While confidence is thus a good trait that needs to be developed by professionals, subjective confidence on the other hand is mostly illusive and misleading. The main challenge, however, lies in differentiating between the two. Kahneman and Klein (2009) noted a useful rule of thumb for making such differentiation:

> *“True experts, it is said, know when they don’t know, and that non-experts (whether or not they think they are) certainly do not know when they don’t know”* (Kahneman and Klein, 2009, p.524)

Subjective confidence is thus an unreliable indication of how valid one’s intuition is (Shynkaruk and Thompson, 2006). People often assume they are right when the story they tell comes easily to mind (cognitive ease) with little or no contradictions or opposition (coherence) (Evans and Over, 2010). Unfortunately, findings have shown that cognitive ease and coherence do not guarantee that a belief held with confidence is true (Messick and Bazerman, 1996; Kahneman, 2003; Hallinan, 2009). Although some actors actually recognize the fact that they are skilled (conscious competence), but remain largely unaware of the boundaries of their skills and when they are likely to be betrayed by them (Krunger and Dunning, 1999; Johansson, Hollnagel, and Granlund, 2002; Dunning *et al*., 2003; Kahneman, 2011, p.241). This is another fertile ground for overconfidence.

Furthermore, the extensive knowledge and skill sets possessed by experts can also serve as a potential source of overconfidence. When experts attain a certain level of competence they resort to mainly relying on automated knowledge. This sometimes means ignoring certain cues which they feel are not worth attending to and focusing on the more relevant and pressing cues (Rasmussen, 1983; Feldon, 2007; Salas and Klein, 2001; Pliske, McCloskey and Klein, 2001; Horstmann *et al*., 2009; Myers, 2002). The danger, however, lies in missing out or ignoring some important cues simply because an operator is not familiar with them (Dane, 2011; King III, 2007). Klein (2003) used the term *fixation* to explain how actors can sometimes choose a particular course of action and tenaciously cling to it without the willingness to compromise. This tendency has been termed *cognitive narrowing* (Weick, 1993); *tunnel vision* (William, 1985) and *failure of foresight* (Turner, 1976), all of which have the effect of limiting the creative power of decision makers. A number of scholars have shown that experts are significantly more likely to approach problems with a flexible and adaptive mindset while novices on the other hand tend to be more rigid with the way they develop and implement their action plans (Calderwood, Crandall and Baynes, 1990; Paley, 1996; Baylor, 2001; Dreyfus, 2004). A commander's adherence to false and erroneous perceptions may create a breakdown in collective sense-making of a crisis management team such that shared perceptions about risk and success fail to align with current situation (Lagadec, 1997).

Another consequence of *fixation* is that experts may be tempted to actively "explain away" data that appears unfamiliar to them (Perrow, 1999; Klein, Moon and Hoffman, 2006b). In one study, for example, Ingham (2007) reported how a commander discarded the reading from a firefighting appliance as incorrect, with the assumption that the appliance was faulty. Further analysis from the study showed that the commander's conclusion was mainly influenced by a mis-match between the recorded data and his expectations (mental model). What people perceive to be useful information is what actually appears relevant to their world — both in data and meaning (Spender, 2008). Meanings are therefore lenses that individuals put over the data they receive, through which they are able to bring data into their world.

Overconfidence can prevent experts from objectively challenging their pre-conceived belief about a particular course of action (Turner, 1978; Kahneman 2011, p.225). Moreover, even when the need for additional information is acknowledged, processing such information may be biased to conform to prior beliefs and hypotheses. This cognitive tendency has been termed *belief bias* (Evans, 2007) or *confirmation bias* (Bazerman, 2008).

What then can experts do to be able to mitigate the risk of overconfidence? The recognition-metacognition (R/M) framework which was pioneered by Cohen, Freeman and Wolf (1996) seems to provide a useful guide. The framework provides a systematic way of explaining how best experts can develop action plans under novel conditions, especially where pattern recognition proves less helpful. The main strength of the model is the fact that decision makers are able to conduct a series of cognitive tests before implementing any course of action (Thompson, Cohen and Freeman, 1995; Lipshitz and Cohen, 2005; Frye and Wearing, 2014).

2.8.1. Recognition/Metacognition Model

The role that experience plays in intuitive decision making has been widely reported in the naturalistic decision making literature (Shanteau, 1992; Federico, 1995; Flin, 1996; Falzer, 2004; Gore *et al*., 2006; Klein, 2008; Hoffman and Militello, 2008). A number of models have been developed in the field of cognitive psychology to describe how actors make decisions, and each model is focused on one or more macro-cognitive elements e.g. situation awareness, sense making, teamwork, pre-planning etc. (Klein 2003; Endsley, 1995; Lipschitz and Strauss, 1997; Cohen *et al*. 1996). For instance, the recognition primed decision (RPD) model (see section 2.11.3.1), which appears popular as a prototypical decision making model in the naturalistic decision making community, holds that proficient decision makers are mainly “recognitionally skilled” i.e. are able to recognize familiar situations from the repertoire of patterns stored in their memory, accumulated over years of deliberate practice (Gobet, 2005; Fessey 2002; Shanteau *et al*., 2002). According to Klein (2008), these patterns are what help decision makers to recognize the most relevant cues, provide expectancies, identify the main goals to be pursued, and then suggest the most plausible action plan. Simply put, the RPD model suggests that experienced officers mostly rely on patterns recalled from previous experiences (in the form of cues, expectancies, goals and actions) to solve current problems. But in their study aimed at investigating how actors make decisions in novel and time pressured environments, Cohen *et al*. (1996) emphasized one of the limitations of the recognition primed decision model. The authors drew attention to the possibility of rare or novel situations occurring that could altogether defy existing knowledge. This insight eventually propelled them to develop another useful cognitive model which they termed the recognition/metacognition (RM) model. Thus in contrast to the RPD model which suggests that proficient decision makers often rely on recognized patterns in solving current tasks, the R/M model argues that decision makers must, in addition to being recognitionally skilled, be metacognitionally skilled.

The model, as shown in Fig 2.4 below follows a two-tier process:

- An activation stage where action scripts are developed through pattern recognition
- The *critiquing* and *correcting* stage where the products of recognition are evaluated where and when necessary.

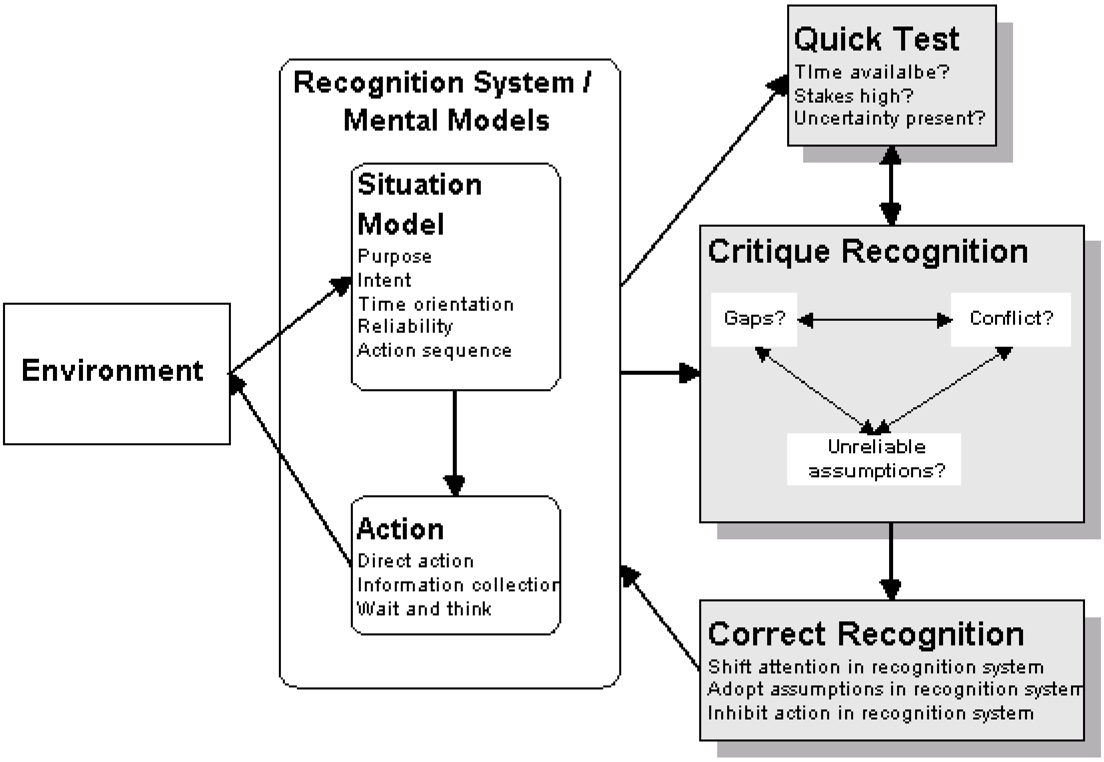

Figure 2.3 The Recognition-Metacognition Model (Cohen et al. 1996, p.5)

Together, these two processes help in building, verifying and modifying the mental model of the decision makers even as events unfold (Calderwood, Crandall & Klein, 1987).

Quick test: A quick test is a control function that helps decision makers decide whether to immediately act on a recognized pattern or delay actions a bit more (Calderwood *et al.*, 1987). The decision to conduct a quick test and the extent to which the test should be conducted are influenced by several factors such as the level of stakes involved, how familiar the current situation is, and the amount of time available to make decisions (Lipshitz and Strauss, 1997). During a quick test, the mental model of the decision maker is subjected to cycles of critical thinking till the point where the cost of further delay becomes too high. The quick test stage is quite important when making high-staked decisions since the urge to act often tends to precede reflective thinking (Bargh and Morsella, 2008).

Critiquing & Correcting: Critiquing involves a deliberate act to search for faults in one's mental model and to deal with such faults accordingly (Proctor and Dutta, 1995). Through critiquing, three kinds of faults can be identified in a potential action plan: (i) incompleteness — when there is not enough information with which to formulate an action plan (ii) unreliability — where information to support potential actions or goals is subject to alternative interpretations or questionable premises (iii) conflict — a situation where available data, although reasonably supporting a proposed action plan, seems to contradict expectations of the decision maker (Lipshitz, Klein, Orasanu and Salas, 2001)

Correcting, on the other hand, is aimed at responding to identified problems or knowledge gaps accruing from the critiquing process. Correcting might also require that further observations are made, that additional information is generated, that current assumptions are revised, or all of the above (Azuma, Daily and Furmanski, 2006).

The strength of the R/M model therefore lies in the fact that the critiquing and correcting phases are *iterative*, so that solving one problem in a proposed action plan could eventually result in identifying a new/unforseen problem (Kaempf *et al*., 1996). For example, it would be expected that a decision maker would fill in the required gaps in the event that a proposed action plan was found to be incomplete (e.g. by collecting additional information). However, in the process of collecting additional information some form of cognitive conflicts could be generated if the new information appears to be inconsistent with the mental model of the decision maker. At the same time, an attempt to resolve the generated conflicts might also require, for example, that assumptions about the trustworthiness of the sources of information are questioned. Hence, through this iterative process decision makers continue to improve their understanding of a situation.

2.8.2 Team decisions

The dynamic nature of crisis environments, mostly characterized by complexity, ill-defined goals and time-pressure, has encouraged research in the area of team decision making and support systems (Shanteau, 1992; Desanctis and Gallupe, 1987). Developing and maintaining an effective crisis management team has hence been regarded as one of the most important steps towards building good crisis management culture (Gore, Banks, Millward and Kyriakidou, 2006; Crichton and Flin, 2004; Flin *et al*, 2002).

In reality, the demands encountered when responding to crises are usually beyond individual capabilities (Paton and Flin, 1999). No single individual can possibly cope with the collective pressures associated with task constraints or with the intellectual resources required for solving complex crisis problems. This therefore implies that a combined team effort usually exceeds contributions from individual team members (Alexander, 2000; Paton and Flin, 1999; Paris, Salas and Canon-Bowers, 2000; Zander 1982; McLennan, Holgate, Omodei and Wearing, 2006). Furthermore, a team seems to have better retentive ability, known as *transactive memory* — a shared system for encoding knowledge (Wegner, Erber and Raymond, 1991). A team can collectively remember more information than even the best single individual in the team (Elliot, 2005).

Good teamwork provides a number of benefits, for instance, it facilitates decisions and actions by accelerating the flow of information and resources, increases the variety of perspectives and skills available, fosters synergistic contributions and enhances access to essential resources (Salas and Canon-Bowers, 1993; Zander, 1982; Flin, O'connor, Crichton, 2008). Psychological research has also shown that teamwork generates a higher degree of motivation among team members. In other words, people tend to be more confident when they realize that the physical or mental pressure associated with solving a difficult task is somehow shared amongst the team members (Descantis and Gallupe, 1987; Salas 2003).

Lave and Wenger (1991) in their seminal work introduced the term community of practice to explain the notion that learning is not a property of individuals or the representations in their heads (the cognitive view), but rather a more relational property of individuals in context and in interaction with each other (the situated view). The concept of communities of practice, which has now gained popularity in the literature, has been used by scholars to describe the way learning takes place within a social as opposed to a conventional didactic setting; amongst groups of people who share a burden, a set of problem tasks, or a passion about a theme, and hence deepen their knowledge and expertise in these areas by interacting on an ongoing basis (Lave and Wnger, 1991; Lave, 1993; Wenger, McDermott and Snyder, 2002, p.4; Erden, Von Krogh and Nonaka, 2008; Hoadley, 2012, p.288). As members of a "community" of practice spend time together, they implicitly begin to share information, develop insights, and build cognitive patterns, developing what Erden, Von Krogh and Nonaka (2008) called *Group tacit knowledge*

Johnson and Johnson (1987) defined a "team" as a structured setting in which each member of a group has a role and works interdependently towards fulfilling a meaningful goal. For the purpose of this study the term "team" was preferred to "group" for a number of reasons. First, a team has a history and a future whereas a group most times gets disbanded after achieving specific short-term tasks (Paris, Salas and Cannon-Bowers, 2000). Also, cohesiveness might be irrelevant in a group since arriving at good decision outcomes is usually the primary objective. On the other hand, whilst effective task performance is also a desired objective for teams, ensuring cohesiveness amongst the team members is even more crucial. Strong morale, long term cooperation and conformity to group norms are all important factors that can sustain a team (Desanctis and Gallupe, 1987). Hence, one of the major tasks for future research in the aspect of team decision making lies with finding a desirable balance between optimum task performance and team cohesion (Pennington, 1986).

But how can team performance be made more effective? Several possible options have been reported in the literature. The first is by addressing the way information is communicated among team members. The pattern through which information flows within a team has been shown to determine, to a large extent, the decision making strategy that is adopted by incident commanders (Azuma, Daily and Furmanski, 2006). Two main communication styles are common in the crisis communication literature depending on team size, task type and the time available for making decisions (Desanctis and Gallupe, 1987; MacMillan, Entin and Serfarty, 2004; McLennan, Holgate, Omodei and Wearing, 2006). These are: (i) open communication, which is more demographic and where an incident commander seeks support from other team members (ii) a restricted communication structure, which is a more militaristic or autocratic approach and limits the level of contribution that can be made by team members at any given time.

Studies have, however, shown that employing the open communication style is mostly problematic in time-critical and high staked domains such as firefighting (Flin, 1996; Orasanu and Martin, 1998; Grimwood, 1992). This is because collaborative decision making under time pressure and attempts to justify potential courses of action are likely to slow down the speed of events and subsequently affect overall team performance (Dane, 2011; Dickson, McLennan and Omodei, 2000).

Team effectiveness can also be enhanced by properly managing the perceptual and cognitive differences that exist amongst team members. It has been shown that differences exist in the way various officers perceive what is more/less risky and how they recognize and interpret different cues. Such perceptual differences could even get more complicated if the team has a wide variation in their level of expertise (Dreyfus and Dreyfus, 1986; Baylor, 2001; Salas, 2003). In such circumstances, most authors believe cognitive differences amongst team members can best be managed when the most experienced individual within the group, or the person appointed as incident commander, takes responsibility for the more strategic decisions (Klein, 1998; Tissington and Flin, 2005; HM Government, 2008). However, consultation with other team members might be required if conditions become more uncertain or novel. This way, new patterns may be recognized by other team members, and weaknesses in the proposed course(s) of action may also be discovered and corrected.

Further to the above, Paton and Flin (1999) identified three factors necessary for enhancing team effectiveness i.e. a proper analysis of the required team roles, sufficient training regarding the required skills and the existence of a favourable work climate. Flexible sets of behaviour, adaptability, shared situational awareness, performance monitoring, evaluation and feedback and a well-defined leadership structure have all been identified as important ingredients for effective teamwork (Lipshitz, Klein, Orasanu and Salas, 2001).

Despite the importance that has been ascribed to having an effective crisis management team, a number of scholars yet argue that the progress made in understanding how teams make decisions is still relatively slow within the naturalistic decision making community (Caverni, 2001; Salas, 2003; Marold *et al*. 2012). This was attributed to two major reasons. First, the scarcity of empirical studies on team decision making — there seem to be more laboratory studies on teamwork than those conducted in the naturalistic settings (Pearson and Clair, 1998; Lipshitz *et al*., 2001; Salas, 2003). Second, the complexities, rigour and cost associated with studying team decision making are quite high compared to studying how single individuals make decisions (Azuma, Daily and Furmanski 2006; Salas, 2003). In the words of Lipshitz *et al*. (2001, p.342) "it takes a team to be able to study another team in context". There therefore seems to be a compelling need to step up research efforts, especially in naturalistic studies in order to gain a better understanding of the dynamics of decision making within teams (Salas, 2003; Crichton and Flin, 2004; Crichton, 2009).

2.9. THE ROLE OF TASK ENVIRONMENT IN DECISION MAKING

In one of his articles entitled "*competence in experts: the role of task characteristics"*, Shanteau (1992) highlighted five conditions upon which experts' competence depend. These are: (i) a sufficient knowledge about the domain (ii) the psychological traits associated with expertise (iii) the cognitive skills required to make difficult decisions (iv) the ability to use the most appropriate decision making strategies, and (v) a task with suitable characteristics. The author argued that whilst the first four conditions are attainable e.g. through training and experience, the last condition tends to lie beyond the control of experts. This is because people cannot easily alter the features of the environment where they operate (Goldstein and Gigerenzer 2002).

Gigerenzer and Goldstein (1996) in their famous fast and frugal heuristics theory explained the role of task environment in the overall decision making process. As an analogy, the authors used a pair of scissors to analyse how human beings rationalize their behaviour while performing a complex task. One side of the scissors was said to represent the structure of the task environment, while the other represents the computational capabilities of the decision maker. Gigerenzer and his colleagues later used the term *ecological rationality* to demonstrate that rationality and behaviour are not only bounded, but also ecological (Gigerenzer *et al*., 1999; Gigerenzer, 2004). The term *ecological* suggests that performance is context-based and driven by the features of a particular environment.

The task types and the environment in which they are performed are becoming important variables for assessing competence in the expertise literature (Simon, 1990, p.7; Gigerenzer, Hoffrage and Goldstein, 2008; Comfort, 1994; Shanteau, 1992; Keller, Cokley, Katsikopolous and Wegworth, 2010; Jenkins *et al*., 2010). For example, Desanctis and Gallupe (1987) noted that task type accounts for up to 50% of the variance that is likely to occur in both individual and team performances. Certain characteristics differentiate one task environment from another, such as the nature of goals pursued by decision makers, criteria for task completion, availability of domain rules and the extent to which such rules must be adhered to, time stress, presence or absence of environmental stressors (e.g. severe weather conditions), and the consequences of success or failure (Salas, Rosen and DiazGranados, 2010; Dickson, McLennan and Omodei, 2000).

All the afore-mentioned factors ultimately determine the dominant decision making strategy that experts are likely to default to. For example, in complex environments where tasks are required to be performed amidst incomplete information and time pressure, intuitive decision making is most likely to be more effective than the analytical/deliberative strategies (Hammond *et al*., 1987; Hammond, 1996). Part of the reason for this is that the analytical mode possesses a “low capacity” and can therefore be easily inundated with large amounts of information. The intuitive mode on the other hand possesses a higher capacity as it is designed to process information quicker and is thus more appropriate in time-pressured and high-staked environments. Hence, employing the intuitive decision making strategy, or what Epstein (2010) called *experiential knowledge*, will more likely provide actors with the ability to integrate complex sets of cues concurrently ─ exactly what is required for solving complex problems (Salas *et al*. 2010)

There is a growing body of evidence to show that the strength of competence in experts varies across different disciplines (Meehl, 1954; Calderwood, Crandall and Klein, 1987; Crandall and Gretchell-Leiter, 1993). It is therefore more of the characteristics of the particular domain people operate in and not necessarily their level of experience that determines competence (Shanteau, 1992; Salas, Rosen and DiazGranados, 2010; Dane, 2011). This assertion is well supported by the work of Hammond *et al*. (1987) who developed the popular intuitive/analytical decision making framework. In their research with expert highway engineers, Hammond and his colleagues showed that applying intuitive reasoning did not lead to a better or poorer performance than analytical reasoning. Instead, all that mattered was whether or not the environment provided adequate informational cues upon which decisions were based.

Furthermore, a number of scholars have studied experts in the behavioural domain i.e. a domain involving the study of, or interaction with human beings, such as medicine (Shah and Oppenheimer, 2008; Goldstein and Gigerenzer, 2002; Marewski, 2009) and in more static domains (Shanteau, 1992; Cooke and Breedin, 1994) and comparative analyses of findings from both domains showed that experts in the behavioural domain mostly perform less well than their counterparts (see Table 2.4 below). This is because experts in the behavioural domain are expected to evaluate situations that are dynamic as well as make decisions about moving targets (Calderwood, Crandall and Klein, 1987; Dickson, McLennan and Omodei, 2000; Shanteau, 1988; Dane, 2011; Eraut, 2004). For example, Shanteau (1992) studied a wide range of experts across different disciplines and found some level of variation in their competence levels. More specifically, the author discovered that proficiency of experts in certain domains such as weather forecasting, medicine, auditing and livestock management was quite high, but somewhat discouraging in other domains such as nuclear power stations, stock brokers etc.

Table 2.2: Task characteristics associated with good and poor performance in experts (Adapted from Shanteau, 1992)

Good performance	*Poor performance*
Static stimuli	Dynamic and changing stimuli
Decisions about things	Decisions about behaviour
Experts agree on stimuli	Experts disagree on stimuli
More predictable problems	Less predictable problems
Some errors expected	Few or no error expected
Routine tasks	Non-routine or unique tasks
Feedback available	No available feedback
Objective evaluation available	Limited to subjective evaluation
Problems decomposable	Problems not decomposable
Decision aids are common	Decision aids are rare

Table 2.2 shows the characteristics of task environments with emphasis on the conditions that make good or poor performances possible. It therefore seems that commanders now need to better understand the environments where they operate, the constraints and affordances of those environments, and the kinds of knowledge and skills required to respond to task demands (Lipshitz *et al*., 2001).

2.9.1. The relevance of cues and feedback in the task environment

Intuitive skill performance depends largely on the structure of the informational cues available in an environment; the distribution and validity of the cues and the correlation between the cues and the ease of identifying them (Broder, 2003; Reimer and Otto, 2006). For example, if an environment provides valid cues and good feedback, skill and expert intuition is more likely to develop in individuals with sufficient talent (Clark *et al*., 2006).

Wong (1996) defined a cue as any stimulus with implications for action. Task environments have been broadly categorized into "high-validity", "low-validity" or "zero-validity" depending on the ease with which useful cues are identified by decision makers (Kahneman, 2011, p.241). A high validity environment is one where a stable relationship exists between objectively identifiable cues and the events that eventually happened i.e. a situation in which identified cues accurately predict the outcomes of events. In high validity environments, valid cues are usually specifiable, at least in principle, thereby putting the onus of cue identification and interpretation on the decision makers.

Zero-validity, at the other extreme, describes an environment where future outcomes are extremely unpredictable (Wong *et al*., 1997). Examples that fit into this environment include predictions of the future value of individual stocks, long-term forecasts of political events, detection of frauds, predictability of industrial accidents etc. (Pliske, McCloskey and Klein, 2001; Kahneman 2011). This explains why it is difficult or even almost impossible to attain expertise in such domains because actors often tend to rely more on validated scoring rules or decision aids over human judgment (Meehl, 1986; Phillips, Klein and Sieck, 2004).

It must however be noted that validity and uncertainty are not incompatible; some environments have been shown to be highly valid and yet substantially uncertain (Comfort, 1994). Professionals performing within such environments rarely have the opportunity to receive accurate and timely feedback on their judgments, and when they do, it only seems to be relevant in the short term (Hogarth, 2001; Klein, 2003). For example, physicians in an emergency room can only receive short-term feedback on how patients responded to their immediate actions such as drug prescriptions. The physicians will rarely find out the longer-term effects of their actions on the patients as some patients might never return to the same hospital, and when they do, they might not be attended to by the same physician (Hogarth, 2003). But other domains such as weather forecast tend to give experts both short and long term feedback e.g. the fact that the eventual weather condition is not influenced by the predictions of meteorologists makes it easier for experts to learn from their mistakes in such a domain

The role of feedback cannot be overemphasized in developing domain expertise. In his book entitled "*Educating intuition in the 21st century*", Hogarth (2003) explained that deficiencies in the feedback people receive tend to be one of the greatest barriers to developing intuitive skills. Poor quality feedback over a long period of time will end up distorting the knowledge base of operators and ultimately weaken their level of competence (Hogarth and Karelaia, 2007). Hence, people's mental models can only be strengthened when they are provided quality feedback that is both 'relevant and exacting' (Dane and Pratt, 2007). Accurate and timely feedback plays a critical role in any learning process; it ensures that the validity of the experience encountered is reinforced and subsequently indexed into the long term memory for future use (McCaffrey, 2007)

Although some domains are characterized by slow and prolonged feedback as earlier discussed, the good news is that operators in such domains could still be encouraged to develop their skills by imitating and learning from the most successful members in the team (Chaiklin, 2003; Ericsson, Prietula and Cokely, 2007; Gigerenzer et al., 2008). This is one of the primary goals of the current study. In addition to learning from others, individuals can also receive feedback from themselves by scrutinizing their "not too good" decisions and congratulating themselves on the good ones (Klein, 2003). However, this tendency of self-appraisal would require a high level of discipline on the part of the decision maker and must be devoid of self-serving bias, confirmation bias or hindsight bias (Bazerman and Watkins, 2008).

It is also important that the whole feedback mechanism has *learning* at its centre. Feedback is only effective if people are willing to learn from their mistakes and subsequently develop strategies to overcome such mistakes (Schon, 1983; Ericsson, Prietula and Cokely, 2007). This aligns with Senge's (1990) definition of *learning* as the process of detecting and correcting errors. The study of Dunning *et al*., (2003) also provides additional evidence to suggest that most novices are likely to learn from their errors, but only if they are shown how to recognize and avoid them.

2.10. TRAINING INTUITIVE SKILLS

A number of authors are generally convinced that new ways of thinking as well as new methods of training are needed if emergency managers are to become better equipped for the challenges posed by present day crises (see Boin and Lagadec 2000; Rosenthal, Boin and Comfort 2001; Boin and 't Hart 2007; Alexander 2000). These scholars argue that knowledge derived from 'normal' training procedures coupled with the emphasis on routine skills seem no longer sufficient in coping with modern crises. This therefore suggests the need to develop collective capabilities and to acquire "soft" skills that transcend beyond mere technical knowledge (Boin and Lagadec, 2000; Rosenthal *et al*., 2001).

Although intuitive skills are difficult to acquire in practice, evidence suggests the process of gaining them can be effectively propelled through training (Klein, 1993; Flin, O'Connor and Mearns, 2002; Hogarth, 2003; Clark *et al*. 2006; Sarfo and Ellen, 2007; Gasaway, 2012). The over-arching goal of training is to help people climb the learning curve at a faster rate (Hutton, Miller and Thordsen, 2003; Phillips, Sieck and Klein, 2004). Thankfully nowadays, the scientific measurement of intuition and how it can be taught or transferred is increasingly gaining more ground as the concept is becoming better understood (Hogarth, 2001). Training people to become better intuitive decision makers basically entails strengthening their experience base, such that their schemata (action scripts, repertoires and mental models) are developed through the training they receive and the lessons learnt from such training. Training allows operators to gain more confidence until they are able to perform non-recurrent tasks or attain automaticity in the tasks they are already familiar with (O'Hare *et al*., 1998; van Merrienboer, Clark and de Croock, 2002)

In his book entitled "The power of intuition", Klein (2003, p.52) highlighted some intuitive skills that can be developed through training, showing that less experienced personnel can be trained to become proficient in:

- Sizing up situations faster and more efficiently
- Having a good sense of problem recognition
- Feeling very confident that the first option selected will most likely be a good one
- Having a good sense of what is going to happen next
- Understanding how to filter information to avoid data overload
- Managing pressure and uncertainties more professionally
- Finding alternative solutions when a plan runs into difficulty
- Developing a sense of acknowledging the importance of critical cues and patterns
- Building and validating stories during situational assessment

(Klein, 2003, p.52)

A variety of training methods are available for improving expertise, depending on the available resources and the type of tasks involved (Gaba, 2004). Intuitive skill training does not necessarily have to be complicated (Desanctis and Gallupe, 1987), in fact, it could be as simple as helping personnel make good sense of the decisions they routinely make, or to identify difficulties in the tasks they perform and propose ways to overcome such difficulties in the future (Klein, 2003; Freitas and Neumann, 2008). Examples of training techniques that can thus be explored by emergency response organizations include: Map tactical decision games, sand-table exercises, computer generated simulation exercises, large scale field simulation exercises, and real-life training (Borodzicz and Haperen, 2002; McLennan, Omodei, Holgate and Wearing, 2006; Flin *et al*., 2008). Depending on the purpose of training, small scale and table top exercises could be used to develop simple routine and recurrent skills, while large-scale field exercises can be focused on developing key skills such as information processing and incident command skills, communication skills and team metacognition.

Sceptics have consistently displayed concerns about the inherent limitations of training officers with simulation games or other decision support systems (Shanteau, 1988; Shanteau, 1992; Serfaty, Mac Millan, Entin and Entin, 1997; Clark *et al*. 2006; Spender, 2008). Some of these concerns were based on the assumption that simulations cannot absolutely mimic the psychological and cognitive traits of experts. This is because game developers often seem to emphasize aspects of declarative (or codified) knowledge in their design, overlooking the most important aspect of expertise — tacit knowledge (Polanyi, 1958, 1962; Clark and Elen, 2006; Grant, 2007). Shanteau (1992) argued that most decision support systems are quite rigid and that expert systems would be more useful if they could be designed to be as flexible as the experts they aim to mimic (since rigidity is taken to be a characteristic of novices).

But, regardless of the training method employed, it is important to ensure that scenarios and procedures within the training package accurately reflect the context in which they would normally be applied in real life (Wong, Sallis and O'Hare, 1997; Patton and Flin, 1999; Crichton, 2009; Gasaway, 2012). The best training strategy according to van Merrienboer (2002) is therefore one that showcases the challenges that would likely be encountered by decision makers in real life. Also, since the domains referred to here are also characterized by time-pressure and complexities, Wong (2000) suggested that training programmes and instructional curricula should be designed so as to improve the intuitive skills of decision makers through pattern recognition rather than through analytical comparism of options. In other words, trainees should be made to learn new tasks by applying what they already know in solving current problems.

How then do we determine the tasks to be included in a training package? A few strategies have been reported in the literature. First, facilitators can convert people's personal field experiences into a scenario based on what went right or wrong (Gasaway, 2012). Second, facilitators could capitalize on the particular task constraints that crew members seem to be repeatedly struggling with and then design a part-task practice [i.e. training conducted in repeated sessions until learners gain automaticity (Kirschner and van Merrienboer, 2007; Gaba, 2004)]. Third, taking a new or upcoming project (such as the installation of a new equipment) and turning it into a decision making exercise or scenario (Klein, 2003, p.50). This will ensure*,* *inter alia*, that team members are aware of the project *apriori* thereby making the learning of it a lot easier when the equipment is eventually installed. Depending on the difficulty of each task, training sessions can be repeated as much as necessary till learners are able to fully master the required skills (van Merrienboer and Kirschner, 2007). The first and second strategies are the focus of the current research i.e. converting expert knowledge to forms that can be used to enhance learning.

2.11. A REVIEW OF THE VARIOUS APPROACHES TO DECISION MAKING IN THE NATURALISTIC ENVIRONMENT

> *"The failure of the incident commanders to cope with the problems they faced on the night of the disaster clearly demonstrates that conventional selection and training of staff and experts is no guarantee of the ability to cope if the responders themselves are not in the end able to take critical decisions and lead those under their command in a time of extreme stress"*
>
> *(Cullen, 1990, p.353)*

In his Nobel Prize winning work, Simon (1957) noted that the field of decision making is roughly divided into two: the *normative* and the *descriptive* models. A normative theorist will, for example, suggest a mathematical model that might help decision makers to act rationally and perhaps optimally (Dougherty, Franco-Watkins and Thomas, 2008). The descriptive decision model, on the other hand, describes how decisions are actually made (Montgomery, Lipshitz and Brehmer, 2005) and emphasizes the reasons why the normative model will not work in time-pressured environments (Ross *et al*., 2004; Cokely, Kelley and Gilchrist, 2006; Riabacke, 2006)

Managing real-world crises poses numerous challenges to professionals such as having to cope with intense time pressure, uncertainty, dynamic and changing conditions, ill-defined goals, ambiguity and high stakes (see Orasanu and Connolly, 1993; Lipshitz, Klein, Orasanu and Salas, 2001; Falzer, 2004; Klein, 2008). However, ample evidence exists to show that experienced decision makers still carry on despite these challenges and also perform reasonably (and sometimes exceptionally) well under these conditions (Lipshitz, 1993; Lipshitz and Strauss, 1997; Matzler, Bailom and Mooradian, 2007; Klein *et al.*, 1995; Serfaty, MacMillan, Entin and Entin, 1997; Burke, 1997; Fessey, 2002).

This section aims to explore the various decision making models used by actors under different conditions. It is assumed that understanding the decision making strategies used by experts will help clarify where novices are likely to make mistakes. Such understanding would also help suggest how novices can best be made to learn from experts. Three decision making strategies will be examined in this section i.e. the classical decision making theories, the heuristic and biases approach and the recognition primed decision model (RPDM). The section will then conclude by suggesting how the two modes of thinking — generally known as system 1 and system 2 (Bazerman and Moore, 2006) — operate under time pressure, and how they are interchangeably used by domain experts.

2.11.1. The traditional decision making model

The traditional or classical decision making model is similar to the concept of *unbounded rationality* (see Marewski, Gaissmaier and Gigerenzer, 2010) which assumes that people have all the relevant information that aids effective performance. For example, it assumes that people are aware of all the possible choice options and the potential impacts of each. The classical theory also assumes that people have unfailing memory and also possess large computational ability needed to run complex decision calculations (Satz and Ferejohn, 1994; Scott, 2000). In theory, this approach should allow people to take the “best” option provided they have the mental energy, unlimited time and all the relevant information to analyse their thought processes (Marewski, Gaissmaier and Gigerenzer, 2010, p.104).

The classical model also includes, for example, laboratory experiments where subjects perform trivial tasks, or where individuals are given several hours or days to carefully evaluate their options (Klein, Calderwood and Clinton-Cirocco, 1988). At its simplest form, the classical model consists of the following stages:

- Identifying the problem
- Generating a set of options for solving the problem/choice alternatives
- Evaluating these options concurrently using one of a number of strategies e.g. cost/benefit analysis
- Choosing and implementing the preferred option.

The prescription made by classical decision theorists is – and often continues to be – that professionals should avoid making intuitive decisions as much as possible and think more deliberately instead (e.g. Simon, 1955, 1956; Bonabeau, 2003; Schoemaker and Russo, 1993; Scott, 2000).

Unfortunately, the 'rationality' and 'optimality' claimed by the classical theorists have been proved to be unrealistic from the point of view of the naturalistic decision making paradigm (Tsoukas, 2003; Azuma, Daily and Furmanski, 2006; Klein, 2003 p.21). For example, studies have shown that even when decision makers attempt to keep an open mind by considering several options, they often still know *a priori* what option they want for themselves (Tversky and Kahneman, 1973; Wegner, 2002; Kahneman, 2003). People frequently tweak pre-set evaluation criteria in order to arrive at the option(s) they originally wanted (Spender, 2008). Polanyi, in his early research, emphasized this notion, claiming that no knowledge can be regarded as wholly explicit or totally objective but is rather influenced by the beliefs and values of individual decision makers (Polanyi, 1962, 1966)

In more recent years the shortcomings of the classical model seem even more obvious as organizational decision-making environments became increasingly fast paced and dynamic (Tissington and Flin, 2005; Sinclair and Ashkanasy, 2005). Hence, although theoretically stronger than its counterparts, the rational choice model has been criticized for over-simplifying decision making as it is rarely concerned with the volatility, uncertainty, complexity and ambiguity that are peculiar to the more dynamic settings (McCaffrey, 2007; Ingham, 2007; Spender, 2008).

There is little doubt that performance could be improved if conditions allowed sufficient time; unfortunately, time, knowledge, computational ability and other forms of valuable resources seem to be limited in real life emergency situations (Keller, Cokely, Katsikopoulos and Wegwarth 2010).

For instance, in two different experiments conducted by Howell (1984), it was demonstrated that time pressure seriously infringed upon participants' ability to apply some pre-set decision formulas. These studies showed that time pressure interacted with other variables to produce a more intuitive approach to problem solving (see Zsambok, 1997). This suggests that, although unbounded rationality may be a convenient way of modelling decision making outcomes, it is an unrealistic way of describing how people actually make high-staked and time-pressured decisions (Kahneman, 2003; Sinclair and Ashkanasy, 2005). Thus, the classical model mostly seem to be applicable in environments with routine tasks for which problems are often artificial in nature, where inexperienced decision makers are involved, or where stakes are relatively low (Flin, 1996; Gore *et al*., 2006; Dane and Pratt, 2009).

As Spender (2008) puts it, there is no other option left but to think outside rationality's box. The concept of naturalistic decision making and other "fast thinking" models have therefore emerged from an initial rejection of the classical decision theory and have collectively inspired further research aimed at considering faster ways of making decisions. An example of such a movement is the heuristic and bias approach which is discussed next (Shah and Oppenheimer, 2008; Schooler and Hertwig, 2005; Hilbig, Scholl and Pohl, 2010; Reimer and Rieskamp, 2007; Gigerenzer, 2007; Hogarth, 2003; Marewski, 2009; Keller *et al*. 2010; Matzler, Bailom and Mooradian, 2007; Katsikopoulos, 2010).

2.11.2. Heuristics and Biases (HB) Approach

The heuristics and biases (HB) approach initiated by Kahneman and Tversky in the 1970s is one of the popular routes in studying how people make decisions (Lipshitz, Klein, Orasanu and Salas, 2001). This body of research is mainly concerned with the intuitive judgments that arise from simplifying heuristics rather than from specific experiences as claimed by the naturalistic decision making (NDM) community (see

Kahneman and Klein, 2009 for a review on the differences between NDM and HB paradigms). The major difference between the NDM and the HB schools is that NDM researchers compare the performance of professionals with that of the most successful experts in their field, whereas HB researchers prefer to compare the judgments of professionals with the outcome of decision support systems or algorithms (Gigerenzer and Gaissmaier, 2011; Meehl, 1954; 1986). Proponents of the HB school believe it is entirely possible for the predictions of an experienced clinician, for example, to be superior to those of novices in the same field but appear inferior to those from a mathematical model or an intelligent system. As a result, HB researchers also view experts as possible victims of the same cognitive illusions and biases novices suffer from (Tversky and Kahneman, 1971; Caverni, 2001; Evans and Over, 2010).

Up until now, several efforts have been made to redress the meaning and application of heuristics, especially in time-pressured domains (Cioffi, 1997). For instance, many believe that defining heuristics as rules of thumb or irrational shortcuts that result in judgmental bias is probably too harsh (Goldstein and Gigerenzer, 2002; Reimer and Rieskamp, 2007; Gigerenzer, 2008; Dougherty *et al*., 2008; Marewski, 2009). These authors remain adamant that heuristics, regardless of their shortcomings, make judgments and decisions easier in one form or another and that using them does not necessarily affect the accuracy of decision outcomes. Since the original Greek etymology of the term means “to find out” or “to discover”, authors such as Marewski, Gaissmaier and Gigerenzer (2010) have questioned the logic behind the assumption that heuristics are a source of judgmental bias?

Heuristics have been regarded as a powerful decision making tools when applied properly (Keller *et al*., 2010). They offer a more resource-frugal and yet robust way of managing complex tasks (Brighton and Gigerenzer, 2011; Rieskamp and Otto, 2006). The use of heuristics therefore help decision makers to arrive at faster judgments since they are naturally designed to reduce mental effort which helps to relieve the mind of unnecessary arduous computations (Gigerenzer, 2007; Marewski, Gaissmaier and Gigerenzer, 2010; Katsikopoulos, 2010; Hilbig, Scholl and Pohl, 2010)

2.11.2.1. Heuristic versus Intuition

Should the terms "heuristic" and "intuition" be used interchangeably? There is considerable evidence to believe they should not (Benner and Tanner, 1987; Cioffi, 1997; Bonabeau, 2003; Evans, 2008; Epstein, 2010). Intuition entails an "automatic integration of information" and involves a direct knowing without necessarily knowing how one knew (Sinclair and Ashkanasy, 2005) while heuristics on the other hand involve a mere simplification of thoughts, mainly by ignoring information that is judged unimportant (Maqsood, Finegan and Walker, 2004; Marewski, 2009; Gigerenzer *et al*., 2008).

In their experimental research and contrary to existing beliefs, Hilbig, Scholl and Pohl (2010) demonstrated that the application of heuristics is not necessarily a consequence of intuitive thinking, but rather an effort-reduction feature that people call upon when thinking deliberately. A similar conclusion was reached by Plessner and Czenna (2008) who asked subjects to answer a set of questions, comprising of both simple and difficult questions. The authors found that when participants were made to think more analytically (i.e. to answer the difficult questions) their reliance on the anchoring heuristics increased. The anchoring heuristics is a mental shortcut that allows people to make judgments by making adjustments from the initial information they have received (Cioffi, 1997). Conversely, by drastically reducing the time available to deliberate upon the questions, participants were found to rely more on their previous experiences. This therefore suggests that the intuitive judgments produced in the absence of skills are those that are most likely to invoke the operation of heuristics (Cioffi, 1997; Kahneman, 2003).

The debates regarding the role and application of heuristics still remain unresolved in the judgment and decision making literature (see Evans, 2010 for an overview). For example, it has been asked how discussions about heuristics could point scholars in such opposite directions, with suggestions that researchers who see heuristics as a rational decision making tool are only "hiding the real truth" (Evans, 2008; Evans and Over, 2010). Most "anti-heuristic" researchers maintain that relying on one's heuristics in making difficult decisions, particularly under unusual circumstances, will often lead to some degree of judgmental bias.

Thus, although the NDM community favors the term intuition over heuristics, both terms still have certain features in common. They both process information rapidly, and also have tacit properties alike. Integrating both concepts might therefore result in generating more useful fast thinking models for actors operating in time-pressured and high staked environments (See Cioffi, 1997)

2.11.3. Naturalistic decision making

Naturalistic decision making (NDM) is mainly concerned with how experts make decisions in the real world using their experience (Klein 1991; 1993; Salas and Klein, 2001; Zsambok and Klein, 1997; Lipshitz *et al*., 2001; Kahneman and Klein, 2009; Shanteau, 1992; Flin, 1996; Montgomery, Lipshitz & Brehmer, 2005; Jenkins *et al*., 2010). This stands in contrast to the normative model that prescribes how decisions are to be made. The primary motive driving most NDM studies has been made explicit in the words of Kahneman and Klein (2009):

> *"A central goal of NDM is to demystify intuition by identifying the cues that experts use to make their judgments, even if those cues involve tacit knowledge that is difficult to articulate. This way, NDM researchers try to learn from expert professionals"* (Kahneman and Klein, 2009, p.516)

Research on NDM grew out of the early studies on chess by De Groot (1946/1978) and later by Chase and Simon (1973). De Groot showed that chess grand masters were generally able to identify the most promising moves rapidly, while mediocre players often did not even consider the best moves. The author discovered that the main difference between the chess grand masters and their weaker counterparts was the fact that the former were able to appreciate the dynamics of the complex positions and quickly judged a line of play as either promising or fruitless. Chase and Simon (1973) later described the performance of these chess experts as a form of perceptual skill where complex patterns were recognized on the basis of the repertoire of patterns stored in the actors' memory (i.e. between 50,000 to 100,000 immediately recognizable patterns).

Over the years, the number of expert studies conducted within the NDM domain appears encouraging, and still growing (see Lipshitz *et al*., 2001; Elliot, 2005; Gore *et al*., 2006; Klein, 2008; Klein *et al*., 2010 for a review). For example, authors have studied how:

- Acute medical teams regularly deal with patients with uncertain diagnosis and/or rapidly changing medical conditions (Crandall and Gamblian, 1991; Crandall and Gretchell-Leiter, 1993),
- Airline pilots make rapid decisions within seconds when faced with changing demands (Orasanu and Connolly, 1993; Orasanu and Martins, 1998; Endsley, 1995),
- Emergency ambulance control room make decisions of dispatching ambulances amidst limited resources (Wong, 1996; Wong, 2000),
- Battle ground and military commanders successfully strategize against their enemies in the face of external pressures (Ross *et al*., 2004; Klein and Thordsen, 1988; Schmitt and Klein, 1996),
- Industrial and production managers make decisions against a backdrop of highly fluctuating production and economic risks (Muhlemann, Oakland and Lockyer, 1992),
- Offshore oil installation managers cope amidst the high risks associated with various drilling and mining activities (Flin, Slaven and Stewart, 1996; Crichton, Lauche and Flin, 2005) and how
- Fireground commanders make time-pressured decisions amidst conflicting and incomplete information (Calderwood, Crandall and Klein, 1987; Brehmer, 1996; Tissington and Flin, 2005; Klein *et al*., 2010; Okoli *et al*., 2015).

In their theoretical review paper, Lipshitz *et al*. (2001) identified four criteria that distinguish NDM studies from other research areas:

- *The characteristics of domain tasks:* NDM studies are context rich and domain specific
- *The actors under investigation:* NDM studies mostly utilize experts, although novices are sometimes used in the need for comparison.
- *The intention of the research:* NDM studies usually explore and describe the strategies experts utilize in solving difficult problems in their domain

- *The point of interest within the decision points:* NDM researchers mostly define their area(s) of interest from the overall knowledge elicitation process e.g. they can decide to focus on situation awareness, sense making, information filtering, teamwork, decision type etc.

Despite remarkable progress reported in the NDM literature, the field has not been devoid of its own criticisms. Caverni (2001) argued that naturalistic events are beyond what the NDM community can capture and therefore advised that a change of name from naturalistic decision making (NDM) to expert decision making (EDM) would seem more realistic. Furthermore, the methodologies applied in some NDM studies have been criticized for having low experimental control and for being relatively soft; producing only data that favours the NDM model (Doherty, 1993; Rosen *et al*. 2010; Caverni, 2001; Jungermann, 2001; Yates *et al*., 2003). Most experimental psychologists believe that an experimental approach to studying experts tends to be superior to those used by NDM field researchers in terms of rigour (Tulving, 1989; Dougherty, Franco-Watkins and Thomas, 2008; Dreyfus, 2004; Waroquier *et al*., 2010; Dijksterhuis, 2004).

However, NDM scholars have mostly debunked these claims, arguing that every research approach deserves to be judged solely on the basis of its driving principles and not out of context (Kobus, Lipshitz *et al*., 2001; Proctor, Holste, 2001; Salas and Klein, 2001; Montgomery, Lipshitz and Brehmer, 2005; Klein, 2008). NDM proponents have emphasized that the normative decision models (how decisions should be made) and descriptive decision models (how decisions are actually made) pursue different goals. It has been argued that most experimental studies on expert cognition stand the chance of producing misleading results or artificially validating theories (Oppenheimer, 2003; Dreyfus, 1972). Many authors believe that such experimental studies should rather be tested against NDM studies since the latter is closer to real life experience (Klein *et al*., 1989; Hoffman *et al*., 1998; Hilbig, Scholl and Pohl, 2010; Keller *et al*., 2010; Broadbent *et al*., 1986; Salas, 2003; Ross *et al*., 2004; Salas, Rosen and DiazGranados, 2010).

2.11.3.1. Recognition-Primed Decision Model (RPDM)

The recognition primed decision making model, originally developed by Klein and his colleagues (Klein, Calderwood and Clinton-Cirocco, 1986) has remained a prototypical model in the field of naturalistic decision making. The model has been widely used by various authors to either compare or benchmark the decision making process of experts (Skriver and Flin, 1996; Wong, 2000; Gore *et al*., 2006; Jenkins *et al*., 2010; Frye and Wearing, 2011; Okoli *et al*., 2014)

The research that led to the development of the RPD model stemmed from an attempt to describe and analyse the decision making strategies used by fireground commanders who were required to make decisions under conditions of uncertainty and time pressure (Klein, Calderwood, and Clinton-Cirocco 1986). Klein and his colleagues became interested in knowing how these commanders could make accurate decisions without comparing options. Their initial hypothesis was that the commanders would restrict their analysis to only a pair of options. But to their surprise, all that the commanders generated was mainly a single option, which was all they also needed. This was possible because the officers could actually draw on the repertoire of patterns they had compiled during more than a decade of experience to identify a plausible option that was considered first (Falzer, 2004).

Recognition primed decisions are decisions for which action alternatives are directly derived from the recognition of critical information and prior experiential knowledge (Klein, Calderwood and MacGregor, 1989). According to Klein *et al*. (1989), the patterns stored in the memory of the decision maker highlight the most relevant cues, provide expectancies, identify plausible goals, and then suggest workable action plans. In other words, the model typically involves using recognized patterns to solve current problems. The recognition primed decision model links decision making to perceptual learning, pattern matching and the development of prototypes in the memory, and suggests that decision making and behaviour can no longer be well understood independent of these psychological processes (Feldon, 2007; Elliot, 2005).

One important feature of the model is that experts, due to time constraints, typically aim for the courses of action that are satisfactory even if they are not the best option (Hoffman and Militello, 2008)

The RPD model has evolved into three basic levels depending on the severity and complexity of an incident (see Figure 2.4). At level 1 (least complex events), the decision maker recognizes the situation, knows the appropriate response plan to implement and acts promptly. This includes making decisions concerning routine incidents that have formed part of an individual's day to day work ethos (Rasmussen, 2005).

However, as the incident increases in dynamism and complexity, the need for a more thorough diagnosis of the situation becomes obvious. This takes place in level 2 of the model, as shown in Figure 2.4. For the purpose of clarity, the situation assessment phase does not necessarily require deliberating amongst options, rather it is where additional information is sought until an acceptable level of knowledge is reached by the actor (O'Hare *et al*., 1998; Wong and Blandford, 2002; Kobus, Proctor and Holste, 2001). Generally, decision makers are said to be situationally aware if their mental model represents an up-to-date version of proceedings in the environment (Wong, 2000). Several authors agree that situation assessment can be performed either through *feature-matching* or *story-building* (Klein, 1997, 2003; Thompson, Cohen and Freeman, 1995; Salas, 2003; Kobus, Proctor and Holste, 2001; Lipshitz and Shaul, 1996; Elliot, 2005). In the case of feature matching, a decision maker will have to think of several interpretations of the situation using their experience and then use key features to determine the particular interpretation that provides the best match. Alternatively, the decision maker may have to combine these features to construct a plausible explanation for the situation through a process known as *story building* (Phillips *et al*., 2004).

Story building, also known as *gestalt intuition* (Cioffi, 1997), has proved quite useful in situations where it is difficult to identify familiar patterns (Thompson, Cohen and Freeman, 1995; Klein, 1998; Klein, 2003, p.145). It is important to emphasise that stories, if constructed and interpreted properly, can be powerful tools for organizing and explaining less obvious cues, or for making sense of more complex situations

(McCaffrey, 2007). As with other meta-cognitive skills, decision makers could be trained on how to effectively construct and spot gaps in stories (Lipshitz, *et al*., 2001). An example of such training package is one developed by Cohen and his colleagues (Cohen, Freeman and Wolf, 1997) termed the STEP (construct a Story, Test, Evaluate, and Plan). The STEP framework was originally designed for training naval officers in dealing with ambiguous situations and for making decisions concerning hostile intent.

The final stage of the RPD model comes to play in situations where decision makers are uncertain about their chosen course of action (see Fig 2.4). This stage requires that experts conduct a brief mental simulation before implementing any course of action, consciously looking-out for potential problems or loopholes in proposed action plans (Klein and Crandall 1995; Kobus, Proctor and Holste, 2001). With mental simulation, decision makers are able to envision a scenario, build a picture of what is likely to happen and then ready to “pull the trigger” once satisfied with what is being played out in the “scripts” (McCaffrey, 2007; Klein, 2003, p.26).

One of the distinguishing features of the RPD model is its ability to effectively blend intuition (level 1) with analysis (level 3). This arrangement helps mitigate post-decision regrets, since decision makers have the opportunity to pre-test the validity of their judgement before acting (Johnson and Raab, 2003). For example, level 1 of the model occurs when a firefighter understands from previous experience of having managed several incidents that they need to employ an offensive strategy. However, simply acting on recognized patterns could prove counter-productive if the officer is not in the end able to assess whether the tactics that came to mind would work in the current situation (level 2). When assessing the new situation against previous experiences an officer could decide to compare the size of the current building, its location relative to other buildings, the team composition and the layout of the egress routes, and then make more informed judgment regarding the workability of his action plans (level 3). This type of assessment in which existing knowledge is compared against current situations before acting is what Klein (1997) termed mental simulation.

At this juncture it is deemed necessary to emphasize that the RPD model hugely relies on the experience of a decision maker across the three levels of the model. In other words, option recognition, situation assessment and mental simulation all require that decision makers have gained a substantial amount of knowledge of how things work in their domain (Randel, 1996; Tsoukas and Vladimirou, 2001; Ross *et al*., 2004; Ward *et al*., 2011). Expertise is therefore required to recognize and categorize a situation as typical, to construct a useful story that would help determine whether or not a particular option is more workable than another, or to mentally simulate a course of action and predict how it will play out (Lewandowsky and Kirsner, 2000).

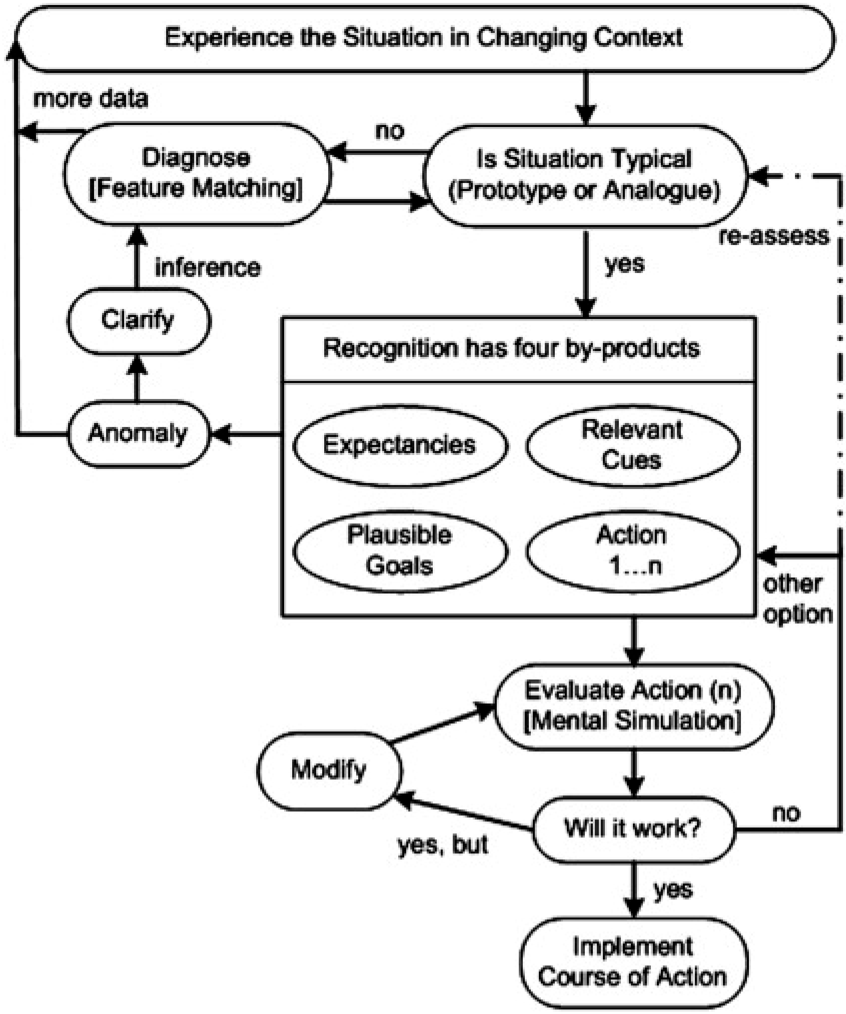

Figure. 2.4: The recognition primed decision model (Klein, 1998, p.24-25)

In sum, the key attributes of the recognition-primed decision model are highlighted below:

- The focus of evaluation is mainly on situation assessment rather than option generation
- The major aim of decision making is to “satisfice” rather than optimize. This principle means finding the best options that work, even if they are not the “best” option (Almerbalti, 2002)
- The first option generated is usually satisfactory for experienced decision makers (Johnson and Raab, 2003)
- The model applies a serial evaluation of options rather than concurrent deliberation between options. This means that the RPD model does not compare an option against other alternatives; rather it compares an option against the current situation in a serial manner (Azuma, Daily and Furmanski, 2006).
- The RPDM uses mental simulation to check the workability of an option
- Decision makers are often *primed* to act fast

Despite the differences that exist amongst the various decision-making strategies discussed above, there also seems to be points of commonality, particularly between the recognition primed decision model and the heuristics and biases approach. Whilst the RPD heavily relies on pattern matching and mental simulation skills as the basis for assessing expertise, the validity of these skills becomes the main point of investigation for the heuristic and bias community, mainly through laboratory investigations. Gore *et al*. (2006) compared the NDM research with the heuristics and biases approach and observed that the HB community is quite obsessed with studying what experts do wrong while the NDM community is more concerned with what experts do right. There is therefore no best decision making research strategy, they all seem to be investigating important cognitive elements but in different ways.

2.12. TWO MODES OF THINKING: THE INTUITIVE VS THE ANALYTICAL

It has been widely reported that individuals generally make task related decisions using two main cognitive modes. Interestingly, a number of authors have described these cognitive modes with different terminologies. For example, Kahneman (2011) called them — slow vs. fast thinking; Dane and Pratt (2007) — intuitive vs. analytical; Bazerman and Moore (2006) — system 1 vs. system 2 thinking; Bargh and Morsella (2008) — conscious vs. unconscious, and Evans (2008) — rational vs. experiential strategies. However, despite reaching an agreement that effective decision making may in some instances involve combined use of intuition and analysis, agreeing on the dominant thinking mode still appears unresolved (Goldstein and Gigerenzer, 2002; Hogarth, 2003; Evans, 2008; Dane and Pratt, 2009; Epstein, 2010; Dörfler and Ackermann, 2012). Little consensus has emerged concerning the preferred sequence by which individuals do, or should, employ the two cognitive modes (See Hammond, Hamm, Grassia and Pearson, 1987; Klein, 2003; Evans, 2008; Dane and Pratt, 2009; Hilbig, Scholl and Pohl, 2010). Some of the lingering questions continue to be: should people take stock of their intuition first and then engage in analysis, or should intuition guide analysis? In other words, it is not entirely clear whether intuitive and deliberative thinking represents two different modes of thinking or whether they are end points of the same dimension.

Scholars have expressed varying opinions regarding the sequence of operation between the intuitive and the analytical modes (Simon, 1987; English, 1993; Lamond and Thompson, 2000; Jungermann, 2001; Lipshitz and Cohen, 2005; Evans and Over, 2010; Kahneman, 2011, p.223). For example, Gary Klein argues that the most effective way of combining these two thinking modes is to allow intuition to guide analysis (Klein, 2003, p.64). He considers that intuition ensures that patterns are recognized faster, making it possible for actors to react quicker to more pressing task demands. In most cases the intuitive (tacit) mode serves as the default system as mental energy is more easily freed up for performing difficult tasks. The deliberative mode is only invoked when the former struggles to solve a problem at hand, or when there is need to make some form of conscious decisions (Wulf and Shea, 2002;

Hogarth, 2003; Azuma, Daily and Furmanski, 2006), or when there is need to justify one's actions (King and Clark, 2002; McCaffrey, 2007).

Interestingly, the way the intuitive and analytical mind operates has been likened to the functions of the eyes (see Broadbent, 1977; Dörfler and Ackermann, 2012). Just like the *peripheral vision* of the eyes, the intuitive mind helps actors become more aware of their surrounding environment, and having a lower "capacity" than the analytical mode, actors are thus able to subliminally track other activities going on within and around them simultaneously. This function contrasts the analytical mode which is mainly designed to focus on one element at a time — similar to the *foveal vision* of the eyes. The analytical mode can only illuminate one element at a time i.e. the particular thing the decision maker is conscious of. This lack of flexibility hence makes it less viable in the dynamic environments (Polanyi, 1966; Dörfler and Ackermann, 2012; Dane, 2011).

A few sceptics have voiced their lack of trust for intuition, instead preferring the analytical style whenever and wherever possible (Messick and Bazerman, 1996; Lamond and Thompson, 2000; Falzer, 2004). These authors argue that the strength of the analytical/deliberative mode lies in the fact that it is mainly driven by the need to think more explicitly about one's actions in the past, present or future. It entails the conscious use of one's prior knowledge, sometimes in familiar ways, sometimes in entirely new ways that require creativity, and sometimes in ways that appear more critical (Lamond and Thompson, 2000). It is strongly believed that understanding the conditions where analysis is likely to be flawed remains a unique feature of expertise. This includes, for example, complex and dynamic environments where multiple cues need to be attended to, under time pressure. In these circumstances, it has been shown that deliberating on multiple choice options at the expense of trusting one's intuition will often prove detrimental to performance (Dijksterhuis, 2004).

The debates regarding the preferred thinking mode have, amongst other things, point to the inherent difficulty, at least in practice, of separating intuition from analysis. Evidence exists to show that intuition and analysis are complementary rather than competitive (Simon, 1990; Epstein, 1994; Ten Berge and Van Hezewijk, 1999; Sinclair an Ashkanasy, 2003; Dane and Pratt, 2009; Sinclair, 2010; Kahneman, 2011). Hence, although intuition operates in the sub-conscious realm, it does not necessarily contradict analysis, neither is it the opposite of analysis (Khatri and Ng, 2000). The words of Simon (1987, p.63) — "*intuition is analyses frozen into habit and into the capacity for rapid response through recognition*" — has gained prominence in understanding the relationship that exists between the two cognitive modes. Simon explained that intuition and analysis are mainly distinguished on the basis of the speed of recognition, implying therefore that intuition is made possible because the skills required for task performance have become ingrained in an actor's subconscious mode. Polanyi and Prosch (1975, p.144) also referred to this as *participation through indwelling*

Deliberating on possible options does not always translate into incompetence, what matters is to understand the circumstances that best suit a particular cognitive strategy (Hoffrage *et al*., 2000; Goldstein and Gigerenzer, 2002; Marewski *et al*., 2009; Marewski, Gaissmaier and Gigerenzer, 2010; Evans and Over, 2010). Goldstein and Gigerenzer (2002) used the term *adaptive toolbox* to explain how people adapt their decision-making styles to environmental structures and the degree to which various decision strategies fit into different conditions. The authors defined the adaptive toolbox as a collection of various cognitive strategies and the core capacities they exploit (Goldstein and Gigerenzer, 2002; Gigerenzer, 2004). The adaptive toolbox is based on the assumption that no universal tool can solve all tasks — simple and complex ones alike (Brighton and Gigerenzer, 2011; Reimer and Hoffrage, 2006). Just like a hammer is ideal for hammering-in nails and useless for tightening nuts, so also are certain decision strategies useful for solving specific problems and useless for others (Broder, 2003; Gigerenzer, Hoffrage and Goldstein, 2008). The adaptive toolbox therefore contains heuristics that allow people to make inferences (e.g. to estimate the intensity of a blazing fire), develop preferences (e.g. whether to deploy an offensive or a defensive strategy) and plan interactions with others (e.g. using an open or closed communication style)

The cognitive continuum theory (Hammond *et al*., 1987) plays a role in explaining the interplay between various cognitive strategies and how they may possibly combine during task performance. The theory classifies task characteristics into "analysis-inducing" and "intuition-inducing" tasks, and asserts that intuition is only one of the many different modes of thinking available to decision makers (see Figure 2.5). The analysis-inducing class includes decomposable tasks with reliably measured cues, while the intuition-inducing class includes non-decomposable tasks with unreliably measured cues, an ill-structured environment with ill-defined goals. The cognitive continuum theory, similar to other theories (e.g. R/M model Cohen *et al*., 1996; sense-making theory, Klein *et al*. 2006), suggests that the amount of information and time available to a decision maker determines the dominant decision making strategy they are likely to employ (Hammond, 1996)

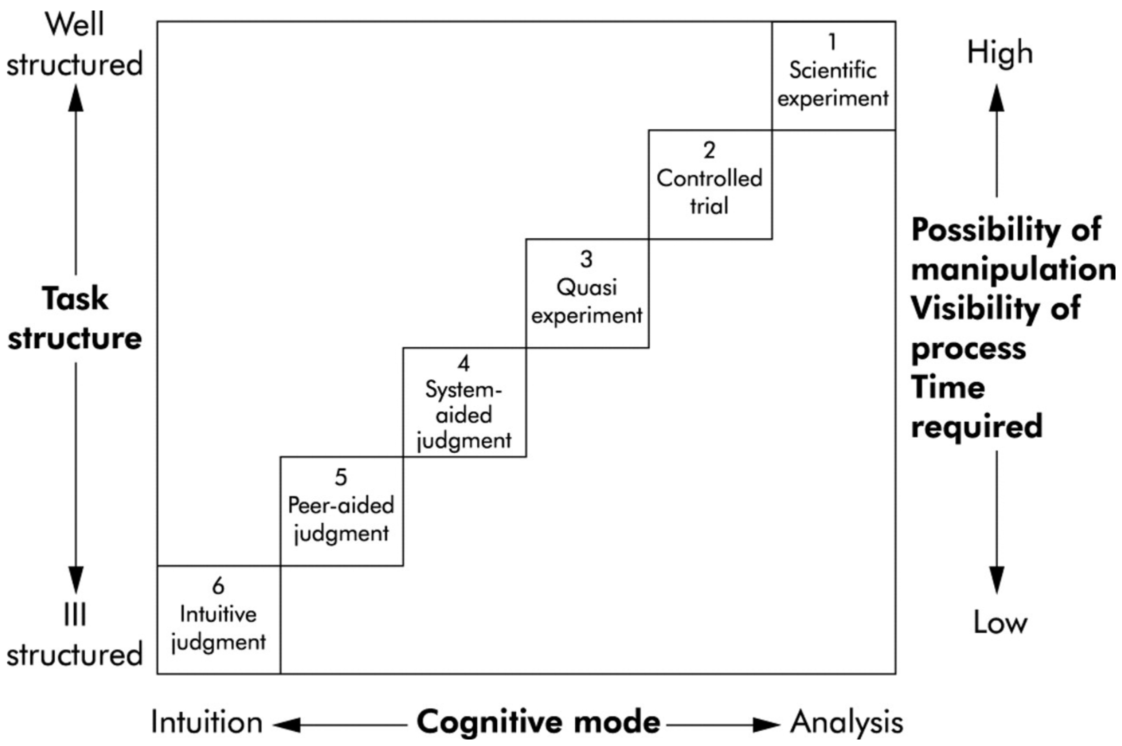

Figure 2.5: The intuitive-analytical decision making framework (Hamm, 1988:33)

In his popular book entitled "*Thought and choice in chess"*, de Groot (1986) reported how grand masters used their intuition to recognize some promising moves that required close examination and then switched to a more analytical mode afterwards. According to de Groot, the transition from intuitive to analytical mode gave the chess players a little more time to reflect on their potential moves as the game progressed.

De Groot reported that the chess players were able to analyse their potential moves through the process of *mental simulation* where moves that were perceived to be less rewarding were screened out, leaving the grand masters with a single move they considered playable. De Groot's study, which has been advanced by other scholars (Chase and Simon, 1973; Gobet and Simon, 1996; Gobet 2005; Ericsson, 2006), provides additional evidence to the fact that intuition and analysis can be used interchangeably in practice.

However, to avoid post-decision regret when switching between the intuitive and analytical modes it might be worth revisiting the advice of Hogarth (2003), who emphasized the role of self-awareness and advised decision makers to consistently regulate their natural tendencies to intuit e.g. by imposing "circuit breakers" (self-regulating mechanisms).

2.13. THE HUMAN MEMORY VERSUS DECISION AIDS

The competition over superiority between the human memory and decision support systems has created much interest in the field of judgment and decision making. Some authors have questioned the acclaimed infallibility of the human memory, insisting that decision aids will always outperform human beings (Meehl, 1957; Tversky and Kahneman, 1973; Dawes, 1979; Dawes et al., 1989; Gilovich, Griffin and Kahneman, 2002; Riabacke, 2006). For example, Meehl (1957) carried out a series of meta-analyses in which he reviewed the findings from twenty studies that had compared the clinical predictions of trained professionals to the statistical predictions made by rule based ratings or decision aids. The essence of Meehl's investigation was to test which predictions were more accurate, to which he found that the accuracy of experts' clinical judgment was matched or exceeded by a simple algorithm in every case.

Some explanations have been put forward as to why algorithms would perform better than humans (Kahneman, 2011, p.223). In situations where cues are difficult to identify or completely missing, algorithms (e.g. statistical analysis) can more easily identify such missing or uncorrelated cues (Dana and Dawes, 2004). Human beings in such circumstances would possibly attempt to be clever and seek other alternatives e.g. by thinking outside the box. In so doing, they apply complex combinations of variables in making their judgments. Although it is true that creative problem solving is obviously one of the hallmarks of expertise, the challenge remains that unnecessary cues might be introduced into the system in such simple circumstances, thereby adding extra noise to the environment (Weick, 1993)

In another meta-analytical study, Hogarth and Karelaia (2008) showed that *consistency* is what accounts for much of the advantage algorithms have over humans. For example, when humans are asked to evaluate a piece of information twice, there is tendency they will give different answers. Such inconsistency in human judgment has been shown to be a major concern for scholars. In the words of Kahneman (2011, p.225) such act "is destructive of any predictive validity". Most of the inconsistencies associated with human judgment are engendered from the unnoticed stimuli in the environment that tacitly manipulates the thought processes and actions of decision makers. As these external stimuli portray themselves in different ways actors tend to also fluctuate their judgments in response, most times unconsciously (Meehl, 1954). But algorithms and formulas do not seem to suffer from such inconsistencies; given the same input they always produce the same result (Meehl, 1986; Dana and Dawes, 2004).

On the basis of the perceived differences in predictive accuracy between humans and algorithms, Meehl (1986) concluded that the responsibility for making predictive judgments should be left to algorithms, especially in low-validity environments (environments characterized with high level of uncertainty). But the problem with this proposition, according to Salas *et al*. (2010), is that critics of human judgement (e.g. Meehl and co) have limited the task environments where decisions are being made to suit the purposes of their evaluation. It is difficult to see, from the point of view of the naturalistic settings, how algorithms can replace human judgment (Khatri and Ng, 2000; Dreyfus, 2004). It has been shown that some of the assumptions that underpin the construction and use of algorithms are too stringent, and thus contradict the possible circumstances that could be encountered in real-life (Shanteau, 1992; Kahneman, 2011). Such faulty assumptions relate to:

I. The confidence placed in the adequacy of variables included in algorithms i.e. the assumption that such variables can cover all possible circumstances in real life
II. The belief that performance is measurable and that the criterion for measuring it is also reliable
III. The notion that a body of similar cases will always be encountered in real-life
IV. The belief that the changing conditions in real life incidents would not render the algorithm obsolete.

Kahneman and Klein (2009) also warned that introducing algorithms would most likely encounter opposition or unexpected problems of implementation in organizations. The authors attributed this to the egocentric nature of human beings as only very few people enjoy being replaced by mechanical devices. To further illustrate this claim, Marewski, Gaissmaier and Goldstein (2010) reported how physicians in a Michigan rural hospital disapproved of the use of a decision support system that was introduced to the hospital. The heart disease predictive instrument (HDPI) was launched to assist physicians in determining whether patients were to be assigned to a coronary care unit or to a regular nursing bed. Marewski and his colleagues (2010) found that the physicians disliked using the machine because it was cumbersome, complicated, and non-transparent, despite the fact that the machine made the decision process relatively easier. Also, because the physicians were required to compute the combinations of seven symptoms and insert their corresponding probabilities into a pocket calculator ─ they saw the equipment as a major threat to their human judgment.

Experts have always disagreed about whether algorithms outperform their own judgment (Yates, Veinott and Patalano, 2003; Ericsson, Prietula and Cokely, 2007; Kahneman, 2011). Their argument has included views that algorithms are “mechanical, atomistic, additive, unreal, arbitrary, incomplete, fractionated, trivial, forced, static, superficial, rigid, pseudoscientific and blind” (Marewski, Gaissmaier and Goldstein, 2010). Humans are naturally created as sense-making and intuitive beings; therefore expecting them to make such creative abilities redundant is perhaps tantamount to relegating them as dummies.

2.14. Chapter summary

A building on fire poses serious threats to human lives, properties, livestock, communities, local economies, natural resources and the environment at large. Although managing real-world fire incidents often pose numerous challenges to professionals such as having to cope with intense time pressure, uncertainty, dynamic and changing conditions, ill-defined goals, ambiguity and high stakes, evidence was found to suggest that experienced decision makers still carry on despite these challenges and also perform reasonably (and sometimes exceptionally) well under these conditions.

This chapter evaluated the role of expertise in fireground decision making and examined some of the salient features that make experts who they are. One of such feature was seen as experts' ability to perform recurrent aspects of tasks using their extensive domain knowledge, mainly through the efficient functioning of schemas. Schemas contain rules and procedures that can systematically link particular features of a problem to a possible course of action (IF condition, THEN action). In other words, experts tend to be imbued with the ability to use the general knowledge they have about a domain, or the knowledge they are able to recall from concrete cases, or both, to form action plans and solve new problems. A direct relationship was thus found to exist between the *skills* possessed by experts, their *knowledge* of the domain and the domain *rules* that guide their actions.

Two definitions of the term 'expert' were particularly found to be relevant in the current study: Shanteau (1992) defined experts as "those who have been recognized within their profession as having the necessary skills and abilities to perform at the highest level". Kahneman and Klein (2009) also used an analogy within the domain of firefighting, stating that when colleagues say, *"If Person X had been there instead of Person Y, the fire would not have spread so far*," then Person X is an expert in that organization.

Building on existing theories and frameworks within the naturalistic decision making domain, the current study explored the concept of intuition, tacit knowledge and other associated concepts such as phronesis and automaticity. Being a process that operates within the sub-conscious realm, intuition tended to have generated a great deal of controversy in the fields of cognitive science and decision making. This can be attributed to the fact that it deals with *tacitly* held knowledge which is, itself, difficult to verbalize and articulate. The review also showed that the way intuition was perceived by authors was mixed in the literature. Whilst some scholars see intuition and its outcome (intuitive judgment) as a mysterious concept that is far from any scientific measurement, others, though not denying that intuition is an important part of human cognition, remain adamant that the outcome of such process will, more often than not, usually provide a favourable ground for judgmental bias.

Despite some of the debates surrounding the role of intuition at workplace, it was found that the scientific measurement of intuition and how it can be taught is increasingly gaining ground in recent years across disciplines such as management, education, healthcare, military, informatics etc. The following reasons were attributed to the relentless effort shown by scholars over the last two decades in gaining a better understanding of intuition and how it can be better utilized at the workplace:

- The limitations of the so called analytical approach in coping with the requirements of dynamic and time-pressured environments
- The feeling that intuition is probably one of the least understood aspects of human cognition
- A belief that gaining a better understanding of intuition and its scientific measurement will go a long way to guide more meaningful conceptualization of human cognition

Three decision making strategies were critically evaluated in this chapter i.e. the classical decision making model, the heuristic and biases approach and the recognition primed decision model (RPD). In more recent years the shortcomings of the classical model became even more obvious as organizational decision-making environments became increasingly fast paced and dynamic. The concept of naturalistic decision making and other “fast thinking” models was therefore found to have emerged from an initial rejection of the classical decision theory and have collectively inspired further research aimed at considering faster ways of making decisions. Hence, although theoretically stronger than its counterparts, the classical decision model has been criticized for over-simplifying decision making as it is rarely concerned with the volatility, uncertainty, complexity and ambiguity that are peculiar to the more dynamic settings. Despite the differences that exist amongst the various decision-making strategies discussed above, there also seems to be points of commonality, particularly between the recognition primed decision model and the heuristics and biases approach. Whilst the RPD model heavily relies on pattern matching and mental simulation skills as the basis for measuring expertise, the validity of these skills becomes the main point of investigation for the heuristic and bias community, mainly through laboratory experiments. Comparing the NDM research with the heuristics and biases approach showed that the latter is obsessed with studying what experts do wrong while the former is more concerned with what experts do right. No best decision making research strategy was therefore believed to exist, rather they all seem to be investigating important cognitive elements but in different ways.

In sum, the arguments regarding the preferred thinking mode have, amongst other things, pointed to the inherent difficulty, at least in practice, of separating intuition from analysis. It therefore seems that intuition and analysis are complementary rather than competitive i.e. although intuition operates in the sub-conscious realm, it does not necessarily contradict analysis, neither is it the opposite of analysis.

CHAPTER 3
RESEARCH METHODOLOGY

3.0. INTRODUCTION

Three critical questions are central to the design of any research methodology (Creswell, 2003): (i) what knowledge claims are being made by the researcher and what key theories underpin such claims? (ii) What strategies of inquiry will best inform the research aim and objectives? (iii) What methods are most appropriate for collecting and analysing relevant data for the research? The answers provided to these questions will form the basis of the methodological framework that will guide and inform the overall research design. Hence this chapter is structured to provide appropriate justifications for the chosen methods and tools that were used in the study.

3.1. ASSUMPTIONS UNDERLYING SOCIAL SCIENCE RESEARCH

The field of social science is predicated upon various assumptions and beliefs about the nature of the social world, which subsequently determine the particular way in which social scientists investigate their subjects (Gibbs, 2008). For example, the choice of the data collection method which a researcher decides to employ at the beginning of a study (whether survey or interview or other methods) would, implicitly or explicitly, be influenced by the research methodology the author chooses to employ, which would in turn be influenced by the theoretical perspectives s/he adopts, and ultimately by the researcher’s epistemological position (See Fig 3.1). Burrell and Morgan (1979) in their popular book entitled “Sociological paradigms and organizational analysis” discussed four sets of assumptions upon which the foundation of every social science research is hinged. The first are assumptions of an ontological nature i.e. assumptions that concern the very essence of the phenomena under study. Here, social scientists are faced with some basic ontological questions such as whether the 'reality' to be studied is external to the researcher — compelling itself on individual consciousness from the outside or whether it is the product of individual consciousness; whether the nature of 'reality' is 'objective' or the product of individual cognitive construction; whether 'reality' is a given 'out there' in the world or the product of one's mind

The second set of assumptions relate to the epistemological nature. These are assumptions about the tenets of knowledge, about how one might begin to understand the social world and communicate this as knowledge to other stakeholders (Guba and Lincoln, 1985). These assumptions entail presuppositions about the nature of knowledge and how it can be obtained and communicated; how one differentiates between what is to be taken as 'true' from what is to be regarded as 'false'. The epistemological assumptions also determine extreme positions on the issue of whether knowledge is something that can be transferred to others or something that has to be personally experienced strictly on individual basis. Gray (2014, p.19) pointed out the importance of having an epistemological perspective, and posited that understanding one’s epistemological stance can help demystify some of the issues surrounding research design. This means more than just the design of research tools, but also the overarching structure of a research, which includes the kind of evidence that would be gathered, from whom, and how such evidence would be interpreted.

The third set of assumptions that underpin social science research, which is conceptually different from the two mentioned above, is concerned with human nature and, in particular, the relationship between human beings and their environment. Following this assumption, some social scientists hold the view that human beings often respond to the situations they encounter in their external environment mostly in a mechanistic or deterministic fashion. Such researchers see human beings alongside their experiences as products of the environment, wherein people are shaped by their external circumstances (Braun and Clarke, 2008). In contrast to this extreme perspective is another line of thought which advances the voluntariness of the human nature and thereby attribute a much more creative role to human beings. Here, human beings are regarded as people who have the ability to create their own environment — the controller as opposed to the controlled, the master rather than the servant. A stark difference regarding the relationship between human beings and their environment thus seems to be evident between these two extreme views: one proclaims the deterministic nature of human beings while the other believes that every individual has “self-will” through which they can make decisions about their world. The final set of assumptions refers to the methodological nature of a research, which is influenced by the three sets of assumptions outlined above. Each of the assumptions mentioned earlier has important implications for the way a researcher would eventually go about obtaining knowledge regarding the phenomena under study. Different ontologies, epistemologies and models of human nature are therefore likely to suggest different methodologies to social scientists (See Fig 3.1)

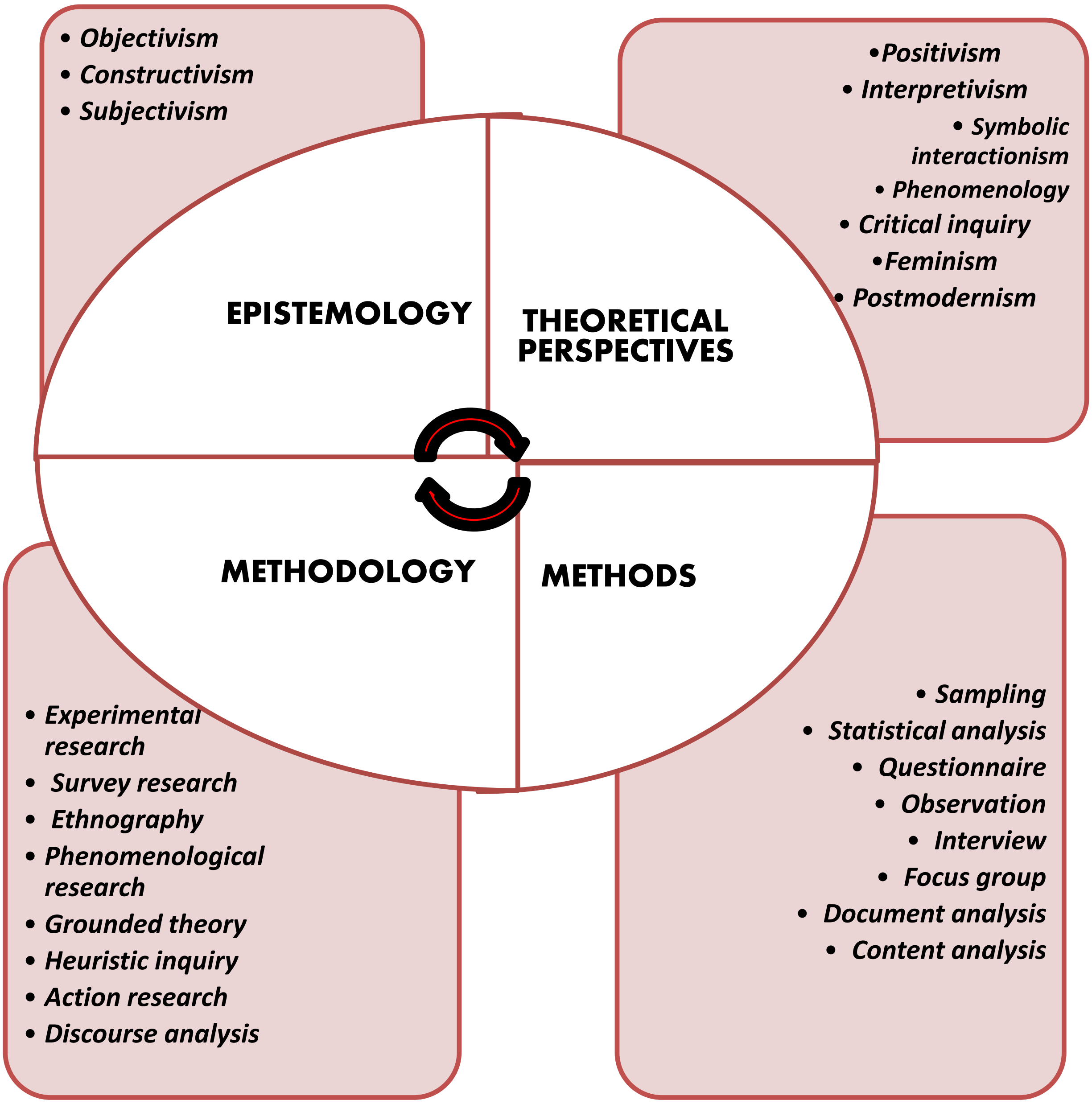

Figure 3.1: Relationship between epistemology, theoretical perspectives, methodology and research methods (Adapted from Crotty, 1998, p.5)

3.1.1. Research epistemology

The work of Crotty (1998) clarifies the relationships that exist between the various research epistemologies, theoretical perspectives, methodologies and methods of data collection (Creswell, 2003; Fereday and Muir-Cochrane, 2008; Gibbs, 2008; Gray, 2014). Crotty identified at least three (qualitative) epistemological positions that have emerged over the years in the research literature: objective epistemology, constructivism and subjectivism (Fig 3.1). Objectivist epistemology holds the view that reality exists independently of consciousness, thereby implying that an objective reality exists 'out there'. In this regard, objectivists argue that the essence of research is about discovering this "objective truth", which is expected to be free from the researcher's personal feelings and values. Gray (2014, p.20) noted, however, that objectivism does not necessarily mean the rejection of subjectivity: it is alright to study peoples' subjective views (their opinions, attitudes and beliefs), but this should only be carried out objectively.

Constructivism on the other hand opines that "truth" and meaning do not exist in the external world, but are created and constructed by the subjects' interactions with the social world (Silverman, 2000; Bradley *et al*., 2007; Bryman and Bell, 2011; Weller, 2014). For constructivists, every individual, even in relation to the same phenomenon, construct their own meaning in different but unique ways. This way, multiple contradictory but equally valid accounts of a phenomenon is seen to emerge (Patton, 2002). Interpretivism is one theoretical perspective that is linked to constructivism.

The final epistemological position based on Crotty's framework is subjectivism, which shares a similar characteristic with constructivism in that subjects also construct meaning. The difference between the two epistemological assumptions, however, is that, with subjectivism, meaning does not emerge from the interplay between the subject and the outside world, rather it is imposed on the subject from within collective unconsciousness, dreams, religious beliefs, etc.

As shown in Table 3.1, Creswell (1994, 2003) similarly identified several paradigms or schools of thought about knowledge claims, which include: post-positivism (which views reality as objective), constructivism (which views reality as individually or culturally constructed), Advocacy (which aims to rigorously challenge existing reality), pragmatism (action research focused on solving specific problems). The author argued that all of the paradigms entail contradictory worldviews and remain distinct and distant from each other, meaning they will *see* things differently and as a result, ask questions differently (Sandelowski, 2000). Consequently, each paradigm would address a similar research question through different methods and techniques.

Table 3.1 Alternative knowledge claim positions (Research Paradigms)

Post-positivism • Determination • Reductionism • Empirical observation and measurement • Theory testing	**Constructivism** • Understanding • Interpretative • Multiple participant meanings • Social, historical and cultural construction • Theory building
Advocacy/Participatory • Political • Empowerment issue oriented • Collaborative • Change-oriented	**Pragmatism** • Consequences of actions • Problem-centred • Pluralistic • Real-world practice oriented

Adapted from Creswell (2003, p.6): Research Design

Considering the various research paradigms identified above, this current study is therefore deemed to be best approached from a *constructivist* worldview. This worldview, as discussed below, suggests that people construct their own understanding and knowledge of the world through the things they experience on a daily basis.

3.1.2. Constructivism

The idea of the social construction of reality came from the early work of Berger and Luckmann (1967) but became even more popular from the work of Lincoln and Guba (1985) tagged “naturalistic inquiry”. The term social constructivism stems from the belief that people’s nature (their skills, competence, experiences and values) are not just imprinted in them, rather people develop useful traits as a result of their interaction with others, as well as through their historical and cultural background (Billett, 2010; Fessey, 2002; Eraut, 2004; Graneheim and Lundman, 2004). The duty of the researcher or inquirer operating in this worldview is therefore to search out the complexity of views or meanings across all participants rather than compress meanings into a few categories or ideas, as is the case with post-positivism (Fereday and Muir-Cochrane, 2008).

Furthermore, in contrast to the positivist and post-positivist paradigm which assumes that knowledge is “objective” and “pure” and that it can be accurately measured (for example, using some statistical tools), the constructivist paradigm posits that knowledge is subjective and contextual. The term “subjective” implies that meanings are constructed by human beings as they engage with the world they are trying to interpret (Graneheim and Lundman, 2004). Hence, a constructivist believes that the inquirer cannot be separated from what is being studied whereas a positivist holds the view that investigators do not and should not interfere with the phenomena being measured (Schutt, 2011).

Constructivism was therefore deemed most appropriate for this study as it fits perfectly with the exploratory nature of the naturalistic decision making paradigm (which is the framework that supports the current study). Since expert fire-fighters attain expertise following the multiple experiences they have acquired over time, the constructivist approach can therefore provide an opportunity to engage participants in a fruitful discussion. This in-depth discussion then allows participants to construct meanings from the particular incident they chose to narrate. From a constructivist perspective therefore, care must be taken in the selection of participants to ensure that only those who meet the requirements of the study are selected (see section 3.4

for selection criteria). It is also important that the investigator chooses the most appropriate tool for inquiry. Hence the decision to favour the critical decision method over concurrent verbal protocol and semi-structured cognitive interview probes over a close ended questionnaire in this study.

Another useful philosophical view relevant to this study is what Lincoln and Guba (1985) called *naturalistic inquiry.* According to Sandelowski (2000), naturalistic inquiry entails studying subjects or characters in their "natural" state, with little or no manipulation to the variables under investigation. The main duty of the naturalistic inquirer is to deploy strategies (in this case, the critical decision method) that allow participants to present themselves as they would even if they were not under study (Lincoln and Guba, 1985).

Furthermore, as shown in Table 3.1, another key feature of the constructivist world view is its emphasis on theory-building, as it is mostly concerned with inductive and exploratory studies. This is seen to align well with the aim of this current study i.e. to explore the decision making and problem solving strategies used by expert firefighters and to seek adequate interpretations for such strategies. This approach stands in contrast to other research strategies that emphasise hypothesis testing and make deductive inferences from a population sample, as is the case with the positivist approach (Thomas, 2006). Employing such approaches will certainly be inadequate here because studying how experts make decisions in dynamic and time-pressured environments is unlikely to align with strict rationalistic assumptions about behaviour. For this reason, it became necessary to allow experts narrate their experiences, how they do things as well as the rationale behind their actions. Each of these elements is then captured inductively and directly from the CDM data (Pope *et al*. 2000; Thomas, 2006; Fereday and Muir-Cochrane, 2008).

Quantitative or statistical measurements have been shown to frequently fall short in providing rich answers to some of the important research questions that apply to this study. For example, questions such as how best can we elicit the tacit knowledge used by experts in making critical decisions, how can we unmask the intuitive skills that typify experts' performance — all seem best answered using a qualitative approach (Lipshitz *et al*., 2001)

3.2. RESEARCH STRATEGY

Table 3.2 below shows a summary of the various strategies used in conducting research within the qualitative and quantitative spheres. Despite the various options that are available within the qualitative sphere, phenomenology was seen as the most appropriate strategy for this study, as discussed below:

Table 3.2: Strategies of inquiry

STRATEGIES OF INQUIRY	
Quantitative	**Qualitative**
Experimental designs	Narratives
	Phenomenology
Non-experimental designs e.g. surveys	Ethnographies
	Grounded theory
	Case studies

Adapted from Creswell (2003, p. 13); Research Design

3.2.1. Phenomenology

The term phenomenology, although used frequently in research scholarship, is accompanied with much confusion concerning its nature (Dowling, 2007). Part of the reasons for this is the fact that phenomenology is not only a research method bust also a philosophy, having many perspectives and styles (see Crotty, 1996 and Dowling, 2007 for a review). For example, Crotty (1996) argued that the transformations which have been experienced over the years with the numerous applications of the phenomenological school have resulted in it being categorized as traditional phenomenology (e.g. Spiegelberg, 1982) and new phenomenology (Crotty, 1996). Crotty (1996, p.272) summarized the later thus:

> This later form of phenomenology presents itself as an attempt to understand and describe people's subjective experience. For this to happen, we are told, things need to be seen from the other person's perspective. Researchers are urged to engage in a single-minded effort to 'bracket' their own presuppositions, prior knowledge and espoused viewpoints and allow the data to speak for themselves

The concept of phenomenology was reportedly made popular by Edmund Husserl, who drew his inspiration from the early works of Franz Brentano (1838–1917) who first introduced the word as “descriptive phenomenology” (c/f Dowling, 2007). Husserl’s concept of phenomenology has since then gained a wider coverage both as a methodology of inquiry and also as a philosophical position in the research literature (Moustakas, 1994; Crotty, 1996; Garman, 1996; Racher and Robinson, 2003; Weller, 2014). The word phenomenon according to Moustakas (1994) was derived from the Greek word *phaenesthai*, which means to flare up, to show itself, to appear. Husserlian phenomenology, as it is popularly known, is notable for its dogged epistemological position for which the author regards experience as the fundamental source of knowledge (Racher and Robinson, 2003). Husserl’s main goal was therefore to establish the idea that researchers intending to embark on a phenomenological inquiry must first set aside all previous habits of thoughts and learn to see what stands before their eyes, what he termed *phenomenological reduction* (Husserl, 1931, p.43). Similarly Heidegger (1962, p.96) emphasized the need to thrust aside one’s interpretative tendencies as such tendencies tend to conceal the entities that one is likely to encounter. The phenomenological procedure involves a thorough study of a given number of subjects (or actors) through prolonged engagement that allows patterns and relationships of meaning to be developed (Moustakas, 1994; Graneheim and Lundman, 2004; Fereday and Muir-Cochrane, 2008). Husserl (1931) developed the idea as a descriptive and interpretive theory that aims to explore the subjective experiences of individuals within the taken-for-granted world of their daily life experiences. Hence phenomenology calls to question what is taken for granted, thus making it also a critical methodology (Crotty, 1996).

The interest of this current study is driven by the desire to better understand, *inter alia*, how expert fire fighters assess and interpret a wide range of informational and environmental cues on the fire ground; how they carry on amidst various task constraints and yet able to make good decisions. The phenomenological approach is therefore deemed important so as to safeguard and preserve important knowledge from real experts. This is aimed to ensure, amongst other things, that the world of social reality (in this case, tacit knowledge in the firefighting domain) is not replaced with some fictitious or trivial conclusions that are constructed from other untested sources.

Phenomenological research emphasizes the need for researchers to discard their own experiences in order to freely understand those of the participants (Creswell, 2003), which implies that explanations are not permitted to be imposed until the phenomena have first been understood from within (Racher and Robinson, 2003). It is experiencing things exactly as they are before thinking of ways to understand and explain them (Crotty, 1996, p.95). In this regard, phenomenologists, and Husserl's phenomenology in particular, talk much about putting oneself in the place of the person being investigated, what Crotty (1996) termed "the great phenomenological principle".

> So phenomenology is about saying 'No' to our meaning system. It is about putting that meaning system in abeyance. Instead of inviting us to explore our everyday meanings as they stand, it calls upon us to lay them aside for the moment and to open ourselves to phenomena in their stark immediacy to see what emerges for us (Crotty, 1996, p.275).

Social phenomenology purports that individuals in their respective endeavours (e.g. workplaces) are able to ascribe meanings to a situation, which subsequently inform the judgments they make. This therefore implies that an inquirer must constantly reflect upon his/her culture and beliefs, doing everything possible to "bracket" such pre-conceived assumptions and beliefs in order to make real sense of the meanings ascribed to a phenomenon under study. This is precisely one of the dominant doctrines of the phenomenological inquiry. The need to shove aside, as far as one can, all ideas, judgments, connotations, assumptions, beliefs and feelings that usually come to mind when one thinks about a phenomenon, cannot be overemphasized in a phenomenological study. This is because such pre-conceived notions do not only stand for things but also come to stand between the inquirer and things, or to be more precise, between the inquirer and his/her immediate experience of the phenomenon. They tend to inhibit the immediate experience of the things the inquirer, through them, make sense of. In other words, our culture tends to substitute itself for what we actually hear, see, smell, feel or even imagine (Schein, 2004)

How then can a phenomenological study be conducted? Crotty (1996, p.279) although acknowledging that the act of putting oneself in the position of others is not something straightforward, summarized the process of phenomenology under three main steps that require the researcher to:

- Focus strictly on the phenomenon being studied (what is being experienced) and not on one's self (the one experiencing).
- Make a conscious and sustained effort to ignore all the usual understandings s/he tends to attribute to the phenomenon under study.
- Focus on the phenomenon purely and simply as it is being experienced, in its immediacy — to the exclusion of every other thing. This implies that the researcher opens themselves to what is being experienced, surrender to it, critique and contemplate it and listen to it.

3.2.2. How researcher's bias was managed in this study

Many authors agree that researchers always enter a field of research with certain opinions and/or preconceptions about what research entails. It was also suggested that such preconceptions often emerge from personal or professional experiences or from theoretical perspectives and foundations related to the field of interest (Malterud, 2001). Denying the existence of these pre-conceived beliefs might therefore prove counter-productive in the end (Sandelowski, 2000). This is what phenomenology does — making researchers explain and perhaps question the basis of their pre-conceived ideas rather than holding deluded thoughts that such pre-conceived notions do not exist. Malterud (2001) explained that preconception is not the same as bias, as long as the researcher mentions them *a priori*. Stating these beliefs and making them clear from the beginning of the study ensures that any new knowledge or theme that subsequently emerges from the analysis of the data is not confused with those intuitively held in the mind of the researcher (Firestone, 1987; Creswell, 2003).

Since every real phenomenological study is expected to provide evidence as to how it intends to minimize researcher bias, this issue is addressed in the section below as it relates to the current study:

As earlier stated, it is worth reiterating that phenomenologists do not deny pre-conceived beliefs, rather they acknowledge the fact that every researcher comes into a field with their own personal experiences and expectations. Hence one of the ways to avoid researcher bias, from the point of view of phenomenologists, is to first identify what the potential biases are. This way, it becomes easier to design strategies to minimize them. In this study therefore, although the conceptual framework (i.e. the naturalistic decision making paradigm) and the methods (the critical decision method) that were utilized played a key role in designing the interview guide, they did not necessarily influence the themes that emerged from the data. Rather conscious efforts were made to ensure that findings from this study were derived directly from the experiences of the participants by allowing the data to speak for themselves. The data analytical method employed in this study, the emerging theme approach, proved effective for this purpose (See section 3.6 for details)

Also since the outcomes of any phenomenological study should be ones that are grounded in the subjective meaning of the experiences shared by the participants (Thomas, 2006), this study ensured that any product developed from it had a traceable link to the participants. Appendix F shows the audit trail for the thematic analysis, which details how the narratives from the CDM data were coded, how the codes were developed into categories and how the categories were merged into themes.

The whole essence of making the audit trail of the analysis available as well as discussing the analytical process with my supervisors is to attain, as much as possible, an unbiased interpretation of the participants' views. This makes sense since everything said in an interview is said in context; removing context out of any analysis is therefore tantamount to distorting the meaning of what was originally said (Burnard, 1991).

Data collection was designed to ensure that all the interviewed fire officers were randomly selected from the outset, without having any prior relationship to the interviewer. The recruitment process was mainly based on a snowballing sampling strategy, also known as referral or chain sampling (Morgan, 2008). See section 3.4 for details of sampling strategy and the selection process.

Finally, some of the findings from the study benefitted from expert scrutiny and have been published in two peer-reviewed journals (Okoli *et al*., 2014; Okoli *et al*., 2015) and one conference proceedings (Okoli *et al*., 2013). This was to provide a platform to consider authenticity, credibility and dependability of the findings, which are useful ways of assessing qualitative research (Appleton, 1995)

3.3. THE NATURE OF QUALITATIVE RESEARCH

Before discussing the nature, components and qualities of a piece of qualitative research, it is deemed necessary to first define what qualitative research is. Malterud (2001) and Bryman (2004, p.266) both defined qualitative research as an approach to the study of the social world that involves collecting data either from talking to people or observing them, as well as the organization and interpretation of such data, usually in textual format. From the point of view of this study, a qualitative approach was preferred to its quantitative counterpart because it is holistic, inductive and naturalistic in nature (Marshall, 1996). Thus, by asking experts to recall a memorable incident, qualitatively rich accounts of experts' reasoning mechanisms can become more easily accessible (Ericsson and Simon, 1980). To the realists or positivists, the social world exists independent of an individual. An individual is therefore seen as only living within a social world which has a "reality" of its own, a world no one can create because it is already existing 'out there'. Thus, ontologically, positivists strongly believe that whatever phenomenon is being studied had already being in existence prior to the consciousness of any single human being (Burrell and Morgan, 1979, p.4). This current study is based upon what Burrell and Morgan (1979, p.5) called the anti-positivist epistemology which, as with this study, argues that the social world is relativistic in nature and can only be understood from the perspective of the individuals who are directly involved in the activities that are to be researched. The approach of this current study is therefore to "understand from the inside rather than the outside"

Although some sceptics accuse the proponents of qualitative methods of professing a research paradigm that is both subjective and value-laden (Firestone, 1987) which they regard as a limitation, most qualitative research experts believe it is exactly those same attributes that make the method uniquely suitable for exploring human behaviours compared to other research methods (Burnard, 1991; Crotty, 1996; Bradley *et al*. 2007; Fereday and Muir-Cochrane, 2008). According to this view, qualitative research is imbued with standards such as credibility, confirmability, dependability and transferability that are to a very large extent non-negotiable. In relation to the first three standards, qualitative researchers have been praised for their willingness to question findings and interpretations from a qualitative study rather than taking such findings at face value. Garman (1996) lamented on how scholars, especially those who belong to the quantitative or scientific camp, often fail to grasp the notion that qualitative assertions are primarily designed to illuminate, explain, interpret rather than verify. Other qualitative researchers have also noted a common mistake people make in thinking that X or Y has simply been "proven" because two or three people have been found to make similar statements, as in samples of interview transcripts (Bassey, 1998; Braun and Clarke, 2006). On this note, therefore, it becomes important to mention that the current study primarily aims to develop a deeper understanding of the decision making processes and problem solving strategies of expert fire-fighters in the UK and Nigeria, as opposed to consciously verifying the phenomenon under study.

Qualitative researchers also strive to reflect on the effect of context and bias on their findings rather than assuming the human mind does not influence the outcome of research, as is the case with quantitative researchers (Graneheim and Lundman, 2004; Bryman and Bell, 2011). In his important book: “The enlightened eye”, Eisner (1991) highlighted one of the most remarkable characteristics of qualitative investigation, which is the fact that “the self” is what engages and facilitates the phenomenon under study, and makes sense of it. In other words, it is the investigators that, themselves, see and interpret significant aspects of the discourse, and it is this characteristic that eventually generates the desired insights into the experience being investigated. Qualitative researchers do not deny this fact.

The last standard, transferability, explains the notion that qualitative research embraces a systematic and reflective process in developing knowledge that can be contested and shared beyond the study’s settings. In other words, it should be possible, for example, for the research design to facilitate understanding of the extent to which it is possible to transfer the tacit knowledge checklist that was developed in this study to other domains besides firefighting. In line with this, Malterud (2001) asserts that scientific standards, guidelines and checklists exist as guides for qualitative researchers, in order to ensure qualitative studies are conducted thoroughly and with adequate rigour. An example of such a checklist is shown in Table 3.3 below.

Table 3.3: Guidelines for assessing the integrity of qualitative studies

Aim
• **Is the research question a relevant issue?**
• **Is the aim sufficiently focused, and stated clearly?**
• **Does the title of the article give a clear account of the aim?**
Reflexivity
• **Are the researcher's motives, background, perspectives, and preliminary**

hypotheses presented, and are the effects of these issues sufficiently dealt with?

Method and design

- Are qualitative research methods suitable for the exploration of the research question?
- Has the best method of inquiry been chosen with respect to the research question?

Data collection and sampling

- Is the strategy for data collection clearly stated (usually purposive or theoretical, rarely random or representative)?
- Are the reasons for this choice stated?
- Has the best approach for data collection been chosen, in view of the research question?
- Are the consequences of the chosen strategy discussed and compared with other options?
- Are the characteristics of the sample presented in enough depth to understand the study site and context?

Theoretical framework

- Are the perspectives and ideas used for data interpretation presented?
- Is the framework adequate, in view of the aim of the study?
- Does the author account for the role given to the theoretical framework during analysis?

Analysis

- Are the principles and procedures for data organisation and analysis fully described, allowing the reader to understand what happened to the raw material to arrive at the results?
- Were the various categories identified from theory or preconceptions in advance, or were they developed from the data?
- Which principles were followed to organise the presentation of the findings?
- Are strategies used to validate results presented, such as cross-checks for rivalling explanations, member checks, or triangulation?

Findings

- Are the findings relevant with respect to the aim of the study?
- Did the findings provide new insights?
- Is the presentation of the findings well organised and best suited to ensure that they were drawn from systematic analysis of material, rather than from preconceptions?
- Are quotes used adequately to support and enrich the researcher's synopsis of the patterns identified by systematic analysis?

Discussion

- Are questions about internal validity (what the study is actually about), external validity (to what other settings the findings or notions can be applied), and reflexivity (the effects of the researcher on processes, interpretations, findings, and conclusions) addressed?
- Has the research design been well scrutinised?

- **Are the shortcomings accounted for and discussed, without denying the responsibility of choices taken?**
- **Have the findings been compared with appropriate theoretical and empirical references?**
- **Are a few clear consequences of the study proposed?**

Presentation

- **Is the report easy to understand and clearly contextualised?**
- **Is it possible to distinguish between the voices of the informants and those of the researcher?**

References

- **Are important and specific sources in the field covered, and have they been appropriately presented and applied in the text?**

Adapted from Malterud (2001, p.485); Qualitative research: standards, challenges and guidelines

3.4. SAMPLING STRATEGY AND SAMPLE SIZE

One of the most important distinguishing features between a qualitative and quantitative inquiry is the type of sampling strategy both approaches are likely to employ (Pidgeon and Henwood, 2004, p.634). For example, in qualitative research, random sampling is rarely utilized for collecting data because findings from qualitative studies are not designed for hypothesis testing or for calculating probabilities from a population sample (Thomas, 2006). Thus, the major goal of a qualitative study is not to generalize across a population, but to provide a clearer and deeper understanding or explanation from interviewees' perspectives (Pope *et al.* 2000; Taylor-Powell and Renner, 2003). In other words, as is the case with this study, qualitative research will, more often than not, attempt to answer questions such as what is unique about this individual, group, situation, or incident?

It is important to note that the sampling strategy that is employed in a particular study is closely related to both the internal and external validities, as well as to the transferability of the findings from such study. This therefore explains why the number of participants that is expected in qualitative studies is often lower than that expected in quantitative studies. In a qualitative study the sample size, although an important factor, may not necessarily influence the outcome of the study as much as the type of participants selected and their process of selection would. These factors are important determinants of the quality of conclusions drawn from a qualitative study.

In this current study, a combination of purposeful sampling strategies were employed, as shown below. It was important, for the purpose of this study, to ensure that any sampling strategy that was to be considered was one that facilitated the knowledge elicitation process for obtaining qualitative information from experts and from the incident accounts being reported (Sandlewoski, 2000). Purposeful sampling is inclined towards the development of idiographic knowledge i.e. knowledge from and about specific cases, which is quite difficult to obtain through probabilistic sampling (Patton, 1990). Probabilistic or simple random sampling is typical of quantitative research as most quantitative studies are more inclined towards the development of nomothetic knowledge i.e. knowledge derived from investigations that are made from samples which are then generalized to the wider population (Burrell and Morgan, 1979; Patton, 2002). Since this current research is concerned with the development of idiographic knowledge (i.e. what expert firefighters know and do), it thus became logical to turn to purposeful sampling.

Patton (1990, p.182-183) identified sixteen different sampling sub-types within the purposeful sampling class — a list that proved quite useful as it allowed an appreciation of the variety of sampling strategies that exist in the qualitative research family to be possible. After a careful evaluation, four of the sampling strategies were found to be applicable to this current study:

Criterion sampling: This was an important purposive sampling strategy in this study. Some criteria which served as the basis for screening the participants were set prior to data collection. To ensure that expertise was verified and not assumed, participants were carefully selected on the basis of their rank/position and also through peer nomination. All participants had to have personally been involved in managing real-life fire incidents for which they made critical decisions independently.

Also, they had to have at least operated as incident or operational commander i.e. managing at least one fire engine and leading certain number of fire crews out to a fire call.

Extreme or deviant case sampling: Searching for extreme and critical fire cases that particularly challenged experts' knowledge as opposed to typical or routine fire cases. This strategy fits well with the scope of the current study since it has been shown that experts typically utilize tacit knowledge when managing complex incidents than they would do when managing simple incidents (Wipawayangkool and Teng, 2014)

Stratified purposeful sampling: This illustrates the characteristics of particular subgroups of interest, thereby facilitating comparisons. By collecting data about experts' performances (both in the UK and Nigeria), this study aimed to compare and contrast the decision making strategies used by experts from both groups, with particular interest on the cultural differences that exist between the two groups.

Snowball or chain sampling: Snowball sampling is a non-probability sampling technique that is used by investigators to identify potential subjects (Morgan, 2008). This method is common in studies where subjects with some characteristics of interest tend to be relatively difficult to track down. One of the benefits of the snowball sampling strategy lies in its ability to identify cases of interest from "someone who knows someone", and the chain goes on and on till the investigator perceives that data saturation has been reached (Cohen and Arieli, 2011). It can therefore be inferred that the method is an effective way of identifying and gaining access to subjects, especially where a researcher anticipates difficulties in creating a representative sample of the study population. Although it is true that a number of officers referred the author to other officers during the interview process (either from the same fire station or from another), not all the participants emerged from the snowballing process. Thus, snowballing was used in this study as a complementary strategy rather than as an alternative sampling strategy.

Perhaps one of the most remarkable advantages of using the snowballing strategy was that it allowed past ties and communication with prior participants to enhance cooperation from, as well as trust with the potential participants. This was much evident from this study, particularly in Nigeria where referral seemed to be taken seriously. However, despite the benefits of the snowballing method, representativity has been shown to be its main limitation (Morgan, 2008). Being a convenient sampling strategy, selection bias and external and internal validity limitations tend to be prevalent with snowballing. This ultimately explains existing claim that most snowball samples are biased and cannot be generalized (Griffiths *et al*., 1993; Cohen and Arieli, 2011). Selection bias mainly stems from the fact that participants are often not sought randomly unlike other ‘pure’ random sampling strategies (Patton, 2002), but are rather dependent on the referrals of the respondents first accessed and on the willingness of the research subjects to participate. To overcome any possible selection bias from this method and as part of the quality assurance mechanism, it therefore became important to ensure that all potential participants met the criteria for inclusion discussed above

3.4.2. Sample Size

In the qualitative research community, the issue of sample size has generated much debate: it remains a lingering question as to what particular sample size is ideal for a qualitative study. For example, a wide range of studies that employed the critical decision method have used a varying number of sample size — ranging from 4 to 40 (Klein 1988,; Flin 1996; O’Hare *et al*. 1998; Calderwood *et al*. 1990; Wong, 2000; Hutchins *et al.* 2004; Horberry and Cooke, 2010). Some of these authors (e.g. Weitzenfeld, Freeman, Riedl and Klein, 1990) believe that conducting face-face CDM interviews with 3-4 experts will still generate a reasonable depth of expert knowledge that is both reliable and transferable as would a larger sample size.

Pope *et al*. (2000), Stake (1980) argue that, although it is quite difficult not to have a specific sample size in mind before commencing a study, qualitative researchers should be disciplined not to firmly hold onto their pre-selected sample size. These authors rather suggested that the most important factor to “weigh up” is whether the point of data saturation has been reached, where new concepts or themes no longer seem to emerge from the data. Hence, in a theoretically sensitive sample i.e. a sample that is diverse in characteristics and experiences (as with CDM data), reaching the point of data saturation should be used as the criterion for determining whether or not to collect more data. If more themes are emerging from the analysis of the latest batch of data, then the chances are that more themes are still likely to emerge when additional data is collected.

The sample size for this current study comprises 31 firefighters (made up of 15 experts in the UK and 15 experts in Nigeria, plus 1 trainee commander in Nigeria). This sample size was chosen partly because it exceeds the usual range used in other CDM research, and partly because it has generally been suggested that data saturation starts to occur from a sample size of 8-10 for in-depth qualitative studies (Marshall, 1996). The demographic details of the participants are discussed in chapter 5.

3.5. DATA COLLECTION: QUALITATIVE INTERVIEWING

Data collection by interviewing is a data collection method widely used in studies that are concerned with exploring new concepts, or where it becomes necessary to understand existing concepts in detail. According to Appleton (1995), interviewing involves one person, the interviewer, asking questions from another person, the respondent, which is either done face to face or through a telephone conversation. In this study, all interview data were collected face-to-face due to the interactive and collaborative nature of the critical decision method (discussed in chapter 4).

Many advantages of using interviews have been identified in the research literature. First, it allows important parameters of interest to be explored in depth using open-ended questions (Hsieh and Shannon, 2005). Interviewees are given the opportunity to share their experiences with little or no interruption from the investigator, thereby allowing rich, natural data to be collected. In this study, a semi-structured protocol containing open-ended questions was used throughout (see section 4.3 for the CDM probes). The semi structured interview protocol attempts to strike a balance between a purely unstructured approach such as a concurrent verbal protocol, and a completely structured approach such as close-ended survey questionnaire (Wong, 1996; Weitzenfeld *et al*., 1990; Hoffman *et al*., 1995). One of the perceived benefits of using a semi-structured interview guide is that it provides interviewers with a better opportunity of capturing the most essential aspects of expert knowledge, rather than just listening to "fire stories" from experts (Klein *et al*., 1989). In other words, experts can be curtailed to the key elements of the incident which affected decision making, while at the same time allowing details to emerge from the narration. Also in terms of data analysis, it has been shown that analysing qualitative texts from semi-structured interview is relatively easier than it would be for unstructured interviews (Burnard, 1996)

Second, with face to face interviews, it is much easier to critically apply a purposive sampling strategy i.e. participants can be more carefully assessed to ensure they meet the requirements of the study scope as stated above. At the commencement of the interview process in this study, for instance, two of the potential participants in the UK felt they did not possess enough incident command experience to contribute something meaningful to the study, and were therefore excluded from participating. This type of "onsite screening" is however difficult to achieve with online or postal questionnaires since the researcher may not be able to ascertain with full confidence that the interview questions were actually answered by the right candidates. Furthermore, face-to-face interviewing gave flexibility in ensuring that the interview questions were answered in line with the variables that were of interest to the study aim/objectives, by logically guiding the interview process to ensure that interviewees were not carried away while sharing their experiences regarding the fire incident

Although the whole interview process (from the design of the interview guide to the recruitment of participants to the coding and analysis of data) often tend to be laborious, costly and time consuming compared to numerical data (Sandelowski, 2000a; Patton, 2002; Charmaz, 1994; Silverman, 2000), interviewing was undoubtedly seen as the most appropriate data collection method in this study, especially if the values (axiological stance) attached to the variables and the expected outcomes are to be achieved. Eliciting experts' tacit knowledge by solely relying on survey questionnaires has been shown to be inappropriate (Lipshitz *et al*., 2001; Sinclair and Ashkanasy, 2003). For example, Sinclair & Ashkanasy (2005) reviewed different approaches used by scholars to measure intuition/tacit knowledge and concluded that less qualitative methods stands the risk of generating an incomplete description of experts' cognitive processes.

3.5.1. Data collection procedure

Participants were first asked to recall and 'walk-through' a memorable fire incident that particularly challenged their expertise. Prior to the interview, the author informed participants about the scope of the study as well as the type of incident that will meet the requirements of the study i.e. non-routine incidents for which interconnected and interdependent decisions were made under time pressure.

Participants were allowed to narrate the incident from start to finish, with minimal interference from the researcher. This was to allow a rich context about the incident to be obtained, including a detailed description of the sequence of events that unfolded. After narrating the incident, a timeline was sketched by the interviewer and participants were asked to indicate points along the timeline where key events occurred such that the events necessitated making some form of critical decision. The sketching of the timeline was to make it easier for participants to remember the key decisions they made from the start of the incident until when it was brought under control. During the timeline construction stage, decision points (DP) were also identified. A decision point is defined as any point on the incident timeline where participants admitted following a particular course of action even though other potential options were envisaged. The incident timeline and decision point identification stages were followed by probing each decision point i.e. using a set of cognitive probes to enhance the knowledge elicitation process. The set of cognitive probes used in this study covered key questions such as the cues sought by experts, the main goals pursued at each decision point, the information used to form each decision and their sources, the list of training that was helpful in making each decision etc. These cognitive probes allowed the researcher to gain a detailed understanding of the cognitive processes which made effective performance possible.

Finally on the CDM procedure is the “what-if” stage. Here, a hypothetical scenario was presented to experts in order to identify their possible courses of action. The hypothetical scenario posed to experts in this study read thus:

> *Briefly explain what you would do if you arrive at the scene of a serious fire and discovered that you have very little information about what is happening, and yet you have to make decisions whether to employ an offensive or defensive attack?*

All the thirty-one interviews were tape recorded using an MP3 player and were all personally transcribed verbatim by the author and then readied for analysis. Each interview lasted between 1hr-2.30hr depending on how verbal an expert was. Notes were taken as the interview went on and diagrammatic representation of the timeline was sketched in each interview. A total of 134 decision points were obtained from the whole of the interviews. The interview data were analysed using the emergent themes analytical method (Granheim and Lundman, 2004; Braun and Clarke, 2006)

3.6. DATA ANALYSIS

Generally, three approaches of qualitative data analysis have been identified, depending on the degree to which they relate to pre-determined theoretical constructs (Hsieh and Shannon, 2005). First is the *immersion/crystallization* analytical style in which data is allowed to naturally crystallize out, following a thorough examination of the transcripts. The second is the *editing (data based)* style where the researcher identifies certain units in the narratives which form the basis for developing categories. The generated categories are then used, in turn, to re-organize the narratives so that their meaning become clearer. This process is also known as re-contextualization. The last style of data analysis is the *theory-based*. Here, the narratives are organized according to pre-existing theoretical frameworks with the intention of providing new descriptions of previously known phenomena (Sandelowski, 2000b). Although starting an analysis with some pre-conceived ideas has proved quite useful in establishing new insights based upon the foundation of what is already known, Charmaz (1994) warned that great care must be taken to avoid forcing raw data into these preconceived categories.

The current study employed the aforementioned three different analytical approaches as it required the use of both the inductive (theory building) and the deductive (hypothesis testing) approaches in order to fulfil its set objectives. Hence, although this study is primarily focused on exploring the decision making processes of the expert firefighters as well as their problem solving strategies, it will also evaluate the decision points elicited from the expert firefighters using existing theoretical constructs from the NDM community. Hence, inductive analysis in this study is not expected to hinder deductive testing of existing theories neither is qualitative data analysis expected to affect quantitative analysis (Ryan and Bernard, 2003). This conversion process is explained later on in this chapter.

Graneheim and Lundman (2004) used the term qualitative content analysis (similar to the immersion and data based styles) and quantitative content analysis (similar to the theory based style) to describe the types of qualitative data analysis that exist. The authors noted that the major difference between the two methods (i.e. the qualitative and quantitative content analysis) is that the former is based on developing codes from within the data whereas the latter is based on applying pre-existing codes to the data (Burnard, 1996).

3.6.1. Qualitative Data Analysis

There is a vast range of approaches to qualitative research analysis, ranging from the linguistic tradition that treats text as an object of the analysis to the sociological tradition that treats text as a window into understanding the human experience (Denzin and Lincoln, 2000). Scholars have relied on a number of strategies in analysing qualitative data such as conceptual analysis, discourse analysis, content analysis, repertory grid analysis, account analysis, historical analysis, narrative analysis, ethno-science and structural ethnography, and ethno-methodology, taxonomies and mental maps, to name but a few (Bryman and Bell, 2011; Bradley *et al*. 2007; Firestone, 1987; Taylor-Powell and Renner, 2003). The common theme binding all these methods, however, is the definite need to identify patterns, similarities and differences that exist and emerge from the respective data (Burnard, 1996; Pope *et al.* 2000; Ryan and Bernard, 2003)

However, qualitative researchers have been accused of showing a lack of transparency, traceability and rigour in the way they analyse qualitative data (Appleton, 1995; Schutt, 2011). Burnard (1996), for example, noted that qualitative researchers are frequently unable to defend the authenticity of their findings because they fail to provide evidence showing the link between their final results and the original data source. In other words, antagonists of qualitative research claim that crucial contextual details are often missing from the findings and that critical appraisal of such reports are not usually well audited (Hoddinott and Pill, 1997). As Miles (1979) puts it:

> *"The most serious and central difficulty in the use of qualitative data is that methods of analysis are not well formulated. For quantitative data, there are clear conventions the research can use. But the analyst faced with a bank of qualitative data has very few guidelines for protection against self-delusion, let alone the presentation of unreliable or invalid conclusions to scientific or policymaking audiences" (Miles, 1979, p.591)*

A combination of the qualitative coding process (Miles and Huberman, 1994; Strauss and Corbin, 1998; Silverman, 2000; Graneheim and Lundman, 2004) and the emergent themes analysis approach was utilized in this study so as to provide the required audit trail. Audit trails are important evidence that qualitative researchers provide to enhance the transparency and traceability of their findings. Simply stating that a qualitative analysis was carried out or that certain themes emerged from a set of data is no longer seen as enough justification in defending the validity of the findings from a study (Sandelowski, 2000b).

The process of data analysis in this study is discussed in detail below, starting with the qualitative coding process then the emergent themes analysis.

3.6.2. From CDM data to themes: the transformation process

Note: A brief explanation of some key terminologies used in the qualitative data analysis is presented in Table 3.5 below.

The audio-taped interviews were all transcribed verbatim by the author, after which the transcripts were read through several times "as one would read a novel" (Hsieh and Shannon, 2005), so as to make sense of the whole data and to reduce the risk of fragmentation. Furthermore, decision to personally transcribe the whole data without any external assistance was to allow for immersion in the data (Glaser and Strauss, 1967). Relevant concepts and patterns are often identified even from the early stage of data analysis, from which investigators then proceed to the next level of analysis known as "constant comparison" (Glaser and Strauss, 1967, p.102). This early identification of patterns from interview transcripts is known as *open coding* (Burnard, 1991)

The interview transcripts were exported into an excel spread sheet for the ease of organization, and then sorted into relevant *content areas* such as "Knowledge", "Cues", "Goals pursued", "Rules followed", "Training requirements", "Sources of information" etc. The *units of analysis***,** which relate to the particular subject under investigation, were determined for each content area. The text belonging to each content area was then divided into *meaning units* and each meaning unit was further summarized into a *condensed meaning unit* — in such a way that their intended meanings from the original narrative were not tampered with. This was to help catalogue the key concepts while still preserving the context through which they occurred within the data (Burnard, 1991; Taylor-Powell and Renner, 2003; Fereday and Muir-Cochrane, 2008; Bradley *et al*. 2007). The *condensed meaning units* were then *abstracted* and labelled with a *code*. It was important to ensure the most suitable *meaning units* were selected; using large chunks of data as meaning units were avoided as they may contain many meanings, thereby increasing the chance of missing out on important themes. Conversely, meaning units that contain very limited data size (e.g. single words or very short sentences) were equally avoided, as much as possible, since they could increase the risk of fragmentation.

The creation of *codes* is an important procedure in qualitative research and requires that data are broken down into manageable segments that are subsequently labelled (Pidgeon and Henwood, 2004, p.635). However, as Saldana (2012) puts it: coding is not just labelling the data, but also involves linking data together. It leads the researcher from the data to an idea, and then from the idea to all the data pertaining to that idea. Codes are therefore not synonymous with *categories*, contrary to popular belief. Rather, codes capture the essence of the data such that when clustered together based on their similarities and regularities (patterns), they actively facilitate the development of categories. It is these categories that then help explain the basis of the connections between and within the codes (Saldana, 2012).

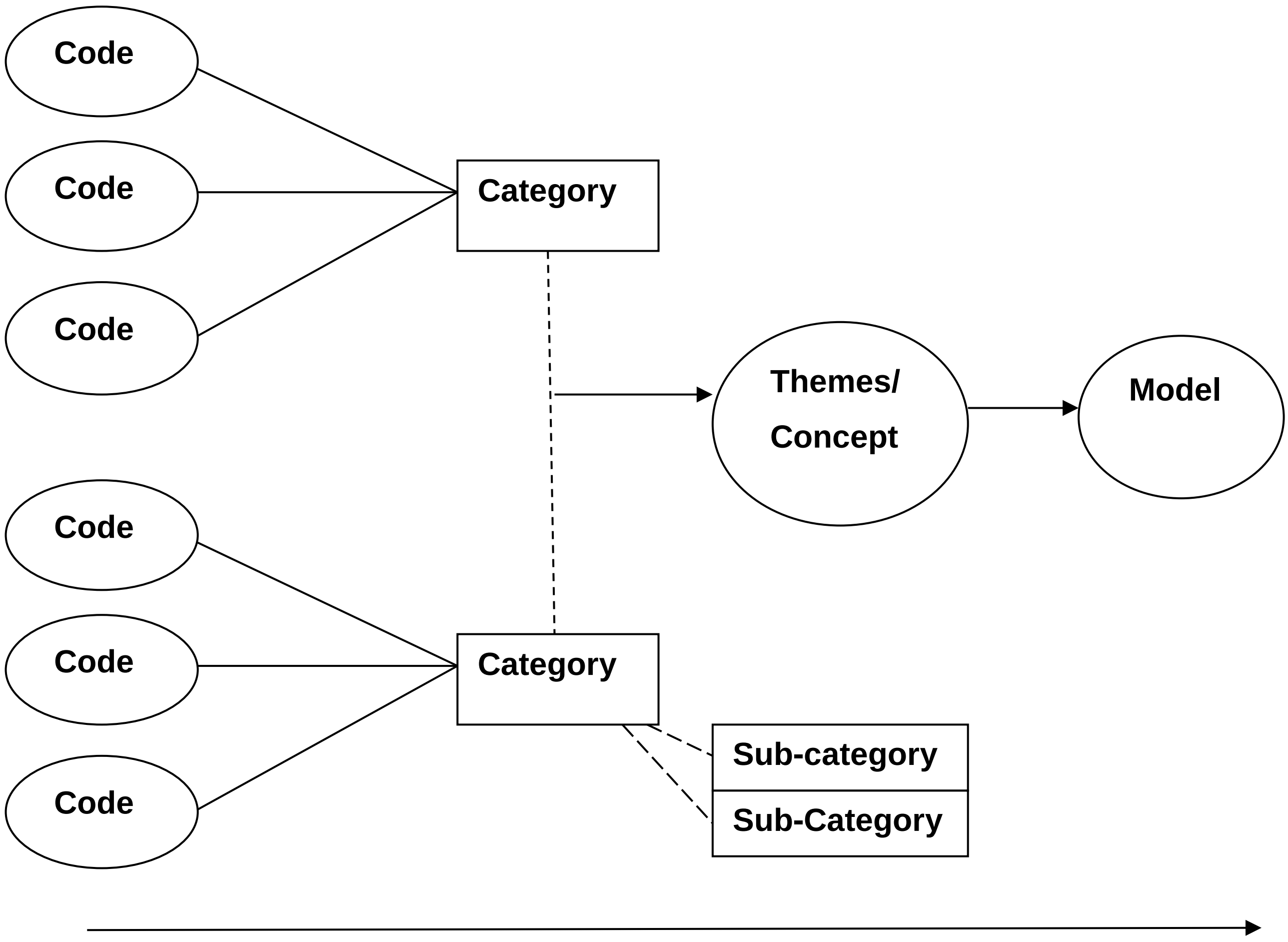

Figure 3.2. A framework for qualitative data analysis from narratives to themes

After the codes had been generated, they were compared and contrasted across all the incidents, and then abstracted into *sub-categories* using *conceptual codes and sub-codes* i.e. labels used to separate data into distinct domains. The sub-categories were also sorted and abstracted into *categories* by looking for common meanings and the relationships between and within the concepts in the sub-categories, across all the incidents. This abstraction process was also achieved by using *relationship codes* i.e. links between categories (see Fig 3.3). Finally, the underlying meaning i.e. the latent content of the categories were formulated into a ***theme*** by looking out for links between the conceptual codes and the relationship codes.

Table 3.5: Summary of the key concepts in the qualitative data analysis. Adapted from Graneheim and Lundman (2004, p.109)

CONCEPT	DESCRIPTION
Unit of Analysis	This refers to the segment of an interview transcript, or persons, characters, specific actions, organizations etc. that has been considered for analysis. A unit of analysis could also be parts of the text that are abstracted and coded, or every word or phrase contained in the transcript. The general rule is that the chunk size of a unit of analysis should neither be too large nor too small.
Meaning Unit	These are a constellation of words, sentences or paragraphs that relate to the same central meaning. A Meaning unit is also called a coding unit or an idea unit (Graneheim & Lundman, 2004).
Condensed meaning unit	This is the stage where meaning units are further summarized, without tampering with the original meaning of the sentence or paragraph. Getting description close to the text as much as possible.
Abstraction	This is process of grouping condensed texts together into higher order headings. These include the creation of codes, categories and themes at varying levels. Abstraction occurs at different stages until the final stage of theory discovery.
Content Area	Content area sheds light on a specific explicit area of the transcript that requires further evaluation. A content area can be parts of the text that address a specific topic in an interview guide.
Code	This simply refers to the process of labelling a condensed meaning unit and allows the data to be thought about in a new way. According to Miles & Huberman (1994), codes are tags or labels assigned to whole documents or segments of documents (such as paragraphs, sentences, or words) to help catalogue key concepts while still preserving the contexts in which they occurred
Categories	This is a core component of qualitative analysis. It represents a group of content that shares a common meaning i.e. an observed thread across the codes (Taylor-Powell & Renner, 2003). It is however important to note that categories should, as much as possible, be mutually exclusive. That is, no data is allowed to fall between two categories and no data should fit into more than one category. In some cases, sub-categories can be formed and then

	abstracted into a category, alternatively, a category can be divided into sub-categories
Themes	The concept of a theme has multiple meanings. Creating a theme is simply linking the underlying meanings that are present in categories together (Thomas, 2006). However, unlike categories, themes can be mutually exclusive i.e. a condensed meaning unit, a code or a category can fit into more than one theme. To develop a theme, data that link categories to each other are tagged.

It should be noted, however, that although the final generation of themes seems to have followed a linear process, this was never the case (Fereday and Muir-Cochrane, 2008). Indeed, the whole process of analysis involved a back and forth transition between the whole and parts of the transcripts (Taylor-Powell and Renner, 2003). This consequently required careful reflection (contextualization, de-contextualization and re-contextualization) all along the way (Burnard, 1991). This also supports the assertion of Strauss and Corbin (1990) that data analysis 'techniques and procedures, however necessary, are only a means to an end and not to be applied rigidly in a step by step fashion' (p.14). In qualitative research therefore, as is the case with this study, there appears not to be clear cut stages between data collection and data analysis. Both stages overlapped and mutually shaped each other (Sandelowski, 2000b).

3.6.3. A summary of the process of thematic analysis utilize in this study

- The transcribed data were re-read and understood in their entirety.
- The transcripts were open coded to identify the potential initial themes which were written down.
- Coding manuals were developed and the inclusion and exclusion criteria for each was determined
- Data was exported to an excel sheet for ease of organization and separated on the basis of the content area. Content areas include the cognitive probes from the CDM protocol (e.g. cues, goals, knowledge, rules and training etc.)

- Data were reduced to a number of condensed meaning units that were codeable
- Codes (i.e. tags that best described the condensed meaning unit without altering their original context) were applied to the condensed meaning units across the whole data set
- Categories (i.e. observed threads throughout the codes) were developed across all of the incidents
- An intra-coding reliability check was carried out in order to verify the developed “codes” and “categories” structures. Intra-coder reliability was achieved by personally applying already developed codes and categories to fresh sets of data in order to check for compatibility and possible adjustments.
- Categories were constantly cross-examined and necessary adjustments and refinement were made. New categories were also added as deemed fit
- Relationships, links and patterns were carefully searched for across the whole of the data, and categories were abstracted into themes/concepts based on the observed patterns
- Evidence was checked for narratives, or combination of narratives which explained the various concepts, categories and themes. It was important to ensure that a clear and transparent audit trail existed for the various themes developed in this study (see Appendix F for examples). All the codes, categories and themes are thus traceable to their respective original narratives.

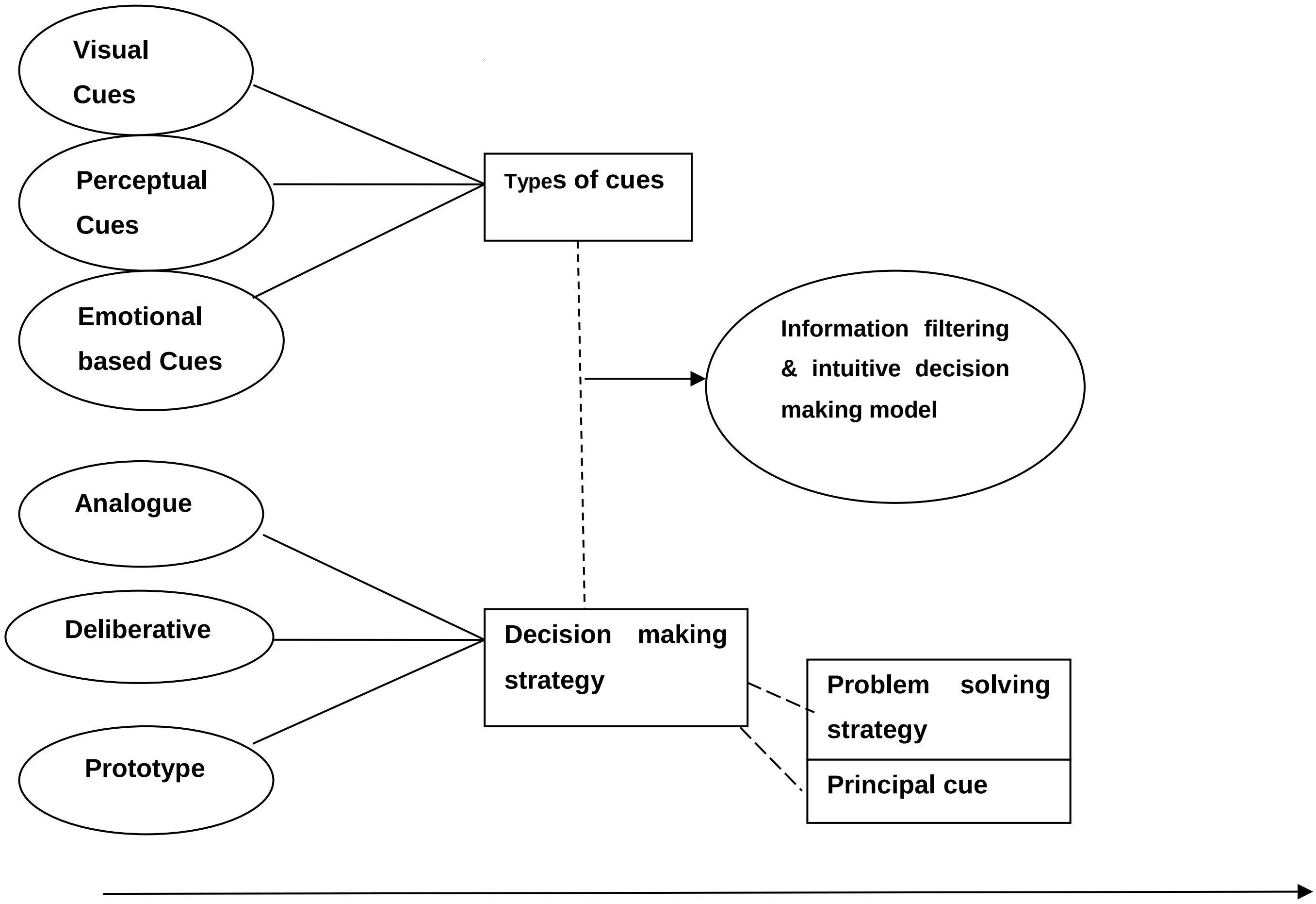

Figure 3.3. An example of qualitative coding utilized in this study, leading to the emergence of the descriptive decision making model

3.6.4. The emergent themes analysis process

Wong and Blandford (2002) developed the emergent themes analysis (ETA) method, which they used in analysing their CDM data (focused on analysing the decision making strategies of ambulance dispatchers). The authors explained that although the method is based on the grounded theory approach, its advantage lies in the fact that it is less expensive and less time consuming than grounded theory or ethnographic observation. The ETA method is able to yield more insights with the same or even less effort when compared to other similar methods. Wong & Blandford (2002) identified three main advantages of using ETA in analysing CDM data:

- Firstly, the ETA approach is tailored to take advantage of the exploratory nature of CDM research, thereby allowing the researcher take account and reflect on the way broad and specific themes emerge from the data (see Fig 2 below).

- Secondly, the ETA approach is able to provide a balance between the emerging themes and existing theories. In this respect, the decision making strategies that emerged from the distillation process can be logically and coherently explained using appropriate theoretical frameworks.

- Finally, the approach is relatively fast, allowing themes to emerge even at the early stages of the data analysis. This therefore means that new discoveries are not left until late.

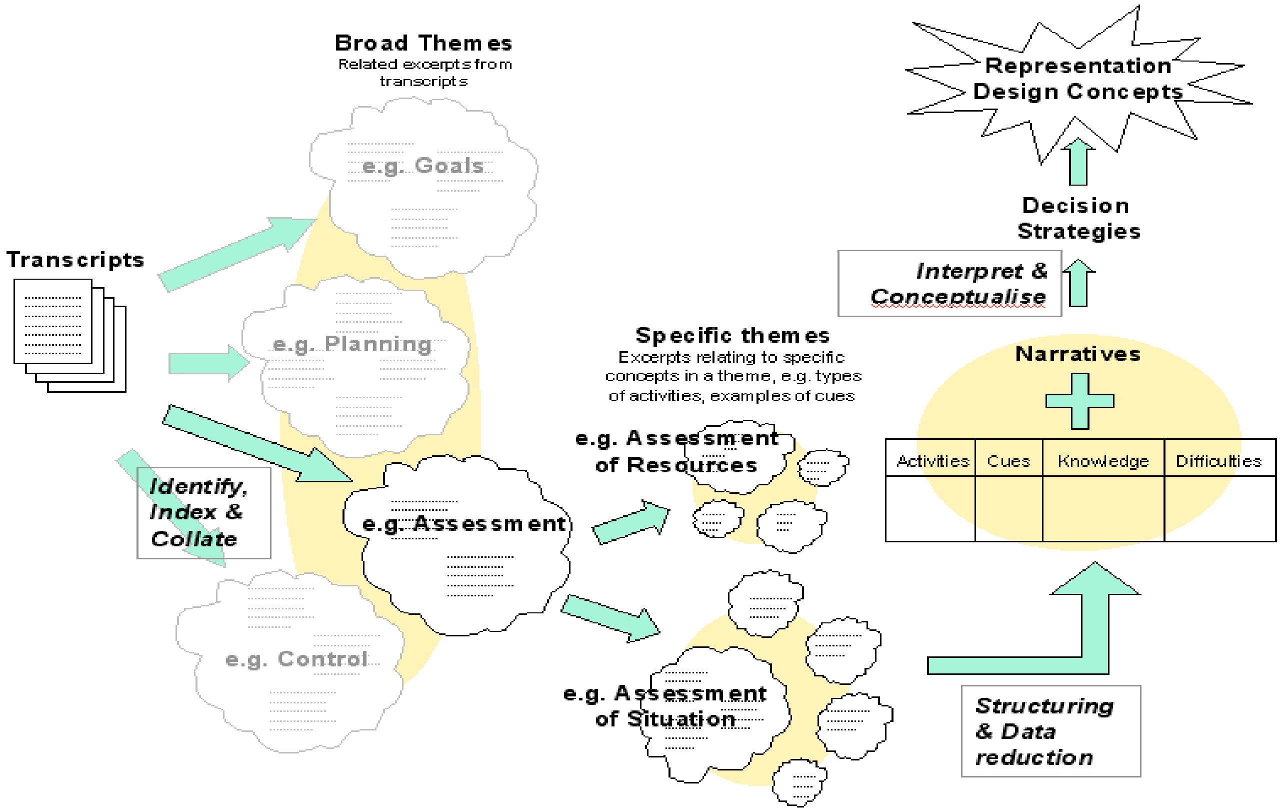

Figure 3.4. The emerging themes analytical process (Wong, 2004)

3.6.5. Procedure

The ETA approach reduces and makes sense of voluminous interview data through an iterative distillation process. First, the analyst identifies and collates concepts that were found to be similar across the whole interview data. These identified concepts form the broad themes (broad themes could be goals, cues, training, time pressure etc.). Thereafter, the researcher uses the same distillation process to closely identify sub-themes or specific themes from within each of the broad themes earlier identified. These sub-themes are then categorized by using a framework that allows the decision making strategies used by experts to be revealed (see Fig 3.4). This framework includes action taken, cues sought, knowledge used and the difficulties encountered in making each of the decisions. The specific themes and the corresponding data/narratives that support them are then tailored into summary tables (see Fig 3.4). The narratives and summary table are then contextualized, and new patterns and ideas are sought. From these observed patterns, the decision making strategies used by experts are identified and are described again in narrative form.

3.7. Ethics

The word "ethics" was derived from the Greek *ethos*, which stands for *character* (Aguinis and Henle, 2002:34). Interest in ethical issues in organizational and psychological research has grown since the 1970s (Aguinis and Henle, 2002), resulting in the implementation of ethical codes that obliges investigators to uphold sound ethical standards. Upholding high ethical values became necessary because of the need to protect the rights of participants, the reputation of researchers and that of their discipline. In line with this thought, therefore, it became important that these ethical standards permeated the design, conduct, analyses and reporting of the current study.

The current study followed and adhered to key ethical principles concerning what is right/wrong, good/bad, acceptable/unacceptable, based on ethical guidelines provided by Middlesex University. Before going to the field for data collection, ethical approval was first sought from the appropriate authority in the department (see Appendix D letter of approval). As part of the ethics application process, a risk assessment form was completed and any potential risks the researcher or the participants could be exposed to were identified and potentially addressed. Also, a participant information sheet, which describes the purpose of study to the participants was provided to the ethics committee for scrutiny.

Since the study involved travelling to Nigeria to conduct interviews, it became important to demonstrate access to the Nigerian firefighters. A letter of confirmation to this effect was received from the Lagos state fire service Headquarters (one of the study areas in Nigeria), duly signed by the director. This allowed access to be gained to interview firefighters across various fire stations within the state (see Appendix E for attachment).

Another principle that was adhered to throughout the research was *lack of coercion*. The recruitment process was strictly through a free-will to participate, more so, there were no existing ties with the fire officers that might have warranted coercion. As stated in section 3.4, some of the participants were recruited through a snowballing process either through an email (mainly the UK participants) or face-to-face, and were clearly asked to indicate their interest to participate. Upon any interview meeting, efforts were made to explain the nature of the interview to the participants after which they were asked again to confirm their willingness to participate. All the participants in the study were also encouraged to read and sign an informed consent form, which indicated their interest to participate in the study and to provide approval in using the collected data for research purposes.

Furthermore, *confidentiality* (which refers to decisions about who will have access to the data, how records will be stored and maintained, and whether participants will remain anonymous) was another principle that was utilized in this study. Considering the fact that the research involved reporting complex incidents some of which involved the death of human beings, participants were assured of complete anonymity — in terms of hiding both personal and organizational identities. All the excerpts quoted from the interview transcripts applied pseudonyms (false names), and conscious efforts were made to ensure that no organizational identity was revealed as all fire stations remained anonymous both in the UK and Nigeria.

CHAPTER 4

CRITICAL DECISION METHOD: A REVIEW OF STUDIES AND JUSTIFICATION OF METHOD FOR ELICITING EXPERT KNOWLEDGE

4.0. INTRODUCTION

This chapter explores a wide range of studies and research across various emergency response and high risk organizations using the cognitive task analysis (CTA) and the critical decision method in particular. One of the major advantages of using the critical decision method is that it allows the actual decision making process used by experts in these domains to be discovered, which can then subsequently be used for training purposes (Crandall, Klein and Hoffman, 2006). The author is interested in examining how the critical decision method has been employed by various scholars in revealing, representing, preserving and disseminating expert knowledge in real world settings. Furthermore, previous CDM studies in the military, aviation, fire-fighting, medical, nursing and midwifery and offshore and mining industries, were reviewed. This chapter also discussed the issues of validity, reliability and generalizability of the critical decision method as a knowledge elicitation tool.

It is important to note, for the purpose of this study, that the term "expert" is used to represent individuals who have been shown to possess relevant skills or a broader knowledge base in their domain of practice (Klein, *et al*, 1989, p. 462; Shanteau, 1992; Elliot, 2005). Thus, the terms “experts” and “novices” are used as a convenience to refer to higher and lower levels of skills and experience throughout this thesis, implying therefore that the term “novice” is strictly used in a relative sense.

4.1. WHY KNOWLEDGE ELICITATION?

Some emergency service organizations such as fire-fighting heavily rely on explanations from experts about the cognitive strategies they use in solving difficult problems, which are subsequently utilized as the basis for developing training instructions for junior officers (Clark *et al*., 2007; Hannabuss, 2000; Feldon, 2007; Wong, 2000). Knowledge elicitation in such domains is therefore seen a crucial aspect of organizational learning (Feldon, 2007; Wong, 2004). The daunting challenge however, from the majority of previous studies is that unless structured knowledge elicitation techniques are used in eliciting domain knowledge, self-reports that are freely recalled from experts tend to be incomplete, inaccurate or error-prone (Breedin, 1994; Eraut, 2004; Wei and Salvendy, 2004).

According to Nisbett and Wilson (1977), explaining *how* and *why* one made certain decisions especially in novel situations can be quite challenging. Yet such explanations remain an important recipe for management in most high risk organizations if the decision making process is to be improved and if novices are to be trained to learn complex skills faster. In the light of this necessity and after an unimpressive progress in the development of decision aids and training methods derived from the self-reports and other formal knowledge elicitation methods available at the time, researchers in the field of naturalistic decision making pioneered by Gary Klein eventually made a breakthrough (Klein *et al*., 1989). One of the most significant aspects of this breakthrough was the transition from the conventional theoretical-based laboratory evaluations of the decision making processes employed by actors to investigating such processes in more precise field settings (Clark *et al*., 2006; Calderwood, Crandall & Baynes, 1990).

Klein's research began in the mid-1980s with a study of urban fire-ground commanders who had to make critical decisions such as whether or not to initiate search and rescue operations, whether to begin an offensive attack or to be more precautionary, what resources they needed and how such resources were to be best deployed (Klein *et al*. 1986; Klein *et al*., 1989). Klein and his colleagues found that the fireground commanders' accounts regarding their decision making process did not fit into any of the rational decision making models that was dominant at the time. The breakthrough began when Klein and his colleagues asked one of the fireground commanders (who had just returned from managing a serious fire incident) to describe the decisions he had just made. The officer simply replied, to the amazement of the authors, that he had not made any decision, but had simply "acted" upon what he already knew (Klein *et al*., 1986). The insights from this study subsequently inspired the development of the recognition primed decision model and led scholars to seek for better ways of exploring the cognitive processes of decision makers. One of the knowledge elicitation tools that emerged from Klein's study is the *critical decision method* (Klein, Calderwood and McGregor, 1989; Crandall and Gretchell-Leiter, 1993; Hoffman *et al*., 1995; Schraagen *et al*., 2000; Hutton, Miller and Thordsen, 2003; Hutchins, Pirolli and Card, 2004; Clark *et al*. 2006).

The goals of knowledge elicitation (KE) have been documented in several studies, and include:

- Generation of cognitive specifications and requirements for tasks
- Prevention of human error in domains involving high risk, time pressure and uncertainty, and
- Enhancement of competence through training, skill remediation and technological innovation (Hoffman *et al*., 1995; Klein, 1993; Kaempf, Thordsen and Klein, 1991; Coombs, 1984).

Through knowledge elicitation, investigators are able to generate insights from experts in a representational format which can then hopefully be transformed into useful products e.g. designing decision aids and training curricula (Klein and Wolf, 1998; Hoffman *et al*., 1995). According to Kolodner (1983), the ultimate aim of knowledge elicitation is to develop systems that contain all, or almost all of experts' skills and knowledge.

Furthermore, knowledge elicitation has also been shown to play an important role in providing reasonable answers to the following critical questions:

- What do experts normally do in their domain of practice (task analysis)?

- What do experts agree that they do?
- What do experts actually do when constrained by some unusual challenges? (Hoffman *et al*., 1995).

Hoffman (1987) compared five methods of knowledge elicitation: documentation based task analysis, unstructured interviews, structured interviews reliant on a first-pass knowledge base, familiar tasks with think aloud processing constraints and tough case materials, and finally, problems that combined limited information with processing constraints. He observed that each of the methods differ in the relative efficiency with which they yield new knowledge. He suggested that knowledge elicitors should strive to utilize the particular method that generates the highest number of outputs within a given total task minute (which includes the total amount of time taken to prepare for the protocol, the length of time taken to carry out the procedure itself and the time taken to analyse interview transcripts). Similarly, other authors have shown that different knowledge elicitation techniques may elicit different types of knowledge (tacit versus explicit knowledge; procedural versus declarative), depending on the overall aim of the elicitation process. Documentation analysis, for example, seems to be best suited to eliciting knowledge concerning the key concepts used in a particular domain whereas sorting and scaling tasks (e.g. repertory grids) are most appropriate in the need to better understand how various elements within a domain interact and relate to each other (see Table 4.1: Hoffman *et al*., 1995). Furthermore, the authors purported that eliciting knowledge regarding the cognitive rule or intuitive skills used by experts would most likely employ either a think aloud problem solving strategy or a cue recall based interview procedure (e.g. the critical decision method).

Table 4.1 below shows the various knowledge elicitation strategies depending on the procedure the investigator deemed most appropriate, as well as the materials available for the study in question. The elements in bold represent the particular strategies adopted in this current study.

Table 4.1. Classification of knowledge elicitation methods (Hoffman et al., 1995, p.140)

Participants	*Experience level* Naivette, Novice, Trainee, Journeyman, **Expert**, Master
	Groupings **Individuals,** small groups, working groups
Procedure	*Familiar task activities* Task analysis, unobtrusive observation, simulated familiar tasks
	Interviews Unstructured, **structured (by probe questions, test cases)**
	Contrived techniques **Event recall,** think aloud problem solving, creative problem solving, decision analysis, scaling/sorting/rating tasks, constrained processing tasks, limited information tasks, graph generation tasks
Materials	Familiar task materials, **probe questions,** limited information materials, archive-based test cases, test cases generated by experimenter, tough case materials, salient case materials, **critical incident records.**

4.1.1. Knowledge elicitation for training purposes

Alavi and Leidner (2001) pointed out the need to pay more attention to the methods and methodologies used by some of the knowledge management theorists in their attempts to convert tacit knowledge to explicit knowledge. The authors argued that a large number of studies tend to deploy weak or ineffective strategies in carrying out such conversions; a process which other authors claim certainly requires more sophisticated approaches than are currently used (Alavi and Leidner, 2001; Eraut, 2004; Fessey, 2002; Maqsood, Finegan and Walker, 2004; Nonaka and Von Krogh, 2009).

One of the justifications for this current study is based on the compelling evidence that experts are not fully aware of about 70% of their own decisions and mental analysis of tasks and so are unable to explain them fully even when such insights are needed to support the design of training, assessment or job aids (Clark and Elen, 2006; Feldon and Clark, 2006). In other words, experts find it difficult to express what they know and do. This is either because they are not used to verbalizing much of the information pertaining to their task, or because the knowledge from which they make those critical task related decisions is tacitly held (Fessey, 2002; Eraut, 2004; Clark, 2014). It therefore appears evident that experts need help telling what they know and do (Crandall, 1989; Tsoukas, 2003). It is important to emphasize the fact that unconscious knowledge needs to be made conscious and tacit knowledge made explicit before they can be utilized for any form of learning or training (Hannabuss, 2000; Bargh and Morsella, 2008; Billett, 2010; Dörfler and Ackermann, 2012). Since knowledge management is therefore more about managing knowledge-absences rather than knowledge-assets, such missing (and usually tacit) knowledge needs to be carefully exhumed from experts (Spender, 2008)

However, despite the importance of eliciting expert knowledge, and tacit knowledge in particular, the fact that expert knowledge is multi-faceted has been revealed as one of the challenges of knowledge elicitation (Billett, 2010; Wei and Salvendy, 2004). Experts possess both explicit and implicit (tacit) knowledge, implying that knowledge elicitors are constantly faced with a huge challenge of identifying the default knowledge mode used by experts at any point in time. In addition, there has been a considerable debate as to the extent to which this tacit knowledge can be made explicit, and evidence gathered from the literature suggests that the ease of conversion between these categories of knowledge has been over exaggerated (Nonaka and Takeuchi, 1995; Fessey, 2002; Tsoukas, 2003; Eraut, 2000, 2004).

The above discourse explains why Hoffman (1987) criticized the knowledge elicitation methods that focus on eliciting explicit and objective aspects of expert knowledge, at the expense of the more tacit ones. Many authors seem to agree that the best knowledge elicitation method is one which, in addition to identifying the codified (or theoretical) knowledge used by experts in performing domain tasks, is also able to reveal the contributions made by tacit knowledge (Polanyi, 1962; Crandall, 1989; Clark *et al*., 2006; Spender, 2008). Simpson, Horberry and Joy (2009) defined tacit knowledge as a type of knowledge that has not been previously expressed or explicitly considered by professionals, even when they possess such knowledge. In other words, tacit knowledge is a component of expertise that is highly resistant to surface articulation, even by experts themselves (Klein, Calderwood and MacGregor, 1989; Eraut, 2004; McCaffrey, 2007).

Having established the value of expert knowledge elicitation for enhancing organizational learning, the critical decision method was chosen in this current study as one of the most appropriate methods for eliciting both explicit and tacit knowledge (Horberry and Cooke, 2010; Wong, 1996; Watkins, 2007; Crandall, Klein and Hoffman, 2006; Hutchins, Pirolli and Card, 2004; Crandall, 1989) for reasons discussed below

4.2. THE CRITICAL DECISION METHOD

It was reported that only a few methods were available for eliciting expert knowledge in the early 80's (Klein *et al*., 1989; van Merrienboer *et al*., 2007). However, the reason for the dearth in the availability of such methods was not necessarily a result of a lack of research progress, but mainly because most researchers were, at the time, more focused on capturing the decision making *process* from a broad sense, with little emphasis on the *content* of the knowledge itself (Hoffman *et al*., 1995). Most of the studies on judgment and decision making at that time were carried out in context-restricted laboratory settings using methods such as multi-dimensional scaling and network analysis, repertory grid analysis etc. (Klein, Calderwood and MacGregor, 1989; Kahneman and Klein, 2009; Bazerman and Watkins, 2006; Riabake, 2006).

Fortunately, with the emergence of expert systems and the growing interest in naturalistic/real world decision making, researchers became more interested in the content knowledge of experts (Barnet *et al*., 2010; Klein, 1989; Rasmussen, 1993; Flin, 1996; Shanteau, 1992; Gore, 2006; Hoffman *et al*., 1995; Zsambok and Klein, 1995). One approach that has been widely used to improve the overall level of human performance in a task is by seeking understanding of how proficient individuals actually perform such tasks in real-life (Coombs, 1984; Okoli *et al*., 2014). The principle behind this approach is that by carrying out a detailed study that covers the general knowledge, specific information, and experts' decision making strategies, a "model" which exhibits some of the properties of experts can then be developed (Klein, Calderwood and MacGregor, 1989; Hoffman *et al*., 1995; Fischhoff, 1989). Such model(s) can be used to identify opportunities for improved training for non-experts, and/or to develop expert-based decision support systems (Wong, Sallis and O'Hare, 1997).

The critical decision method has its root in the work of Flanagan (1954) who initially developed a case-based knowledge elicitation strategy, which he termed the critical incident technique (Flanagan originally developed the critical incident technique for the purpose of job analysis, with the aim of identifying the critical requirements for good performance in high-risk work domains). However, it was Gary Klein and his colleagues in their study with urban firefighters that perhaps made the most successful conceptual adaptation of the early work of Flanagan (Klein, Calderwood and Clinton-Cirocco, 1986). In their first study in 1986, they were able to refine and adapt the CIT to suit their own purpose of investigation, focusing more on the cognitive requirements of job performance rather than on just the job analysis. The researchers consequently rebranded their newly developed "bespoke" version of the method from what Flanagan initially labelled critical incident technique (CIT) to what they preferred to call the critical decision method.

Klein et al. (1989) defined the critical decision method as:

> *"a retrospective interview strategy that applies a set of cognitive probes to actual non-routine incidents that required expert judgment or decision making" (Klein et al., 1989, p.464)*

The strength of the CDM is that it is designed to go beyond identifying unsafe acts and conditions that led to a crisis (i.e. what happened?) or analysing the causal relationship between a crisis and the breakdown of the system (i.e. what led to the crisis?). Rather, the method is designed, more importantly, to allow for a better understanding of an incident, including the underlying decisions made by the operational commander(s). The CDM therefore provides a much better description of an incident, not only regarding *why* and *how* the incident occurred, but also how it was resolved (Horberry and Cooke 2010). In order to substantiate this claim, Horberry and Cooke (2010) used the CDM as a follow-up to elicit information about the root cause of mining accidents after they had initially utilized the incident cause analysis method (ICAM). Analysis of the data elicited from both methods showed that the CDM provided significantly more insights into the hidden cues and the tacit knowledge utilized by the experienced mine operators they interviewed. A wide range of empirical studies have shown a similar outcome, suggesting that the CDM is more robust and superior in eliciting expert knowledge than other "think-aloud" methods (Cooke, 1994; Crandall and Calderwood, 1989; Dickson, McLennan and Omodei, 2000; Wong, 2004). Techniques such as task analysis were deemed to be unsatisfactory for the current study because they are not able to differentiate the cognitive performance of an expert from that of a novice (which is the most important aspect of this study). Also, methods such as the concurrent verbal protocol — where decision makers are asked to explain the basis of their actions while performing real-life incidents (Lipschitz *et al*., 2007) would have been detrimental to this study. Asking actors to justify their choice options could easily be distracting at a critical time, as well as hamper their performance. Also, there is only a remote possibility that the researcher would be present during major fire incidents to observe and record how incidents are being managed in real-life.

Thankfully, the critical decision method, being a retrospective interview, does not suffer from these limitations (Fischhoff, 1989; Klein *et al*., 1989; Weitzenfeld *et al*., 1990; Hoffman *et al*. 1998; Dickson *et al*., 2000; Horberry and Cooke, 2010). The method was originally designed to meet three criteria:

- To address the basis of experts' competence in making critical and task-related decisions

- To be applicable under field and naturalistic conditions, and
- To provide useful data that can potentially be used to enhance the design of instructional guidelines for training novices (Klein *et al*. 1989: 464; Klein, Calderwood and MacGregor, 1989; Wong 2004).

Klein *et al*. (1986) in their original research using the CDM developed a set of opening queries to stimulate the recall of salient fire cases i.e. cases where the firefighters made some level of critical decisions and for which their knowledge and skills were stretched beyond their “comfort zone”. They also developed a set of probe questions (see Table 4.2) that guided the knowledge elicitation process, covering important aspects of decision making, which include cues, choice points, options, goals, action plans as well as the role of experience in the overall decision making process.

The CDM has been used across a wide range of disciplines to discover some salient facts surrounding effective performances in the various work domains. For example, it has been used to elicit knowledge about perceptual cues in neonatal sepsis, some of which had never been mentioned in any textbook or training manual (Crandall and Calderwood, 1989; Crandall and Gambalian, 1991; Crandall and Getchell-Reiter, 1993); to improve existing decision support systems (Kaempf *et al*. 1992; Klinger and Gomes, 1993); to prove that the experience of the best programmers could be adequately preserved and disseminated (Sonnentag, 2001); to capture and analyse the root causes of major incidents in the mining industries (Horberry and Cooke, 2010); and to show that designing a computer-based decision support system would be more effective than making changes in existing training methods (Miller *et al*., 1994). In terms of knowledge preservation, the CDM has been used to capture the tasks performed by experts in knowledge intensive organizations to avoid the woeful tales of loss of knowledge due to retirement (Hoffman *et al*., 1995).

4.2.2. The choice of the CDM as a method within the cognitive task analysis family

Breaking the acronym CTA into its component parts Hoffman and Millitello (2008) explained that the first word, "cognitive" signifies that CTA is mainly concerned with the mental and thought processes of the decision makers. "Task" relates to the actual work that people are required to perform in achieving some response goals. Finally, the term "Analysis" implies that CTA permits systematic description, organization and categorization of the collected data.

About 100 different types of cognitive task analysis methods that are in current use have been identified, which makes it quite challenging for a novice researcher to be able to choose the most appropriate method from amongst the available options (see Clark *et al*., 2007 for a review). Since each method has its own demands, uses and application, CTA experts have advised investigators on the need to evaluate their chosen methods to ensure they sufficiently suit the intention of the research (Schraagen, Chipman and Shute, 2000). The main purpose of a cognitive task analysis is to define the decision making requirements and the psychological processes of experts which enables them perform complex tasks and accomplish unusual results (Watkins, 2007; Hutchins *et al*., 2004).

As stated earlier, this current study adopted the critical decision method (CDM) amongst the other numerous methods within the CTA. Below is a list of some of the key features of the critical decision method, which justify the selection for the current study:

- <u>Focus on non-routine cases:</u> Incidents that are non-routine or those that challenged the skills of experts are usually the richest source of data for the CDM. Such incidents increase the usefulness of the elicited knowledge and allow the emergence of certain aspects of expertise that would normally not be apparent in routine incidents (Klein, Calderwood and MacGregor, 1989; Fischhoff, 1989). Data from non-routine incidents pertaining to times when work is most challenging and decisions most critical is more likely to provide useful insights for developing training packages for potential learners or novices (Wong and Blandford, 2002)

- Case-Based Approach: During the cognitive interview process, questions always refer to a specifically recalled incident rather than asking participants about the general procedures and rules they broadly employ — as is the case with task analysis (Calderwood, Crandall and Klein, 1987). The critical decision method uses the semi structured interview to shift the perception of the experts from providing operational and generic accounts of an incident into more descriptive detail on how the specific incident was managed (Horberry and Cooke, 2010).

- Cognitive probes: Cognitive probing, also known as *progressive deepening* (Kahneman and Klein, 2009; Hoffman, Crandall and Shadbolt, 1998; Clarke *et al.* 2006), is one of the greatest strengths of the CDM. The responses which decision makers give to probe questions are not just taken at surface level, rather the probe questions are specifically designed to cause the decision makers to retrospectively reflect on their own thought processes during the incident. The CDM cognitive probes give extra vigour to the approach when compared to other methods such as verbal protocols (Shanteau, 1992; Hoffman *et al*., 1987). Table 3.2 shows a summary of the cognitive probes that were adopted specifically for this study.

- Semi-structured interview: The CDM also uses a semi structured interview protocol, and with this it attempts to strike a balance between a purely unstructured approach, such as an ongoing verbal protocol, and a completely structured approach such as a close-ended survey questionnaire. The CDM allows a significant amount of interview time to be allocated to eliciting experts' tacit knowledge, perceptual cues and decision making strategies (Wong, 1996; Weitzenfeld *et al*., 1990). Structured interviews are generally more organized, making data analysis and coding processes relatively easier compared to unstructured interviews (Silverman, 2000).

- Focus on research goals: Another benefit of using this semi-structured approach of data gathering is that it gives the interviewer the opportunity to capture the most essential aspect of expert knowledge and decision making procedures rather than just listening to "fire stories" (Klein *et al*., 1989). That is, the focus of expert participants can be curtailed to those elements of an incident that most affected decision making, ensuring responses are structured in a way that can be summarized along a specified set of dimensions while still allowing details to emerge from the narration. The CDM focuses specifically on the decision making process (rather than on the entirety of complex tasks), which fits perfectly with the overall scope of the current research.

- Combination of knowledge elicitation methods: One of the reasons the CDM has been widely accepted by scholars as a credible knowledge elicitation tool is due to its high level of internal triangulation or internal validity (Hoffman *et al*, 1995; Ericsson and Simon, 1980; Schrageen, Chipman and Shute, 2000; Watkins, 2007)

The method typically combines four basic techniques:

- (i) a form of protocol analysis
- (ii) case-based reasoning
- (iii) structured interviewing
- (iv) a form of retrospection

4.3. THE FULL CDM PROCEDURE

The critical decision method as a logical and systematic knowledge elicitation tool involves a series of steps that must be followed in order to boost the outcome of the procedure. The steps described below formed the basic foundation upon which the interviews were carried out in this study

Step 1: Preparation

It has been agreed that preparation provides knowledge elicitors with the opportunity of familiarizing themselves with the tasks, contents and procedures of the domain they intend to study before going into the field (Clark et al., 2006; Hoffman *et al*., 1995). Investigators that know very little about the particular domain they intend studying have been generally shown to be more likely to probe experts on trivial issues, with the possibility of losing out on the core cognitive details (Cooke, 1994; Clark *et al*. 2006; Shcraagen, Chipman and Shute, 2000). Hence, the quality of information that can be elicited from participants tends to be richer if investigators have taken time to prepare and familiarize themselves with the key terminologies and jargons used by experts in their domain of interest (Crandall, Klein and Hoffman, 2006)

Preparation for the CDM interviews for the current study started by ensuring that the goals for knowledge elicitation were specified and defined, and that efforts have been made to ensure that the expert firefighters were sufficiently available and accessible both in the UK and Nigeria (Jonnasen, Tessmer and Hannum, 1999). As part of the preparation process, the following materials also proved quite useful in obtaining preliminary knowledge about the firefighting domain: incident command and control fire reports, literatures, fire training manuals and personal observation and visits to fire stations. Furthermore, due to the nature of the critical decision method protocol (which requires intensive probing and attention to details), it was important to be sure that adequate knowledge can be demonstrated in the preparation of the interview guide and in the interviewing process itself. This was possible through two pre-study sessions where the author rehearsed the interview protocol with two firefighters, paying attention to any potential ambiguity in the interview questions in the process.

Step 2: Incident selection

The incident selection phase is particularly important in the CDM protocol because it helps interviewers identify cases in which they might expect differences between the decisions and actions of an expert and those of someone with less experience (Wong, Sallis and O'Hare, 1997; Weitzenfeld et al., 1990). The most appropriate incidents are therefore those where the decisions of an expert altered the outcome of the incident, or incidents that particularly challenged the skills and expertise of the participants (Horberry and Cooke, 2010).

It was important that the incidents used for the CDM interviews in this study were carefully selected, and that participants were guided through the selection process. It was made known in advance of any interview that routine or typical incidents were of no interest in the study. Participants were also advised to share only incidents that emerged from their own lived experience as decision makers or 'doers' (see selection criteria in section 3.4)

Step 3: Incident recall

One of the advantages of the incident recall phase has been linked to its role in establishing mutual interaction between the interviewer and the interviewee, such that the latter is seen as a listener rather than an interrogator (Klein, Calderwood and MacGregor, 1989). In fact, the 'story-telling' aspect of the critical decision method has been regarded as one of the most remarkable features of the method over other knowledge elicitation methods (Weitzenfeld *et al*., 1990). Studies show that experts are often flattered to tell their own stories and to share their experiences with others (Hoffman, Crandall and Shadbolt, 1998; Hannabuss, 2000; Fessey, 2002). It is however important, as suggested by Klein *et al*. (1989), to take interviews beyond mere story-telling to actually identifying the key cognitive elements. This ultimately means that investigators must be able to probe the "story behind experts' stories".

Once the appropriate incident has been selected in this study, participants were asked to recount and 'walk through' the incident, describing it from beginning to end. This spanned across the moment the fire call was received to the time the fire was eventually brought under control. Participants were allowed to give as many details as possible about the incident at this stage, with very minimal interference.

Once an expert has finished narrating an incident, the story was told back to them, matching as closely as possible the expert's own phrasing and terminology to the original incident account. Participants were then asked to assess the accuracy of the story and to offer additional details, clarifications and corrections where possible. This stage allowed the elicitor and the participant to arrive at a common understanding of the incident in the end.

Step 4: Time line verification and decision point identification

The main goal of an investigator at this stage is to specify and verify decision points, which Klein *et al*. (2010) defined as points where different possible ways to understanding a situation existed, or where different possible courses of action could have been used to solve a problem. To avoid treating every single action as a decision point, participants were encouraged to concentrate on key decisions that the less experienced officers would perhaps not have considered if they were in the same position. The incident timeline was carefully verified with the participants until an agreement was reached on what constituted a decision point. Events within an incident included both objectively verifiable occurrences (e.g. the time a third fire appliance arrived at the scene) or the thoughts and perceptions reported by an officer (e.g. colour of smoke indicating the presence of a toxic substance). In other instances, experts' assertions could also suggest feasible alternative courses of action that were considered and discarded (e.g. "I thought I might have to call a second engine if the intensity of the fire increases").

As an incident was being reported, the elicitor asked for the approximate time of key events. The elicitor's goal at this point was to capture the salient events within the incident, ordered by time and expressed in terms of the points at which important input information was received or acquired, points at which decisions were made, and points at which some level of key actions were taken (Calderwood, Crandall and Klein, 1987).

Step 5: Application of cognitive probes (progressive deepening)

Following the timeline and decision point verification phase, the elicitor led the participant back over the incident account yet again. But this time, efforts were concentrated on applying cognitive probe questions, emphasizing the various aspects of decision making that concerns the study e.g. cues, experience, pattern recognition, training etc. (see Table 4.2). The cognitive probe phase was the most intensive of all the phases in the CDM procedure as it was the point where specific information and knowledge relating to the purpose of the study mainly derived from. With appropriate and adequate probing of experts' decision making process, key insights (including tacit knowledge) were deciphered (Weitzenfeld *et al*., 1990).

The cognitive probing began with questions about the informational cues that experts relied upon in making the initial assessment of the incident, including the source of the knowledge that formed the basis of such assessment. The cognitive probe questions also attempted to elicit the meanings that the informational cues held for the decision makers, the expectations, goals and actions they engendered, as well as the options they might have considered (Wong, Sallis and O'Hare, 1997). The elicitor examined each segment of the story and asked for additional details if needed. As advised by CDM experts, participants were encouraged to make more specific as opposed to generic statements while describing their action points (Hoffman *et al*., 1995), e.g. it was better to say "my goal was to attack the seat of the fire" than saying "my goal was to put out the fire".

Table 4.2: Sample of CDM probe questions used in this study (Adapted from Hoffman et al., 1998, p.273)

Probe Type	**Probe Content**
Cues	What were you seeing, hearing or smelling that helped in formulating your action plans?
Knowledge	What information did you use in making these decisions and how was it obtained?
Analogues/Prototypes	Were you reminded of any previous incident(s) while managing this particular incident
Level of Novelty	Does this case fit a standard or typical scenario? Does it fit a scenario you were trained to deal with?
Goals	What were your specific goals and objectives at each decision point?
Options	What other courses of action were considered or were available? Why were these options not considered?
Rules based /Adaptive/Creative decisions	What rules were you following at each decision point? At what point did you go beyond following SOPs or firefighting rules? Were you being creative with any of your decisions?
Most important information	What was the single most important information that you used in formulating your action plans?
Experience and prerequisite knowledge	What specific training or experience was necessary or helpful in making these decisions? What training, knowledge, or information might have helped?
Time pressure	How much time pressure was involved in making each of these decisions? How long did it actually take you to make these decisions?
Errors	What mistakes are likely at each decision point? Did you acknowledge if your situation assessment or option selection were incorrect? How might a novice have behaved differently?
Hypotheticals	Briefly explain what you would do if you arrived at the scene of a serious fire and discovered that you have very little information about what was happening and yet have to make decisions whether to employ an offensive or a defensive attack?

Step 6: Hypothetical Scenario

This is the final step of the CDM procedure and involves shifting the perspective from participants' actual experience of an event to obtaining information about their depth of knowledge regarding the domain of practice. The hypothetical scenario posed to experts in this study read thus:

> Briefly explain what you would do if you arrive at the scene of a serious fire and discovered that you have very little information about what is happening, and yet you have to make decisions whether to employ an offensive or defensive attack?

4.4. METHODOLOGICAL RIGOUR IN CONDUCTING AN INQUIRY USING THE CRITICAL DECISION METHOD

One of the most effective ways of measuring the trustworthiness of the findings of a particular study is by evaluating them in relation to the procedures and methods used in generating them (Graneheim and Lundman, 2004; Sandelowski, 2000a; Lincoln and Guba, 1985; Patton, 2002; Bryman, 2006; Creswell, 2003). In a recent review of the existing knowledge elicitation methodologies, Cooke (1994) noted that though there is no shortage of methods, the lack of compelling evidence on the modes of evaluation remains a challenge. As a result, the issue of reliability, validity and generalizability of the CDM has therefore received more methodological attention in recent years than it has in the past.

4.4.1. Reliability of the CDM method

According to Gordon and Gill (1997), some of the questions commonly used to challenge the reliability of the critical decision method are: can participants be expected to report the same details when asked about the same incident at a later time? Can participants be expected to identify the same proceedings in the timeline (decision points, critical cues, action etc.)? Furthermore, issues have also been raised about the reliability of the procedures used to analyse the CDM data and decision points in particular (Hoffman, Crandell and Shadbolt, 1998). In this regard, sceptics have asked whether independent data analysts would generate the same results from the coding of raw CDM data. Finally, the reliability of the identified decision points has also been questioned.

Some authors have also questioned the *retrospective* nature of the critical decision method (e.g. Nisbett and Wilson, 1977; Ericsson and Simon, 1993), arguing that individuals do not always accurately report information that has to do with the recollection of past events due to the inherent limitations of the human memory. In line with this argument, it is believe that the exact circumstances surrounding an incident can never be recreated, and that once interviewed, the interviewee's memory about the event will alter to some unknown degree (Maqsood, Finegan and Walker, 2004). In addition, sceptics have often laid emphasis on the effect of *hindsight bias* i.e. the tendency to view events as more predictable than they really were (Turner, 1976; Messick and Bazerman, 1996; Kahneman, 2011). Hindsight bias has been attributed to the main reason why people will attempt to cover up their mistakes and report only the aspects of an incident that favour them (Ericsson and Simon, 1980; Kahneman, 2003; Weitzenfeld *et al*., 1990; Dickson, McLennan and Omodei, 2000).

Despite all the questions and concerns regarding the validity and reliability of the critical decision method, most empirical studies, particularly those that utilized real experts, have persistently shown that the critical decision method has proved to be effective and reliable in eliciting expert knowledge. (Klein *et al*. 1988; McLennan *et al*. 2006; Burke and Hendry, 1995; Wong, 2004; Lipshitz *et al*., 2007). Although it should be noted that CDM experts do not deny the possible limitations associated with the use of retrospective verbal protocol in knowledge elicitation, they simply suggest that some of the criticisms tagged with the method are slightly exaggerated (see Flanagan, 1954; Klein *et al*., 1989; Hoffman *et al*. 1998 for a review of the CDM protocol). For instance, in their research with fire fighters, Klein, Calderwood and Clinton-Cirocco (1988) observed that most of the very challenging incidents in the career track of the officers were vividly remembered and that many of the non-routine events were reported more accurately and completely than the routine ones (Eraut, 2004; Calderwood, Crandall and Baynes, 1990). This holds true even for incidents dated as far back as 10 years or more (Crandall, Klein and Hoffman, 2006).

In their review of the critical decision method, Klein *et al*. (1989) suggested that the CDM minimizes hindsight bias and other cognitive biases through the same strategies with which it enhances incident recall. These include allowing the same story to be narrated at least twice throughout the duration of the interview (see step 2, 3 and 4 above). The “rule of thumb” is that the more participants are committed to going over an incident, the less likely are there to be discrepancies or variations in the generated CDM data. The incident timeline phase (which allows a timeline of the various events that happened throughout the incident to be sketched), in addition to the fact that participants are allowed to refer back to their log books and registers (in the event they could not remember certain things about the incident) — have both played important roles in enhancing memory recall. Furthermore, the CDM probe questions, regarded as one of the greatest strengths of the method, have also proved useful in reducing any form of inconsistency between what was initially narrated and the subsequent answers provided by participants to each of the probe questions (O'Hare *et al*, 1998).

One of the ways in which the issue of reliability has been mostly addressed is through the use of *inter-coder agreement* (i.e. the level of agreement between two or more independent judges regarding the coding result of interview data). Inter-coding reliability checks have been used to show a high level of coding agreement across a range of CDM studies (Hoffman, Crandall and Shadbolt, 1998; Klein *et al*., 1989; Hoffman *et al*., 1995). For example, in a study involving wild-land fire ground commanders, Taynor *et al*. (1987) utilized two independent judges to code for "decision strategy" across 29 decision points; the corresponding calculation of agreement yielded a rate of 87%. In another study by Calderwood, Crandall and Klein (1987), two independent judges also attempted the classification of the decision strategies from 18 decision points and found their rate of coding agreement to be about 89%.

4.4.2. Content validity

In addition to the issue of reliability, the internal or content validity of the critical decision method has also been addressed in the cognitive task analysis literature (c/f Hoffman and Militello, 2008). The questions posed under this theme can be framed in terms of the quality of data generated from a CDM procedure i.e. examining how comprehensive, accurate, inclusive, and precise such data are. The question can also be framed in terms of the informational content of the data e.g. does the method yield true information about the concepts, principles, decision making styles etc. of the particular domain which was investigated?

In their assessment of the content validity of some CDM studies, Hoffman *et al*. (1998) reported the relevance and value of the products developed from these studies. For instance in a study conducted in the domain of neonatal intensive care unit, Crandall and Getchell-Reiter (1993) interviewed 22 experienced nurses (mean length of experience, 13years) using the CDM protocol. Findings from the study revealed certain diagnostic cues such as muscle tone, sick eyes, edema, clotting problems, a few of which were found to be opposite of what the existing cues (i.e. indicators of infection in adults) were known to be. Also, interestingly, more than one-third of the cues that were discovered in the study appeared to be novel in the medical literature at the time. Following the outcome of the study, Crandall and Getchell-Reiter (1993) went further to conduct a validity check on the identified diagnostic cues, based on independent assessments made by a group of experts. The experts who comprised independent NICU nurses, clinical and specialist nurses and research based nurses were all found to favour the findings from the study, giving credence to the theoretical and practical relevance of such findings.

In another CDM study, Wong *et al*. (1996) interviewed ambulance dispatch officers at the Sydney ambulance coordination centre and used the knowledge elicited from the officers as the basis for the design of a more efficient decision aid. The content validity of the CDM output was attributed to the ability of the authors in transforming the manual system used for collecting and processing information at the ambulance call centre to a more efficient computer based system.

The content validity of the findings from the current study was mainly assessed through discussion with the author’s supervisors and from expert scrutiny. As stated earlier, findings from the study have been published in two different peer-reviewed journals (Okoli *et al*., 2014; Okoli *et al*., 2015) and in a conference proceeding (Okoli *et al*., 2013)

4.4.3. Generalizability of the CDM outputs

As stated earlier, a common criticism of qualitative inquiry relates to its methodical dependence on small samples, which critics believe renders conclusions from such studies incapable of generalization (see Myers, 2000 for example). The term 'generalizability' means the degree to which the findings from a study sample can be generalized to the wider population (Marshall, 1996). In other words, can the conclusions reached in a single study be successfully applied beyond the scope of the instances investigated?

It should be emphasized at this juncture that qualitative studies, and CDM studies in particular, are not generalizable in the literary use of the word, neither do they claim to be (Stake, 1980; Myers, 2000; Wong and Blandford, 2002). Rather they seem to be imbued with other redeeming features which make them highly valuable for transferability to other domains. Every single incident reported in a CDM study is treated as a unique source of data and analyzed for the purpose of theme development, thereby making the issue of generalizability less significant. Studies in the CDM literature have shown substantial records of making significant contributions from and to a wide range of disciplines such as psychology, education, nursing, aviation etc. in diverse ways (Klein, Calderwood and McGregor, 1989; Crandall and Gretchell-Leiter, 1993; Hoffman *et al*., 1995; Schraagen *et al*., 2000; Hutton, Miller and Thordsen, 2003; Hutchins, Pirolli and Card, 2004; Clark *et al*. 2006). Most of the frameworks, theories, models, training needs and conceptual graphs generated from these studies have continued to help in bridging the gap between theory and practice, especially in the aspect of developing instructional designs (see Hoffman et al., 1995; O'Hare et al., 1998 for a review)

4.5. APPLICATIONS OF THE CRITICAL DECISION METHOD

CDM has certainly proved useful in a variety of ways. Below is a summary of how the outputs and products of the critical decision method can be applied or utilized in practice, particularly in the firefighting domain as with this current study:

4.5.1. Training and developing decision aids

The various incident accounts from the CDM interviews can be written up and used as training materials to assist trainees in developing the relevant firefighting skills such as situation awareness, pattern recognition or prioritization skills. These reported incident cases can be used to develop table-top exercises or role playing scenarios that would help prepare novices for dealing with similar non-routine incidents in the real-life (Wong, Sallis and O'Hare, 1997).

Products from the CDM procedure which can serve as decision aids include: (i) a taxonomy of domain concepts and categories along with their definitions (ii) a taxonomy of the changing conditions (situation assessment record) (iii) a taxonomy of principles and causal relations (IF-THEN or CUE-ACTION relationships) (iv) a taxonomy of goals and associated options (v) a taxonomy of skills and sub-skills that are used by experts. On this note, the CDM data generated from this current study were packaged in three major ways as shown below. Each of these outputs are presented and discussed in the next three chapters of this thesis.

1. Descriptive Decision Model: the decision points identified from the CDM procedure can be coded and categorized, and then utilized as the basis for developing a decision model. Such a model is made possible following the patterns and common themes identified across all the incidents. The developed decision model can be used to support, refine or modify previously established models in the field e.g. the RPD model (Klein, 1997), the R/M model (Cohen *et al*., 1996); decision ladder (Rasmussen, 1997) and image theory (Beach, 1978).

In their CDM review article, Hoffman *et al*. (1995) explained that a decision model is also referred to as a "conceptual graph", which they defined as a graphical representation of a domain in terms of the relationships or links between the various elements, concepts and nodes which domain experts use in conveying relevant information. The authors also made a strong case for the use of cognitive graphs, stating that they tend to represent a domain better than would explanatory texts.

A model that describes how experts make intuitive decisions amidst multiple sources of information on the fireground was developed and discussed in this study (see section 5.8), and has also been published elsewhere (Okoli *et al*., 2015)

2. Critical Cue Inventory: Another way the CDM products can be utilized for the development of training materials is by generating taxonomies of informational and environmental cues (e.g. smoke colour, smoke direction, type of building, climatic conditions etc.). The critical cue inventory (CCI) therefore refers to the informational and perceptual cues that have been collected and compiled from the coded incident accounts. Since some of the cues experts use in making critical decisions are mostly tacitly held and thus potentially unknown to them, the critical decision method becomes a very useful tool for eliciting knowledge about such cues. The CCI mostly serve the purpose for developing training protocols particularly for cue-based learning.

A critical cue inventory record was developed from this study, which includes 42 cues used by the expert firefighters who were interviewed in both the UK and Nigeria. The critical cue inventory is presented and discussed in section 5.7 and has also been published elsewhere (See Okoli *et al*., 2014)

3. Competence Assessment Framework: A framework that revealed the relevant skills and knowledge dimensions used by experts across the entire incidents was presented and discussed in section 5.10. The framework is envisaged as a useful tool against which the competence of novice firefighters can be assessed.

CHAPTER 5
PRESENTATION OF FINDINGS AND RESULTS

This chapter presents and discusses the main findings from the study, and compares the insights generated from the UK and the Nigeria experts where possible. The chapter starts by presenting the demographic characteristics of both groups of firefighters, which include their length of experience in the service, educational qualifications, number of stations previously served and their positions/rank in the fire service. Thereafter, the characteristics of the incidents narrated by each participant, the decision points from each incident, the decision making and problem solving strategies used by each participant, the goals pursued at each decision point, the pattern recognition mechanisms, the cues that informed decision making were all presented and discussed. Furthermore, a model that attempts to describe the decision making strategy of the expert firefighters across both countries is presented and discussed. Finally the chapter concludes with a competence assessment framework which was developed from the knowledge elicitation process across the entire incident reports. The framework attempts to outline the key tacit skills that were gathered from the expert firefighters following the critical decision method cognitive probe process.

5.1.1 DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

As part of the interviewing process, demographic and personal information regarding respondents' fire-fighting career was collected (See Table 5.1), which provided a robust background that relates to the participants' firefighting career across the two groups. One of the demographic questions that was asked in this study, which was found to be rarely included in other related CDM studies, was for participants to briefly share their experiences across the various fire stations in which they had previously served. This question was found to be useful as it allowed insights to be gained about how different station-specific features are likely to affect the process of skill acquisition amongst firefighters.

Table 5.1: Demographic characteristics of respondents

PSEUDONYMN/ GENDER	**YRS OF EXPERIENCE**	**POSITION/RANK**	**EDUCATION QUALIFICATION**	**NO OF STATIONS PREVIOUSLY SERVED**
UK FIRE-FIGHTERS				
NATH [M]	5*	Station manager	MSc	3
ADRIAN [M]	17	Watch commander	CCSE/O Levels	5
PATRICK [M]	32	Asst. Fire chief	MSc	20
DICKSON [M]	23	Crew commander	College: TEC Certificate	7
BROWN [M]	27	Crew commander	Nothing	4
LILIAN [F]	15	Director in command	MSc	3
ISAAC [M]	13.5	Crew Commander	A levels	3
DUNHAM [M]	13.5	Station Manager/flexi duty officer	O Levels	9
MARTINS [M]	31	Crew Commander	A levels	5
DAKE [M]	17	Watch Commander	Diploma	5
WILLY [M]	28	Watch Commander	A Levels	8
LAMBERT [M]	26	Watch Commander	Secondary school	11
JADE [M]	15	Crew Commander	A levels	4
DARREN [M]	17	Station Manager/District Commander	MSc	10
TROY [M]	27	Group Commander/Flexi	MSc	13

		duty officer		
NIGERIAN FIRE-FIGHTERS				
YOUNG [M]	8	Fire Supt officer	HND	2
KEVIN [M]	8	Watch commander	NCE	2
SAMMY [M]	8	Fire supt. officer	NCE	2
KNIGHT [M]	8	Watch commander	NCE	2
ADAMS [M]	30	Chief fire supt.	DIPLOMA	2
RYAN [M]	8	Fire supt. officer	NCE	1
MARVIN [M]	30	Commandant trainer/Station Manager	DIPLOMA	3
ATKINSON [M]	8	Watch commander	NCE	2
JACK [M]	30	Chief fire supt.	SSCE	4
SUNNY [M]	29	Asst. Chief fire supt.	OND	4
STEVE [M]	9	Fire Supt Officer	BSc	2
FRANCIS [M]	28	Chief Fire Supt	HND	4
BILLY [M]	25	Principal Fire Officer 1/Asst. Station Manager	ND	3
MARGARETH [F]	11	Fire Supt Officer 1	BSc	2
MIKE [M]	28	Asst. Chief Fire Supt	DIPLOMA	3

****NB: The first participant attended his training in a fire station in Taipei and not in the UK***

5.1.2 The length of experience in the fire service (measured in years)

The length of years professionals have collectively served in their work domains has been used as an important variable in most studies on expertise (Hoffman *et al*., 1995). The rule of thumb is usually that the longer the time people have served in a particular work domain the greater the knowledge they are expected to have acquired in such a domain, although some scholars have challenged this notion claiming that a high number of years of experience does not necessarily signify more domain knowledge (c/f Shanteau *et al*., 2002). These authors argue that other factors such as the type of problems solved, the quality of team composition and the quality of training received are all possible factors that could also influence task performance. It is important to note that although this study initially aimed to maintain the "conventional" minimum of 10 years of working experience (Chase and Simon, 1973; Gobet, 2005) for all the participants as part of the recruitment criteria, it was somewhat difficult to achieve with the Nigerian firefighters. Four of the participants in the Nigerian group had been in the service for less than 10 years; however they are still categorized as experts judging by other variables such as position/rank as well as peer recognition (Shanteau, 1992; Shanteau *et al*., 2002). The years of experience varied across respondents in Nigeria and the UK as shown in Table 5.2. Overall, the mean year of experience across the two groups of firefighters was seen to be significantly higher than the conventional ten years recommended by most scholars (the term "conventional" was used because most of the aforementioned scholars seem to agree that a professional must have served in a work domain for a minimum of 10 years before s/he can be regarded as an expert). Table 5.2 also shows that the Nigerian firefighters had a higher variance in their years of experience compared to their UK counterparts, and this was mainly because of the higher rate of staff turnover in the Nigerian fire service. Officers in the Nigerian fire service are more prone to leave the fire brigade once they find a better opportunity elsewhere, especially the relatively junior officers.

Table 5.2: The distribution of experts' Length of service (years) in the UK and Nigeria

GROUPEXPERTS		N	Minimum	Maximum	Mean	Std. Deviation
UK	YREXPR	*14	13.50	32.00	21.5714	6.78759
NIGERIA	YREXPR	15	8.00	30.00	17.8667	10.45990

****NB: Number of participants in the UK was 14 because one of the participants was exempted who was currently not based in any UK fire station, though a firefighter***

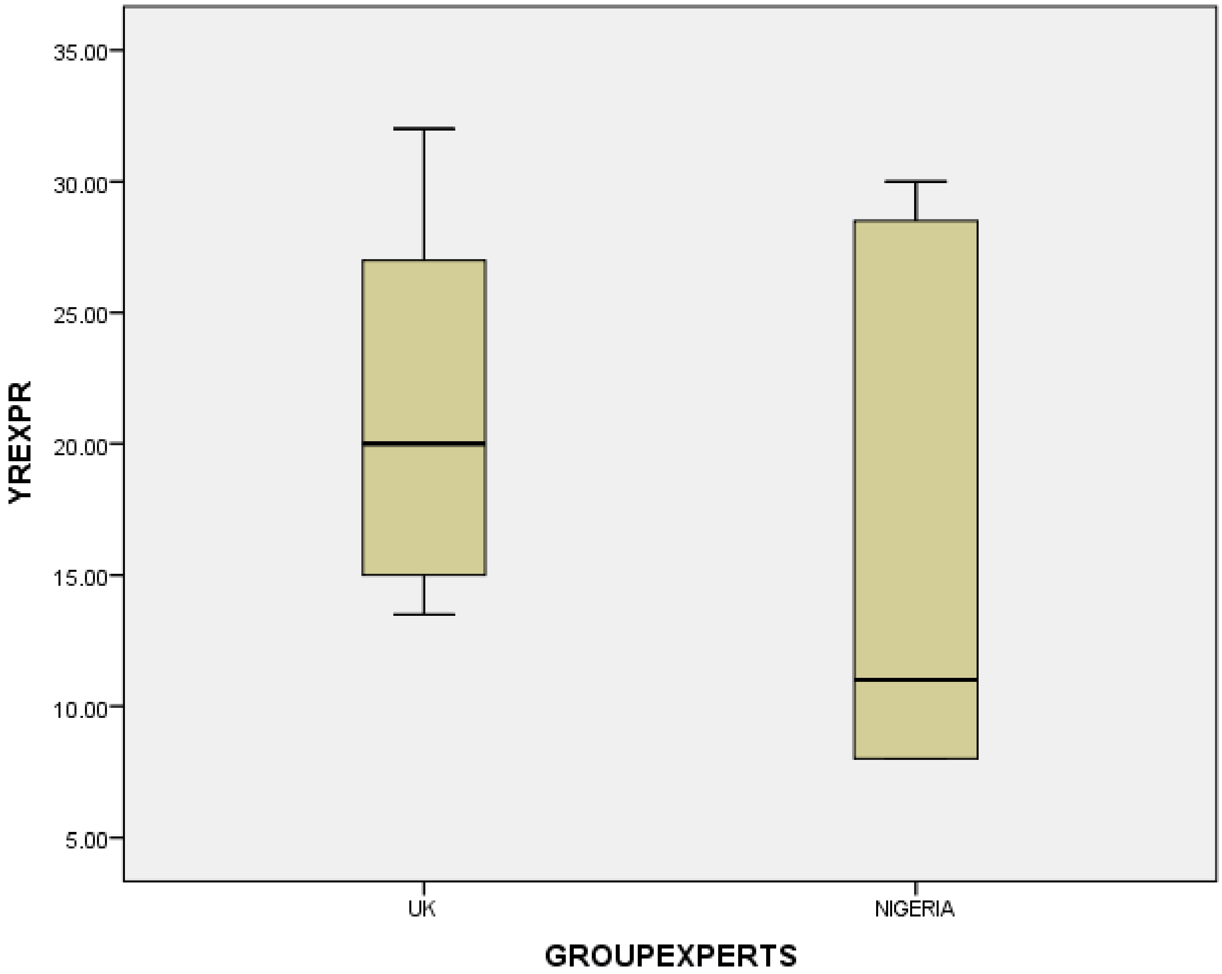

Figure 5.1: The distribution of the length of service for experts across both groups

It was also observed that years of experience do not necessarily correlate with people's position/rank, especially in the UK. From Table 5.1, it can be seen that some of the high ranked officers such as station managers and flexi-duty commanders (e.g. Darren, 17, Dunham, 13.5) have a lower length of service year than most of the crew commanders (e.g. Dickson, 23; Brown, 27; Martins, 31). This seems to suggest that factors other than simply years of experience possibly contribute to people's career progression in the fire service.

5.1.3 Rank/Position

The position/rank of each of the participants served as an important and unnegotiable selection criterion in the study, meaning that all participants were at least required to be in a supervisory management position before they can participate in the study. The fire service in both countries operates a hierarchical organizational structure whereby an officer progressively climbs the scale of authority based on merit. The first point of promotion in the fire service, across both countries, is that of moving from an ordinary fireman to a crew commander. This promotion is heralded by attending and writing a series of courses, after which officers are made to acquire the "all-important" incident command training. It is this incident command training that actually differentiates ordinary firefighters from supervisory managers and beyond.

Participants' position/rank were categorized into three groups: supervisory managers, middle managers and senior managers (see Fig 5.2) Supervisory managers, which mainly include crew commanders and watch commanders, are group of officers that are qualified to lead at least one fire crew to the scene of an incident, acting as incident commanders. These officers ride on fire engines to the scene of an incident with their crew(s) and take a leadership position pending the time a superior officer arrives on the scene. The middle managers are the more senior officers who are tasked with higher levels of command and control and only attend more "serious" incidents; these include station managers and flexi-duty officers (group commanders). Officers in the middle management position are not confined to a particular station; they can also operate within a borough or a district and have management responsibility for people and other resources, beyond just the watch. The last category, senior managers, is the most senior set of officers who make strategic and policy decisions that guide the fire service. Officers in this group include assistant chief fire officers, deputy chief fire officers, area commanders who mainly attend to "catastrophic" incidents e.g. incidents that involve media attention. For large incidents, the most highly ranked officer that is present at the scene usually takes the overall incident command responsibility, but might need to appoint other experienced officers to manage other sectors. Hence, sector commanders take charge of particular sections of the incident/building, giving instructions to the crew(s) working directly under them, communicating with other sector commanders and ultimately reporting to the overall incident commander.

Although a lot of similarities exist in the hierarchical structure between the UK and Nigerian firefighters, a little difference was also found in the way the officer that takes over the overall incident command position is decided. Whilst the Nigerian fire service tend to be hierarchical in this regard and allows only the highest ranking officer present at the scene to take over, in the UK the decision is mainly based on the circumstances surrounding the incident. Although the most experienced of the officers (in terms of length of service) also usually takes over the leadership role in the UK, yet in some other instances the officer who got to the scene of the incident first and has gained the best situation awareness is allowed to assume the overall command position, regardless of their rank — provided they are making the right decisions.

Also, while the senior (strategic) managers in the UK fire service are rarely positioned at a particular station (at least not one that is used for operational service), this was not found to be the case for their Nigerian counterparts. The senior managers in the Nigeria fire service were often based in fire stations, but mostly at the headquarters (which is also used for operational services in Nigeria). This explains why the author was able to recruit four senior managers in Nigeria as opposed to just one in the UK (Fig 5.2)

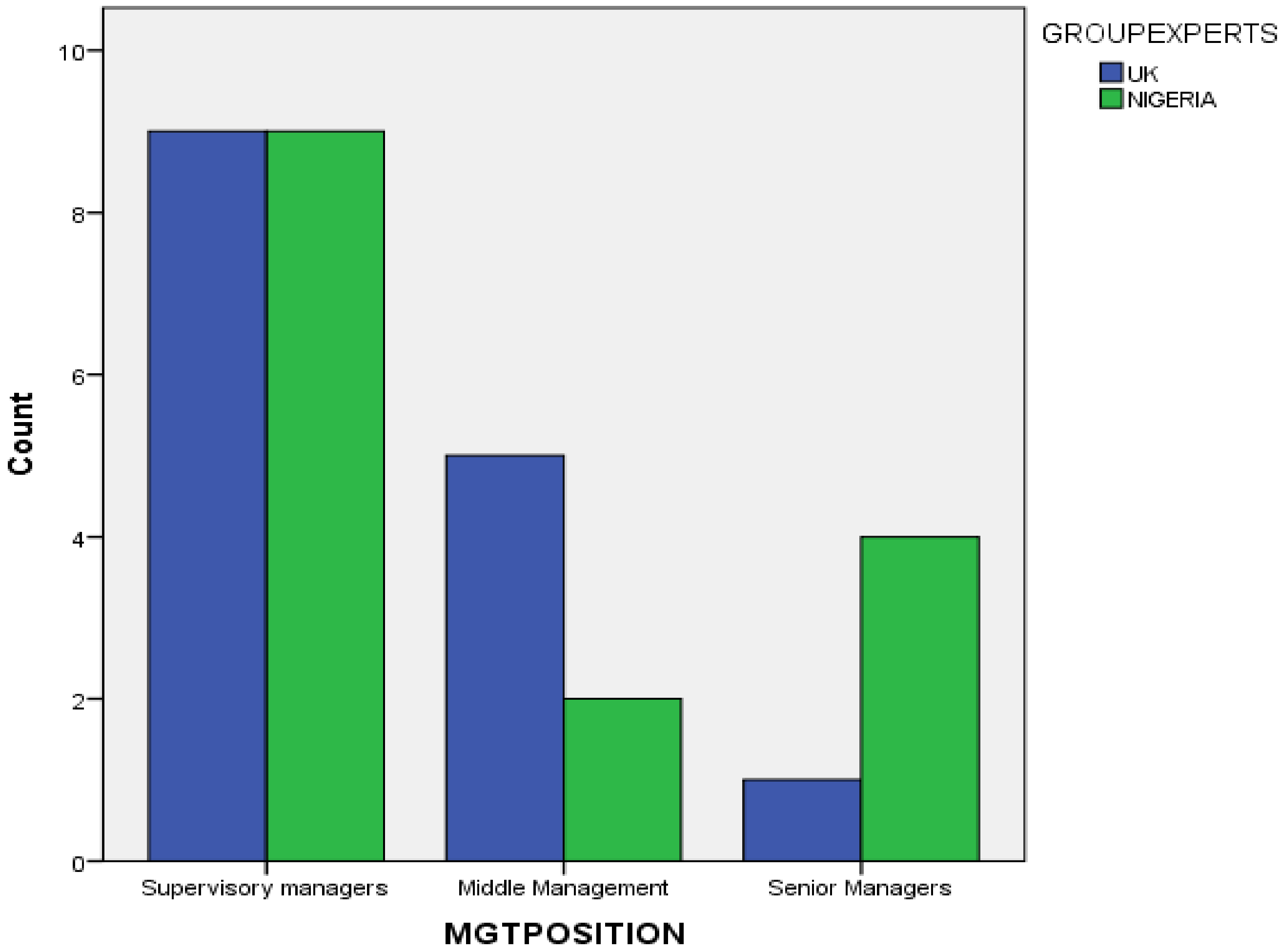

Figure 5.2: Distribution of participants based on management position (n=30)

5.2. Peculiarity of incidents to the participants

As part of the interviewing process, respondents were probed as to why they selected the particular incident they chose to narrate, out of the other numerous incidents they have attended. The main rationale behind this question was to ascertain what actually makes an incident both complex and unique from the point of view of the participants. At the start of the interview, the interviewer ensured that the participants understood the type of incidents that met the requirements of the study i.e. incidents that are memorable and remarkable and those that sufficiently challenged the expertise of the participants. It was important that the incident chosen by each participant was non-routine, and for which some sets of interconnected decisions were made under time pressure, and this is because experts are more likely to reflect their tacit knowledge when managing unusual incidents as opposed to routine ones (Polanyi, 1962). Some of the non-routine incidents reported in the study include incidents:

i. In which combustible and hazardous substances were present (e.g. acetylene and LPG cylinders)

ii. Where getting access routes to the fire-ground was quite difficult or problematic

iii. (iii) where access to the seat of fire was extremely dangerous and/or involved breaking of walls/roofs

iv. Where water was not readily available either because there were no hydrants available or because the available hydrants were not flowing with the right amount of pressure

v. For which members of the public had to be evacuated from their homes to safe shelters

vi. Where information regarding the cause of fire was not readily available.

A content analysis of the CDM data revealed seven different criteria that defined experts' perception on what a "challenging" and/or a "memorable" incident was (Table 5.3). It was interesting to know that participants did not necessarily define a memorable incident on the basis of how recent or how fresh such an incident was in their memory, rather, other variables were seen to influence the decision of each participant to narrate the particular incident they chose to report. These are discussed below:

Table 5.3: Participants' rationale for incident selection

Rationale for selection	No of incidents (UK)	No of incidents (Nigeria)
Unusual incident	5	1
Severity of incident	5	6
Casualties involved	1	3
Requiring complex and multiple decisions	5	1
Recency of incident	2	4
Effective performance	3	2
First incident in charge	1	-

i) Casualties involved: Experts categorized incidents as remarkable or memorable if such incidents involved the loss of human live(s). They also admitted that such incidents are very difficult to forget. As shown in Table 5.3, four of the incidents reported in this study involved the loss of human lives (3 Nigeria, 1 UK). One of the Nigerian incidents was a serious road traffic collision that eventually led to a severe fire outbreak, resulting to the death of eight people. Each of the other two incidents (Nigeria) involved the death of an elderly person that was trapped in the building and unable to escape. The UK one on the other hand was a workshop fire in which the owner of the workshop suffered 30% burns from an acetylene explosion and eventually died three days after the incident.

(ii) Severity of the incident: Experts described an incident as "critical" or "very serious" if a great deal of property was lost or seriously damaged, or if the stress involved in managing the incident was so out of proportion that experts were stretched beyond their comfort zones, or if a number of task constraints were associated with managing the incident. Task constraints refer to the elements of a task that inhibits good performance. Some of the task constraints identified in this study include, for example: ensuring a constant supply of water in rural areas where hydrants sometimes flow with low pressure or where hydrants do not even exist at all; breaking through building walls in order to gain access to the seat of fire; fighting a fire against harsh climatic conditions (such as excessive heat, high wind intensity, negative wind direction); gaining access to fire scenes in tight spaced locations that pose difficulties in setting up fire appliances; and concurrently carrying out firefighting and rescue operations particularly with limited resources.

Experts also seemed to define a severe or a serious incident on the basis of the time it took the firecrew(s) to bring the incident under control. Two massive factory fires (1UK, 1 Nigeria) were particularly memorable to the participants because both incidents lasted for about three days (72 hours), even with continuous firefighting.

iii) The level of risk involved: Experts also defined a “remarkable” or a “memorable” incident on the basis of the amount of risky or life-threatening decisions they were forced to make while managing the incident. Although it is true that firefighting is a type of domain where experts are required to make important decisions with pre-defined standard fire service risk philosophies underpinning task performance as a guide, yet these experts explained that some level of risks are still required to be accepted by the incident commander, beyond what is stipulated in the books. For example, Sunny (ACFS, 29, Nigeria) reported how he entered a building that was well-alight without wearing breathing apparatus as none was available. Though the commander admitted that such level of risk was somewhat intolerable from the point of view of the standard operational procedures in the fire service, it was still the best option that was available to him. The other option was to admit to defeat and allow the building to burn itself out. Similarly, Dickson (23, Crew commander, UK) reported how he and his crew were almost caught up in a warehouse explosion involving acetylene cylinders. Similar to the Nigerian officer, Dickson admitted taking a high level of risk by going offensive (direct firefighting) instead of defensive, which was, in that circumstance against the standard operational procedures of the UK fire service.

iv) Effective performance: It has been shown that experts are naturally motivated by their performance records and therefore strive to maintain good records as much as possible (Zimmerman, 2006). As shown in Table 5.3, it was interesting to note that five of the participants in this study preferred to narrate the particular incident they chose mainly because they were personally satisfied with their performances (3 UK, 2 Nigeria). These experts were therefore excited to share their experiences, stressing the fact that they did everything needful, timely and professionally. The excerpts below shed more light to this:

> *I'm very good at reflecting, I'm very good at saying where I can learn, but I guess one of the reasons I'm using this particular incident to discuss with you is because it is an incident that I was very pleased with and at the end of it I was happy with the decisions that were made and the consequences of those decisions (Jade, crew commander, 15.5, UK)*

> *"I decided to share this incident because if we had not used the tactics we used, the whole town could have been burnt down" (Mike, Assistant chief fire superintendent, 28, Nigeria)*

vi) Novelty of the incident: Six of the participants admitted that the incidents they narrated were quite "strange" and unusual, and thus required making decisions that were beyond normal routine practices, or that exceeded what was covered during training. These incidents were therefore chosen by the participants either because of their rarity or because of the "twists" that evolved along the line. Novel or atypical incidents, unlike routine ones, often place more pressure on decision makers, who are expected to resolve complex problems mainly by relying on creative knowledge. For example, Marvin (Station Manager, 30, Nigeria) reported a fire incident on a moving train and admitted it was his first time of experiencing such in his career in Kwara state (one of the study areas in Nigeria). Darren (Group commander, 17, UK) also reported a school fire incident which had a number of unexpected turns which he had never witnessed in his career as a firefighter. The fire started as a roof fire and suddenly turned into a catastrophic incident, rapidly spreading across two other buildings in ways the officers could not explain.

5.2.1. Why is firefighting a complex domain?

In their research on cognitive task analysis, Clark *et al* (2006) argued that for a task to be classified as complex it must be performed using both automated (tacit) and explicit knowledge and must, in addition, usually extend over many hours or days. The data in Table 5.3, in addition to excerpts from the interview transcripts (see below), provided additional insights into what makes firefighting a complex task. Expert participants in this study reported that the main task difficulties they encountered when managing complex fire incidents included:

- working over a long duration of hours usually without any break or refreshment
- managing and coordinating resources effectively (crew members, fire engines and appliances, multi-agencies)
- the need to continuously monitor a complex situation and develop plans amidst constantly changing conditions
- the possibility of encountering novel situations
- managing the emotions of members of the public and ensuring their safety
- managing the media and public perception
- battling with harsh weather conditions such as wind.
- ensuring the safety of fire crews against physical and verbal attacks from members of the public (peculiar to the Nigerian environment)
- getting adequate water to fight a serious fire without having to go back to the station for replenishing (peculiar to the Nigerian environment)

The following excerpts below show the expressions of some of the participants with regards to the complexities associated with managing fire incidents:

> *"This incident was very challenging for me because we were working against very difficult atmospheric conditions; very dry, severe drought and windy conditions in a densely populated area with houses all over" (Lilian, 15, Watch commander, UK)*

"It was very unusual for me because the woman involved was psychiatric and threatened to burn down the building if we left….so the incident turned out to be a welfare issue" (Adrian, 27, Crew commander, UK).

There are two dangers which you can meet when you enter into an engulfed building: the livewire might drop on the ground which you don't know because it has affected all the roof, so things up would come down which would involve a livewire, then toxic gas might have engulfed all the building – you can't inhale a toxic gas for 2 mins, that officer would suffocate (Young, 28, CFS, Nigeria)

"……the wind factor itself was something I had never experienced before. The wind was like swirling, and the fire was actually drawing the wind in. So even on the opposite side of the fire you might have had a wind say 5, 6, 7 10 miles/hr, it's probably 40-50miles/hr on the opposite" (*Dunham, 13.5, station commander, UK)*

"There was no wind so the smoke didn't blow away, which made it difficult for communication because you couldn't see the person you were talking to because of the smoke, but these can be overcome by tactics" (Lambert, 26.5, Watch commander, UK)

"Because it is a dynamic situation, you had all the factors, the wind, the smoke, the heat, the water, all the different factors that you have to take into account, crews welfare, you have to take that into account, keeping their adrenaline levels up, fatigue was a big one. I was there in charge of that area for 11hrs without being relieved so you think of the mental strain, the mental pressures and tiredness as well as the physical" (Dunham, Station Commander, 13.5, UK)

The above excerpts provide ample evidence that supports existing claims regarding the complexities and ambiguities associated with a fireground environment. Officers noted that the need to attend to a range of external factors is what mostly contributes to the task difficulties they face on the fireground, particularly with the factors they have little or no control over. The influence of atmospheric conditions in relation to task performance was found to be a popular theme amongst the UK firefighters as shown in the above excerpts. This is because fighting a fire under unfavourable conditions (such as excessive heat, high wind, and low humidity) often tends to increase one's mental effort and the amount of resources needed to fight the fire. One of the Nigerian officers, on the other hand, mentioned that firefighting job seems to be complicated for him mainly because officers have to identify and make sense of the various possible risks in their surrounding environment. Based on the excerpt from the Nigerian officer, it appears that ensuring the safety of one's self and that of others amidst unfavourable conditions, while at the same time carrying firefighting operations, explain why the job of firefighting seems complicated.

Furthermore, one of the incidents reported by one of the participants (Dunham, 13.5, Station manager, UK) gave a clearer picture of how complex or messy managing complex fire incidents could be. Important statistics across the timeline of this incident are shown on Table 5.4:

Table 5.4: Statistics of the Smethwick fire incident

- 429 "999" calls were made (this was 3 times the daily average)
- A total of 35 fire engines were deployed to the scene of fire.
- 2 high volume pumping (HVP) units were used
- 3 Aerial appliances were used
- Multi-agency involvement, which include incident command unit, environmental unit, incident support unit and welfare unit.
- Over 14million litres of water was used within the first 12 hours (this is equivalent to six Olympic swimming pools, 300,000 baths or the lifetime water consumption of 24 UK residents)
- 19,000 tonnes of $C0_2$ was produced from the fire (this is equivalent to flying from London to New York and back every weekend for 339 years)
- Smoke plume from the incident was visible from a distance of 40 miles
- Approximately 200 fire fighters were present at the scene of the incident at the same time (a record breaking number).

(Source: Smethwick Fire report 2013)

5.3. DECISION POINT CHARACTERISTICS

A decision point, which is the basic unit of analysis in this study, is defined as the point where participants admitted choosing a specific course of action from amongst several other potentially available alternatives. Examples of decision points from this study are: ‘I committed my crews with breathing apparatus into the building’, ‘I withdrew my crews from the building because it was too risky’, ‘I requested more appliances because I thought we didn’t have enough at that moment’ and so on. A total of 134 decision points were identified from the 30 incidents that were covered in this study (see Appendices A & B for an outline of decision points for the UK and Nigerian experts respectively).

5.3.1 Decision Time

Participants were carefully “walked through” each of the decision points and asked to quantify the time it took to make each decision — either in seconds, minutes or hours. The main rationale behind this question was to ascertain the extent to which these fireground decisions allowed for deliberation. It was made clear to the participants that the decision time in this context refers to the time that elapsed from when the need to decide came into their minds until the decision was made, as opposed to when a course of action was eventually implemented. It was important to clarify this since the latter often depends on other factors that are most times external to the decision maker (e.g. weather conditions, adequate manpower, nature of incident)

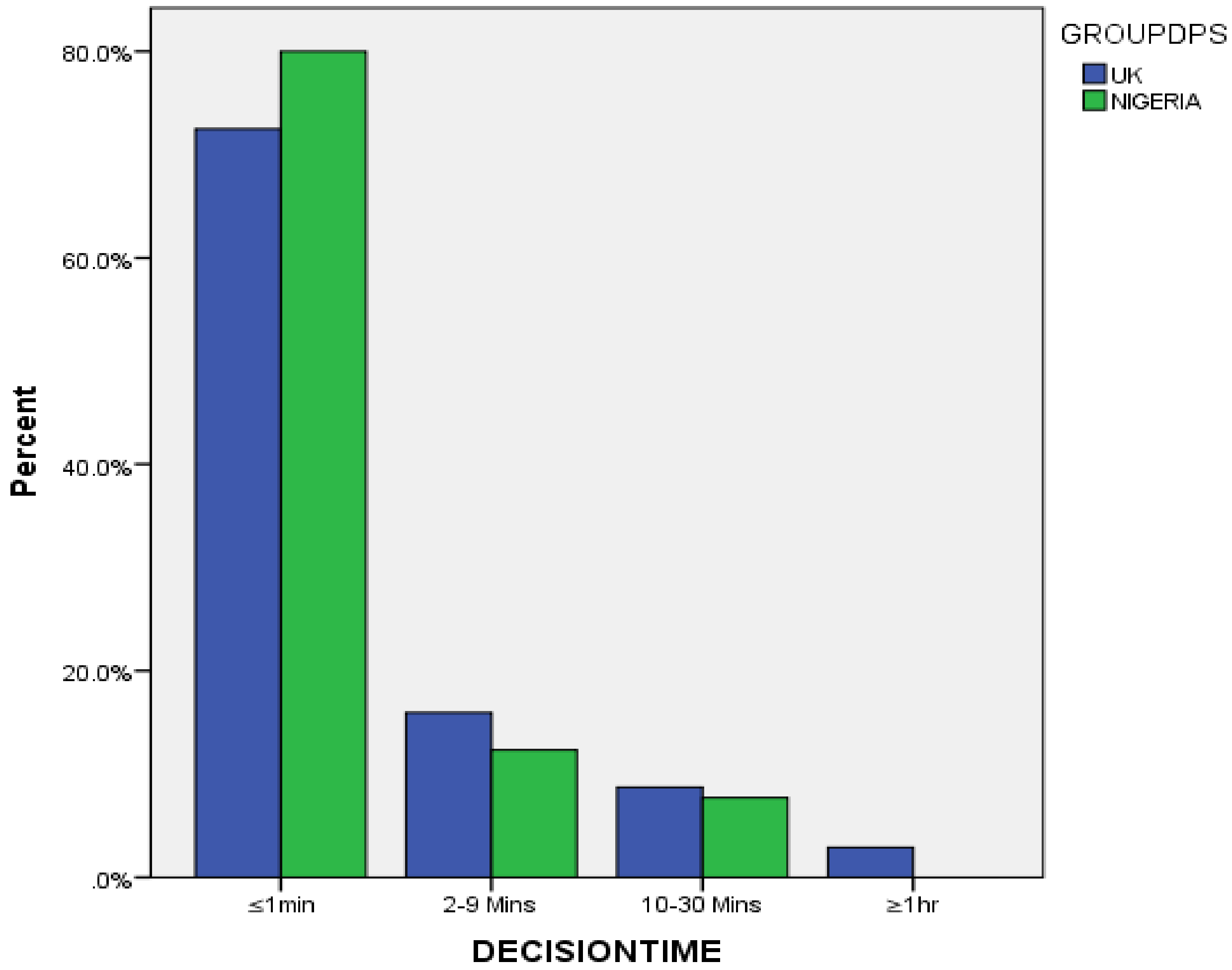

Figure 5.3: A breakdown of decision time across the entire decision points between the UK and the Nigeria participants (N=69 decision points UK, N=65 Decision points Nigeria)

Participants used words such as “instantly”, “straightaway”, “immediately”, “as soon as possible”, “almost immediately” to describe the urgency required in making most fireground decisions. Findings from Figure 5.3 reveal that 80% and 72% of the total decisions made by the Nigerian and UK officers respectively were within 1 min — which, on the basis of the time dimension, can be classified as intuitive decisions (Klein *et al*., 2010; Dorfler and Ackermann, 2012). It is worth mentioning that decisions reportedly made within 2mins were not considered as intuitive, judging by what constitutes an intuitive decision, as discussed in section 2.7 (pp. 51-52). At the extreme end of the analytical or deliberative decision making, only one decision point was found where there was a need to deliberate for up to an hour. In this case (a massive petrol storage fire, UK) the officer in charge (Patrick, Assistant Fire Chief, 32) was forced to change his initial proposed action plan to an alternative one, after the plan was found to be flawed .

Overall, a significant similarity was found in the decision time between the UK and the Nigerian groups.

5.3.2 Time Pressure

Time pressure is a term widely used in the naturalistic decision making domain to depict the psychological state of decision makers upon their awareness of the *urgency* to implement a course of action and/or the implications of not doing so. Participants were probed at each decision point and asked to verify whether they were under any form of time pressure. From the point of view of the reported incidents, all the participants (except one) agreed that firefighting places significant pressures on incident commanders. A content analysis of the CDM reports revealed five sources of time pressure associated with firefighting, as shown below:

- **Pressure to prove worth as overall commander:** Pressure to prove self-worth and to display a high level of professionalism as an officer in charge sometimes puts incident commanders under time pressure.
- **Pressure to return to business as usual:** During fire incidents incident commanders always strive to restore things back to normal and minimize disruption as low as possible. This generates more time pressured reactions
- **Pressure from task constraints:** As shown earlier, the task of firefighting is a complex one that requires incident commanders to make good and yet quick decisions. The need to make complex and high-staked decisions in a timely manner is therefore arguably the most important cause of time pressure
- **Pressure to prevent incurring further losses:** Envisaging that something more critical is likely to happen (e.g. fire affecting other nearby properties,

injury to crews, loss of lives etc.) places incident commanders under significant time pressure since they are then primed to act more urgently

- **Pressure to manage public behaviour:** Members of the public sometimes mount extra pressure on the fire crew(s), in the form of verbal abuse or physical attack. Such aggressive acts consequently distract firefighters from their main firefighting tasks, putting them under more intense pressure instead, which include: first, pressure from managing task constraints and second, pressure from coping with the aggressive behaviour of passersby. However, it is important to note that this issue was more prevalent in Nigeria because members of the public are usually not “cordoned” away from the scene of an incident unlike in the UK.

In order to quantitatively analyse the decision points, the current study employed the 4-point time-pressure scale that was utilized by Klein *et al*. (1988) in their initial study with firefighters as shown below:

Scale 1 (Low): Time pressure was coded “low” when a decision point does not directly impact the outcome of an incident, and most times include decisions made when an incident is still very much within control. For example, the decision to reassure members of the public on their safety (Brown, 27, Crew commander, UK)

Scale 2 (Medium): Time-pressure is rated “medium” in situations where officers had foreseen the potential of an incident escalating and acting to contain the fire or to prevent further spread. For example, the decision to first switch off the electrical supply from the main source after discovering that the incident was caused by an electric fault (Kevin, 8, Watch commander, Nigeria).

Scale 3 (High): Time pressure is high when loss of control over the incident is imminent i.e. when the situation is becoming increasingly complex and difficult to manage. A common example of decision that belongs to the high time-pressure category in this study is the decision to request additional resources (since the extra resources are meant to empower the crews with the hope that they can gain control over the incident). There is also the decision to commit firefighters into a building to initiate rescue operations (Young, 29, CFS, Nigeria; Martins, 31, Crew commander, UK)

Scale 4 (Extremely high): This is the highest level of time-pressure that can be exerted on expert incident commanders, and mostly occur in situations which threaten the loss of human lives. Examples of decisions that fell within this category are safety related decisions such as the decision to resuscitate trapped victims, decision to evacuate the victims to a safe place, decision to switch to a more defensive firefighting strategy for safety purposes.

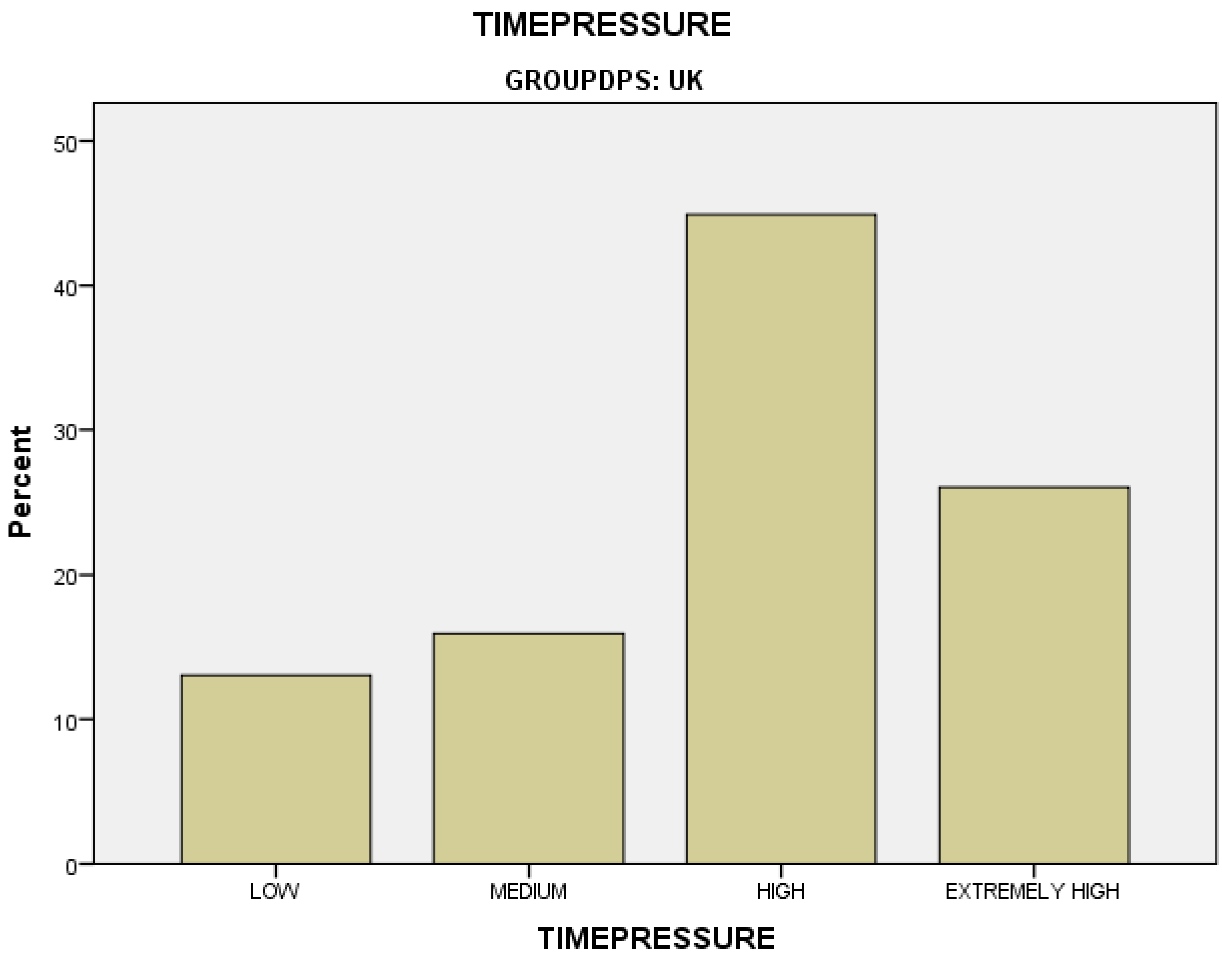

Figure 5.4: Distribution of time-pressure on a 4-point scale (UK Firefighters)

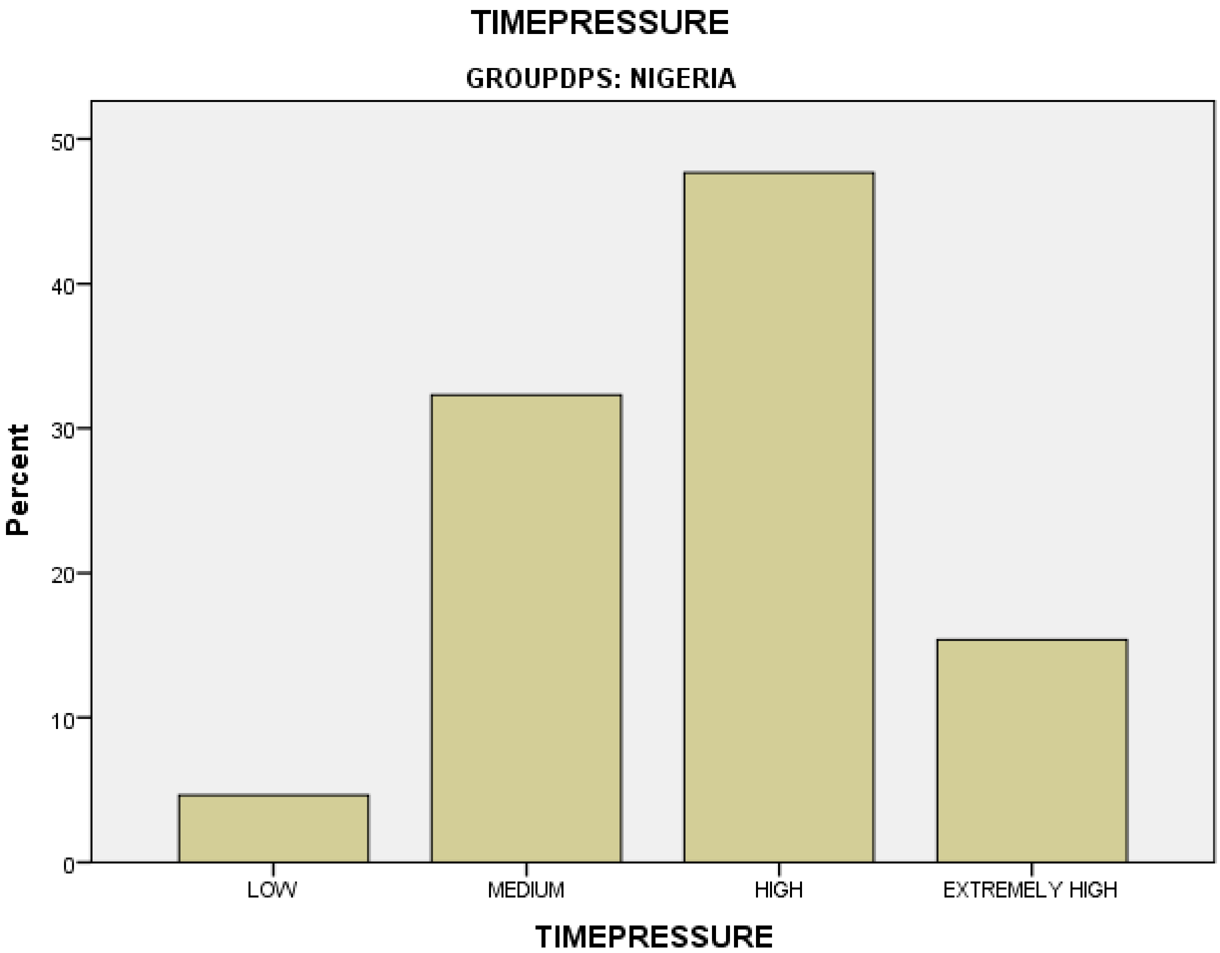

Figure 5.5: Distribution of time-pressure on a 4-point scale (Nigerian Firefighters)

Consistent with the previous studies that have investigated how human beings make decisions under varying levels of time-pressure (e.g. Freeman, Cohen and Thompson, 1998; Holgate, 2003; Reimer and Katsikopoulos, 2004; Hilbig, Scholl and Pohl, 2010), the above findings provide additional evidence to demonstrate that high staked tasks are mostly performed under time-pressure. Figures 5.4 & 5.5 above indicate that 71% and 63% of the decision points amongst the UK and the Nigerian firefighters respectively were made under conditions of high or extremely high pressures.

5.4. DECISION MAKING STRATEGIES

One of the most important objectives this research set out to achieve was to identify the dominant decision making strategy often employed by fireground commanders in solving complex tasks. In addressing the issue and meeting this important objective, a categorization construct was adopted that was similar to that used by O'Hare *et al*., (1998) in their study with expert water rafting guides, aviation pilots and emergency ambulance dispatchers. Each decision point was coded as "option comparison", "deliberated", "analog" or "prototype", depending on the source of knowledge applicable to experts at each decision point:

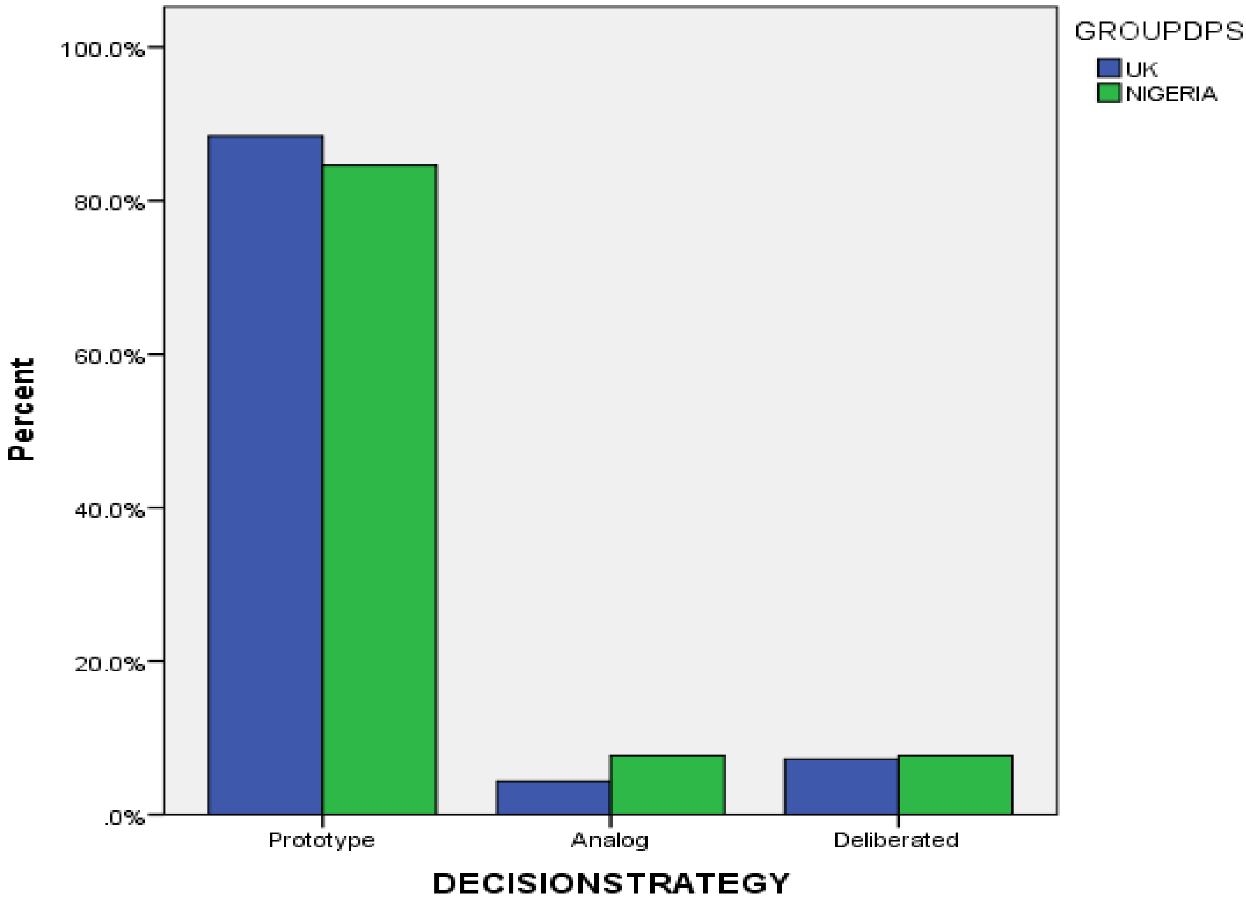

Figure 5.6: The percentage distribution of the decision making strategy between the UK and Nigerian officers

(N=69 decision points UK, N=65 Decision points Nigeria). N.B: Data for option comparison is not visible on the chart as it has zero frequency

Option comparison: Experts are said to be comparing options when they have to rely on pre-determined criteria (usually from external sources) to select their course of action. This approach to decision making involves consciously comparing and contrasting a particular option against other available options, similar to how people choose their holiday sites or the type of car to buy. As part of the interviewing process, participants were asked to explain if other options were available to them at each decision point. They were also asked to explain why they preferred certain options to another if they answered yes to the first question. The main rationale for asking this question was to better understand how experts generate and manage possible decision alternatives on the fireground. Fig 5.6 indicates that in no case was an option comparison strategy utilized

To explore further whether options actually existed, another probe question was applied as shown in Table 5.5. A total of ten participants (6 UK, 4 Nigeria) reported that no other option was available to them at each decision point, meaning they were not considering any other option at all. Twelve participants (8 UK, 4 Nigeria) acknowledged the existence of other options but explained, however, that the option they eventually chose was the best that was available to them at the decision point. Some of these officers emphasized they would still choose the same option if the incident were to repeat itself exactly the same way in the future. Six participants (Nigerian participants only), on the other hand, reported that they could have chosen another option if they had the luxury of choice. This group of experts explained that even though they could identify a few limitations in one or more of their selected options, they had no other option than to improvise with the resources and personnel available to them. Overall, only in one of the incidents was the first option chosen by a commander eventually found to be "unworkable". The officer in charge (Atkinson, 8, Watch commander, Nigeria) claimed he was eventually forced to change his tactics from "offensive" to "defensive" firefighting.

Table 5.5: Respondents' reaction to the availability of options

Categories	No of Participants		Supporting hypotheses in the NDM literature
	UK	NIG	
No other option exists	6	4	It has been reported in a number of NDM studies that the first option generated by experts is usually satisfactory, even for moderate experts (Johnson and Raab, 2003; Ross *et al*., 2004; Ward *et al*., 2011; Kermarrec and Bossard, 2014)
Other options exist but the option chosen was the best in managing the incident	8	4	Simon (1956) used the term "satisficing" to explain the notion that making decisions in time-pressured and high staked environments do not necessarily entail making the best decisions. Officers only need to make decisions that are good enough to get the tasks done in the safest manner.
Option chosen was not necessarily the best, but was the best available to the officers at the time	-	6	Fredholm (1997) developed a model, which he termed tactical problem situations. The model identified four resource levels and their corresponding problem states, and argued that it is the amount of resources available to officers and how they manage them that mostly determine the quality of their performance.
First option was found problematic and an alternative option was subsequently generated	-	1	Klein (1998) in his book entitled "how experts make decisions" argued that experts often employ a serial option selection strategy as opposed to concurrent comparism of options. This means that experts mostly use their experience to determine a most plausible option and then channel their mental energy towards that option.
			A number of authors have identified a relationship between what people know at any point in time and how what they know

Something would have been done completely differently if the incident happened now	1	-	shapes their understanding of the world (Turner, 1976; Ackoff, 1989; Pollock *et al*., 2002; Spender, 2008). It is therefore logical to infer that the accuracy of people's judgment at any point in time will be largely dependent on the quality of their mental model (Salas *et al*., 2010)

Again, as shown in Table 5.5, in no circumstance were any of the incident commanders concurrently comparing different alternatives against each other in order to determine the most appropriate course of action; they either reported that no other options were available to them or that other options existed but were not worth pursuing. Even for the incident where the first option did not eventually work, the incident commander was not found to be concurrently comparing options against each other. Rather he started with an option and then moved to the next available option only after it became obvious that the first option will not work. No evidence was therefore found from the above findings and across the entire decision points where incident commanders compared options in a concurrent manner.

All the participants agreed that the particular decision making strategy eventually adopted in managing complex incidents is usually not pre-determined, but contingent upon the proceedings of an event. Previous studies, including the prototypical recognition primed decision making model, have similarly shown that experts do not compare alternatives concurrently against each other; rather they choose one option at a time in a serial manner, which eventually turns out to be an adequate option even for moderate experts (Calderwood, Crandall and Klein, 1987; Wong and Blandford, 2002; Johnson and Raab, 2003; Klein, 2003; Azuma, Daily and Furmanski, 2006; Ward *et al*., 2011).

Deliberated: Deliberative or analytical decision making involves carrying out a more *conscious* or detailed analysis on a potential course of action before implementing it. Two parameters were considered while coding decision points in this category: (i) decision time – decisions that took experts more than one minute to make were considered analytical. It has been well-established that individuals will only require additional thinking time if they needed to deliberate on a potential action plan, otherwise they simply go ahead with their first impression (see the intuitive-analytical continuum model, Hammond *et al*., 1987; the unconscious thought theory, Dijksterhuis, 2004) (ii) Team collaboration – decision points that entailed an exchange of ideas between the incident commander and other team members in the form of a group discussion.

Figure 5.6 above shows that only 7.2% and 7.7% of the entire decision points in the UK and Nigerian groups respectively were made deliberatively.

Prototypes: Prototypical decisions are decisions that allow actors to draw from their pool of knowledge and skills. It is the culmination of experience(s) obtained from the numerous incidents which officers have attended in the course of their firefighting career. One of the attributes of a prototypical decision is that it therefore becomes quite difficult to specifically attribute development of a prototype to any one incident in particular. Hence, experts were probed at each decision point whether or not the decisions they made brought to their memory how previous incidents were managed. If experts were thus able to demonstrate at each decision point how they used knowledge of previous incidents to manage a current one (i.e. based on their ability to remember the cues sought, goals pursued and actions taken from the previous incidents) it then becomes categorized as a prototypical decision. The concepts of templates, prototyping and pattern recognition are discussed in more details in section 5.8 of the current chapter.

The following excerpts show how the expert participants perceived this experience-based prototypical approach to decision making:

> *"The only way I can describe it is that those incidents contribute to a template, and that's in your head; just a framework for thinking that you call upon instinctively. You may only have 5 or 6 templates perhaps, but most of the*

incidents you go to will fit into one of those templates" (Patrick, Assistant Fire Chief, 32 UK)

"…..at the time, nothing specific, but it's a generic experience. I didn't look at that incident and think this is like any other incident that I went to. I take learning points from all the incidents I go to and that, I believe, produces an ability to then make decisions". (Jade, Crew Commander, 15, UK)

"Yes, [you are reminded of previous incidents] but I think it is more of a collection of experiences as opposed to a particular incident" (Sunny, 29. ACFS, Nigeria)

There are some [incidents] that are similar, and some that are not similar, but you must remember. Like today, if we attended the same scene and we noticed the same building, about 5-7 rooms, and two rooms were not affected, we can apply the same method we used there (Adams, 30, CFS, Nigeria)

The majority of the decisions points across the entire set of incidents fell under this decision making strategy across both groups of experts (UK= 88.4%, Nigeria=84.6%). This therefore suggests that the officers were mainly assessing the current situation against the prototypes they had stored in their memory. It is evident from the above excerpts that experts actually regard this pattern recognition ability as one of the greatest hallmarks of expertise, which they claim is largely based on the amount of chunks or patterns that is available in the long term memory.

Despite the consensus reached by many scholars regarding the possibility of employing the intuitive and analytical thinking modes simultaneously, the challenge has often been that of determining the dominant thinking mode. Furthermore, although there is evidence in the literature indicating that about 80-90% of difficult decisions are made through the pattern recognition strategy, only a relatively few such studies have been reported in the firefighting domain. For example, in their study involving Naval officers, Kaempf *et al*. (1993) showed that 95% of the decisions made by the officers relied on situational and pattern recognition, with only less than 5% being deliberative. Furthermore, in their study with design engineers who were relatively under less time pressure, Klein and Brezovic (1986) found that the experts relied reasonably well on pattern recognition (60% of total decisions) in solving difficult problems. On this note, therefore, it is believed that findings from this current study have contributed to existing evidence suggesting the majority of experts' decisions, and those of firefighters in particular, are based on the prototypical or pattern recognition strategy.

Analog: Analogs were used in this study to describe a situation where incident commanders made particular reference to a *specific* incident or to a specific event within an incident which they had previously managed. Again, as part of the CDM probe questions and in order to avoid confusing analogs with prototypes (since it is a bit difficult to separate a particular event from the multiple events that have been merged into their memory), officers were asked at each decision point to differentiate between decisions made with reference to a specific incident (analogue) and those made using combined knowledge of multiple incidents (prototype). If the officers could specifically attach any of decisions made to any single previous incident or event in particular, then such a decision point was classified as analog.

For example, Jack (CFS, 30, Nigeria) reported how he was able to work out the best way of positioning fire appliances at the scene of what appeared to be a difficult incident — a massive fire in a plank factory during harmattan season (a season characterized by high wind in Nigeria). The commander explained he was able to remember specifically from an incident he attended back in his days as ordinary firefighter how one of his superior officers positioned the firefighting appliances downwind of the fire, so as to avoid further spread. In another incident in the UK, Troy (27, Group commander) reported how he stood firm on his decision to directly attack a massive fire involving acetylene and LPG cylinders in a workshop factory, which eventually proved to be the best judgment call. This course of action was chosen by the expert, as opposed to evacuating the fire crew (which was technically the right thing to do in such circumstances), when he remembered and decided to replicate the action plan he employed in one of the previous incidents.

Analyses of the decision points show that only 4.3% and 7.7% of the entire decision points in the UK and Nigerian incidents respectively could be classified as analogs.

5.5. PROBLEM SOLVING STRATEGIES

Problem solving strategy defines the type of behavior displayed by a decision maker while responding to complex tasks. In one of his early works, Rasmussen (1983) identified three main types of behaviour operators are likely to display at each decision point: rule based, skill based and knowledge based behaviour. Thankfully, a number of authors have subsequently built upon this idea and have developed a similar problem solving construct that has now been widely utilized in a number of naturalistic studies. For example, in the following studies involving firefighters (Calderwood *et al*. 1987; Burke and Hendry; 1995; Klein *et al*., 2010), each decision point was classified as any of standard, typical or creative. The same coding criteria were employed in this study as discussed below:

- **Standard:** decisions made simply by applying existing knowledge which has been taught explicitly as “the standard way of doing things” in the fire service

- **Typical:** decisions made through modifications to the standard operating procedures of the fire service in order to meet the requirements of a current situation

- **Constructed or creative:** decisions made under novel conditions i.e. where no standard solution exists

Figure 5.7 below shows the distribution of the problem solving strategies utilized by expert firefighters across both countries, followed by a discussion of the strategies.

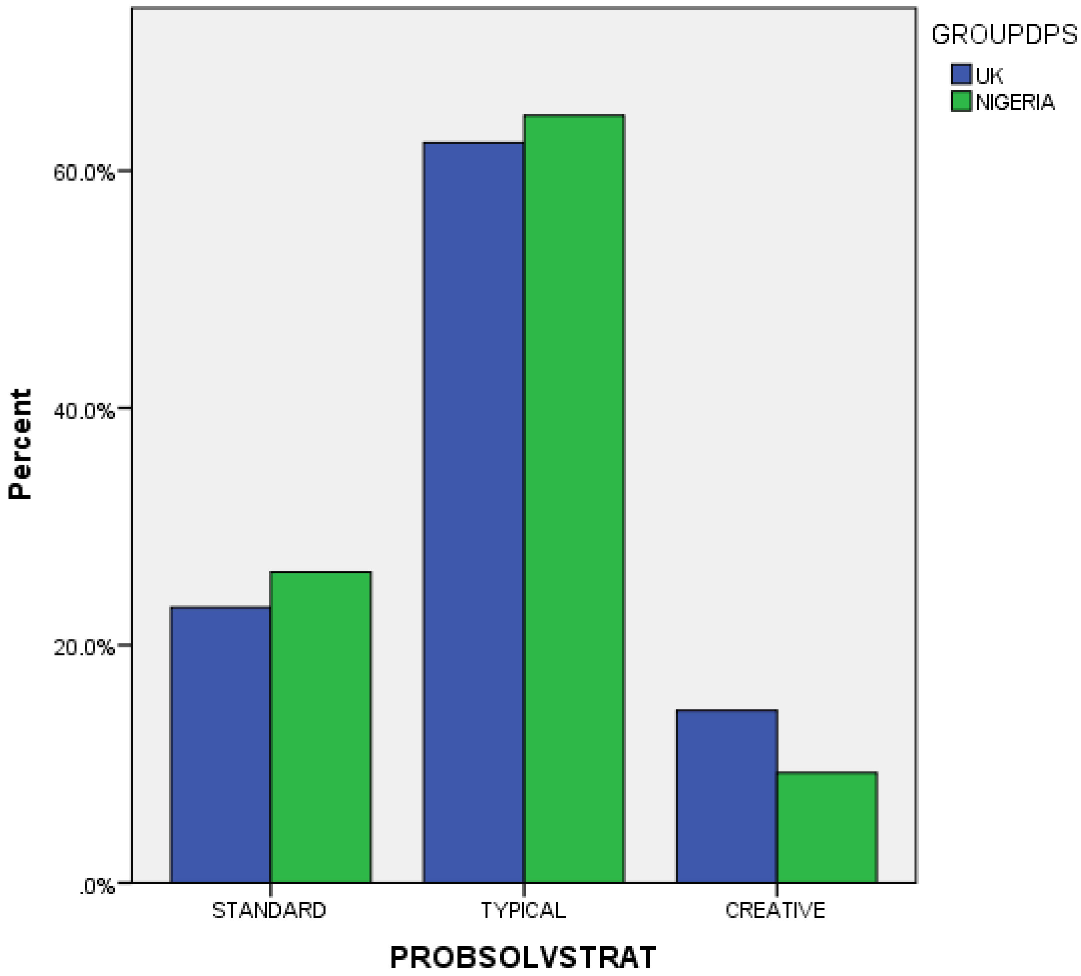

Figure 5.7: Frequency distribution of the problem solving strategies used by respondents

(N=69 decision points UK, N=65 Decision points Nigeria)

Standard: These are basic firefighting decisions for which an average officer, at the least, would have also been expected to act similarly i.e. the "bog standard" way of doing things in the fire service. The fire-fighting domain, being a high risk profession by its very nature, often requires that officers follow some of the rules and procedures binding the service as closely as possible, without which safety could easily become jeopardized. Hence, all the decisions that were arrived at by following firefighting rules, standard operating procedures or fire manuals fell within this category (see table 5.6 below). These include, for example, the rules of communication between the operational team and the control room, entry control rules (committing firemen into a well-alight building with their breathing apparatus), rules for evacuation (withdrawing victims within a certain distance from the scene of an incident).

The participants were carefully probed at each decision point whether or not they were following any standard rule, and their responses were then matched against the incident accounts. Care was taken to note at each decision point where the experts were strictly adhering to standard firefighting rules and where they were making adaptations to the rules in order to suit the current task (typical rules). For example, spotting the need to request additional resources or knowing that a size up (i.e. a 360^0 situation assessment) is needed upon arriving at the scene of an incident — was coded as standard rule. On the other hand, knowing the actual time to request for resources and also providing an estimate of the amount of resources required — was classified as typical (since some modifications have taken place to the standard operational procedures).

Figure 5.7 above shows that 23.2% and 26.2% of the decision points in the UK and Nigerian reports respectively fell under the standard category. This implies that only approximately one-fifth of all the decisions made by both groups of experts followed basic firefighting rules, in these exceptional incidents.

Typical or Adaptive decisions: Unlike standard decisions, typical or adaptive decisions force experts to approach things differently from the way novices would have probably approached them. These decisions are therefore often arrived at by making "calculated" modifications and adjustments to the standard way of doing things, which is possible through the application of extensive domain knowledge and the continuous process of dynamic risk assessment on the fireground. It therefore becomes difficult to mention decisions of these sorts without acknowledging the role of experiential knowledge (which has been accumulated over years of active service) and deliberate practice. The ability to tweak action plans to suit the requirements of a current situation undoubtedly requires experience. Hence, whilst the rule based decisions can easily be implemented by drawing upon factual knowledge or "strict regulations” binding work performance in the fire service, a deeper knowledge of the task as well as relying on experiences drawn from previous incidents appears crucial for adaptive decisions. This also explains why adaptive decisions are sometimes called skill-based decisions, since the knowledge required for making such decisions is expected to have become fully processed, internalized and transformed into skills. This transformation of knowledge into skills is one of the reasons why experts will not have to deliberate so long before implementing a desired action plan.

Using the problem solving criteria outlined earlier, each decision point was carefully matched against the incident report. For example, Patrick (32, Assistant Fire Chief, UK) reported how he over-ruled a less experienced officer’s decision, who was about to make a call for 12 additional pumps. Patrick explained that upon seeing the magnitude of the fire and its huge potential to spread, he became convinced that 12 pumps would not be enough and therefore asked the junior officer to increase the pumps to 15. Another experienced officer, Adam (Chief Fire Superintendent, 30, Nigeria) reported how he instructed his crew to utilize a hose reel (a type of hose that produces small quantity of water but with very high pressure) instead of a main jet (a very big hose that produces large quantity of water but with less pressure) for safety reasons. Adam explained that although judging solely by the size of the fire, a main jet would have been the most appropriate firefighting medium to extinguish the fire. But after spotting some cracks on the wall, the officer immediately knew that using a mainjet would significantly increase the chance of the building collapsing, hence his decision to adopt a more defensive strategy.

It therefore seems clearer from the foregoing that expertise largely lies in recognizing the points where following a standard rule is likely to be flawed and where it is simply safer to follow one. For instance, although it is a recognized rule (both formal and written) in both the UK and Nigeria fire services that a superior officer will usually take over from a less ranked officer e.g. when the number of fire engines at the scene of the incident increases to five, instances were found from the CDM reports where this rule was not followed by experts. In some of the incidents the higher ranked officers took over as overall commander immediately they arrived at the scene of incident, regardless of the number of fire engines in attendance, whereas in other instances (mostly in the UK) the less ranked officers were allowed to continue as overall commander.

Figure 5.7 above shows that the vast majority of decision points across the entire incidents were "adapted to suit", accounting for 62.3% and 64.6% of the UK and the Nigerian incidents respectively.

Creative or constructed: Unlike the first two problem solving strategies, creative decisions usually occur in unfamiliar situations where rules are unavailable and where patterns cannot be matched with any of the pre-stored prototypes from memory. These decisions typically require creative problem solving strategies as no direct rule exists on how things should be done. Experts therefore develop their own solution to a problem, mostly through improvisation, story building (combining bits of elements together to create an action plan). It is also common to find some of the creative decisions being at odds with the standard operating procedures of the fire service (see Table 5.6).

As part of the interviewing process, participants were probed and asked to identify the decision points where they were being creative. Following the coding criteria mentioned earlier, a decision point was then coded as creative if participants were able to demonstrate that their course of action did not fit any of the existing rules or pre-stored knowledge (i.e. they were thinking outside the box). To therefore confirm that the officers were actually being creative as claimed, each of the creative decisions were tested against the task constraints reported in the incident account.

Although the perception and interpretation of what makes up a creative decision differed across the incidents and also within experts, three parameters were generally used by experts to define what a creative decision is:

(i) Decisions that entailed making significant changes to an action plan i.e. moving from doing what is typical to expressing acts of "heroism" (in the words of one of the officers, Brown, 27, Crew commander, UK). He explained heroic acts as the willingness to go the extra mile in finding alternative ways of doing things — even if it meant exceeding the boundaries of one's comfort zones. Below are examples of creative decisions as reported by the expert participants:

- *Manually breaking of walls, doors and glasses so as to gain access to the seat of fire (Sammy, Fire Superintendent Officer, 8, Nigeria; Sunny, Assistant Chief Fire Superintendent, 29, Nigeria)*
- *Completely removing the roof of a building in order to gain access to the seat of a massive petrol fire (Patrick, Assistant Fire Chief, 32, UK)*

The above two incidents were instances where the officers in charge could have easily admitted defeat and withdrawn their crews (which would have also been justifiable from an incident command point of view). But instead they chose to increase their level of risk by going more offensive, which eventually proved more rewarding.

(ii) Decisions that were almost completely opposite to some of the stipulations in the standard operational procedures of the fire service (albeit for a just cause).

- *decision not to withdraw the fire crews to a distance of 200m in an incident involving LPG and acetylene cylinders against what was stipulated in firefighting manuals (Troy, Group commander, 27, UK)*

(iii) Decisions that required creating new ideas through improvisation, especially in novel circumstances

- *Creatively fastening a mainjet water supply to a wall to keep attacking the fire while fire crews were safely withdrawn from the immediate environment (Brown, 23, Crew commander, UK)*
- *Digging a temporary dam where water was stored and also liaising with water carriers to ensure steady supply of water in a rural area with extremely low pressured hydrants (Darren, station manager, 17, UK)*

Figure 5.7 above shows that only 14.5% and 9.2% of all decisions made respectively by the UK and Nigerian experts were creative. As expected, creative decisions appeared to be the least utilized among the problem solving strategies, overall.

Table 5.6: Analysis of rule-based, typical and creative decisions

Actions (Decision points)	**Is this a Standard operational procedure in the fire service? (Y/N)**	**How participants approached the decisions across the entire incidents**		
		Standard (Knowing that)	**Typical (Knowing when & Knowing how)**	**Creative (combining knowledge)**
Situation assessment (Nigeria experts)	**Y**	√	√	
Ensuring that the BA sets are well monitored upon committing crews into a building (UK experts)	**Y**	√		
Rules of communication with the control room every 10mins at the start of an incident, and then every 20 mins as the incident winds down (UK experts)	**Y**		√	
Rules of evacuation within a radius of 200m in the event of acetylene (UK experts)	**Y**	√		√
Requesting extra resources (UK & Nigerian experts)	**Y**	√	√	
Using the appropriate fire-fighting medium e.g. Hose reel or Main jet (UK & Nigerian experts)	**Y**	√	√	
Requesting assistance from other emergency response organizations e.g. Police, Ambulance, Road safety, civil defense (UK & Nigerian experts)	**Y**	√		
Getting to the scene of an incident through the nearest route (Nigerian experts)				

	Y	√		
Ensuring firemen are committed in pairs into a well-alight building (UK & Nigerian experts)	**Y**	√		
Climbing the ladder to the roof of the building or breaking the wall to be able to gain access to the seat of fire (UK & Nigerian experts)	**N**		√	√
Notifying control room when switching from defensive to offensive strategy (UK experts)	**Y**		√	
Crawling into a building to fight the fire (Nigerian experts)	**Y**	√		
Taking over from a less ranked commander at the scene of an incident (UK & Nigerian experts).	**Y**		√	
Sourcing for water in an area without hydrant (predominantly Nigerian experts, only 1 UK expert)	**Y**			√

N.B: The ticked boxes√ represent the decision points that fit into a particular problem solving strategy.

Table 5.6 provides evidence which suggests that experts are not predominantly bounded by rules; they either adapt rules to suit a current circumstance or create new ways of solving a problem if necessary. As shown in the table, adaptive or creative decisions were still utilized by experts regardless of whether or not a decision was regarded as standard rule. Experts therefore seemed to be very much inclined to overrule the "standard way of doing things" if they envisage any potential problem in their action plans. For example, whilst notifying the control room on the proceedings and developments taking place at the scene of an incident every 20 minutes is regarded as a standard rule in the fire service (in both countries), the interview transcripts showed that experts sometimes ignore this rule, especially at the start of the firefighting operation. This is to allow them gain a better awareness of the incident. Hence, a rule that was meant to be a standard way of doing things has now been adapted to suit the current proceedings of the incident in this instance.

Findings from table 5.6 also seem to align perfectly well with Karlqvist's (1997) view regarding the sequence of knowledge types in practice:

> *The application of standard rules does not mean that incident commanders are not creative. Working without rules is uninteresting, and absolute liberty is boring. "The creation of innovative approaches does not happen in a vacuum; rather it is the result of playing with the rules, stretching them, moving and testing them". It is therefore essential to maintain common operating guidelines, or rules, because they form a stock body of common knowledge, but it is also essential to break the rules and play around with them. "Mastery reveals itself as breaking rules". The secret of creativity hinges on this insight: to know the right moment when one can go too far (Karlqvist, 1997, p.111-112, paraphrased)*

Evidence from this study shows that experts utilized each of the three problem solving strategies (i.e. standard, typical and creative decisions) when resolving complex tasks, depending on the nature of the incident. This assertion gives credence to existing beliefs that experts know the boundaries of their skills and when to apply or switch between the three strategies as events unfold (Rijpma, 1997; Kahneman and Klein, 2009; Chrichton and Flin, 2004). Analysis of the various decision points as shown above also provided further understanding regarding the sequence of conversion that exists between the application of rule, skill and knowledge based decisions. The table shows, for example, that rules and procedures are often invoked when performing recurrent (routine) aspects of tasks, since expected outcomes are basically similar from problem to problem. But in situations where expected outcomes vary from problem to problem (non-routine tasks), decision-makers tend to depend less on rules/procedures and to rely more on their prototypical and creative ability.

Does it then imply that strict adherence to SOPs is a feature of novices? The answer is believed to be No. Without much doubt, procedures are quite essential as they provide established safety guidelines for operators in a domain of practice (Klein, 2003). However, the major challenge for novices remains knowing when adhering to a standard procedure is likely to be flawed. In the statement of one of the participants:

> *"People sometimes misinterpret fire guidance notes and try to follow them to the letter where as it is only meant to be a guide"* (Troy, 27, Group commander, UK)

Acknowledging that relationships exist between rule based, skill based and knowledge based behaviours is therefore perceived to be an important factor when developing training protocols for novices. In as much as it is recommended to commence complex skills learning by teaching learners the cognitive rules underpinning a particular skill, it is also important to avoid constraining them within the remit of such rules/procedures. This will undoubtedly reduce the risk of slowing down the learning curve of novices or hampering their creative power (Skriver and Flin, 1996).

Although some of the courses of action reported by both groups of officers appeared to be similar e.g. commanders in both groups seemed to understand the importance of committing firefighters into a well-alight building in pairs for safety reasons, a number of differences still exist between both groups. These differences can be explained in terms of (i) the "weight" of the reported courses of action at each decision point (ii) what constitutes the standard, typical and creative decisions. For example, analyses of the decision points showed that the majority of the Nigerian firefighters reported "conducting a situation assessment upon arriving at the scene of an incident" as part of the important decisions they made, while none of the UK experts considered this as an important decision.

5.6. GOALS PURSUED BY THE EXPERT FIREFIGHTERS ON THE FIRE-GROUND

One of the benefits of using the critical decision method in knowledge elicitation is its ability to capture, *inter alia,* the main goals and sub-goals pursued by experts at each decision point. Rasmussen (1983) has previously shown that humans are not simply deterministic input-output devices but teleological (or goal-oriented) beings that have expectations in mind. This means human beings are able to choose their goals, search out relevant information to pursue their chosen goals and then modify their goals through the cues displayed from the task being performed (Ordonez *et al*., 2009).

As part of the interviewing process, participants were asked to explain the goals they were pursuing at each decision point. Also, since the incident commanders will normally pursue different goals depending on the circumstances surrounding a particular incident, participants were further asked to explain the rationale behind their goals and sub-goals. The goals pursued by expert commanders were analyzed across all the incidents and sub-categorized as shown in table 5.7 below:

Table 5.7: Analysis of goals pursued by experts and the number of decision points associated with each goal.

Goals pursued	**No of Decision points**	
	UK	**Nigeria**
Safety related goals	17	13
Resource reinforcement and support	15	4
Timely completion of task	2	6
Crew-task management	4	-
Situation assessment	-	6
Prevention & Containment	14	21

Rescue & Salvage	5	2
Water sourcing and conservation	4	1
Gaining access to seat of fire	2	8
Professionalism & work ethics	6	4
Total	**69**	**65**

Table 5.7 shows that all the expert participants across both countries were pursuing at least one goal at each decision point. But as expected, these goals varied due to certain factors such as the type of incident involved, the environmental and locational structure, the make-up of the response team as well as the intensity and size of the fire. The table also confirms that firefighters are not simply tied to the goal of extinguishing the fire, contrary to common belief. Members of the public mostly try to relegate the task of firefighting to solely mean "using the white stuff to put out the red stuff", an assumption that often tends to oversimplify the complexity associated with fireground decision making in real life (Okoli *et al*., 2014). Hence understanding the dynamic nature of fireground goals and how informational and environmental cues are likely to affect them is judged to be vital in designing any training curricula for novices (this is exemplified in the situation awareness record shown in Table 5.8). For instance, in riskier incidents such as those involving highly combustible substances, incident commanders seemed to be mainly concerned with safety related goals (UK=17DPs, Nigeria=13DPs). Similarly, for incidents that involved well-alight and rapidly blazing fires, incident commanders were found to be more focused on containing and preventing the spread of fire to other surrounding buildings or properties i.e. the goals of prevention & containment (UK= 14DPs, Nigeria=21DPs).

A closer investigation of the entire decision points across the CDM reports revealed some differences across the two countries based on goal frequencies:

- The goal of reinforcement and support, although reported by all the participants as important and irreplaceable, was found to be significantly lower in Nigeria (Nigeria=4DPs vs UK=15DPs). In periods of utmost duress, incident commanders usually seek support from other fire stations through the fire control department. This support could either be in terms of requesting specialist appliances such as foam compact, high volume pumps, and aerial appliances (e.g. turn table ladders or helicopters), as well as from other emergency response organizations e.g. police, ambulance or fire investigation departments. The nature of firefighting is such that if fireground commanders run out of vital resources such as water, all previous effort automatically becomes futile due to the volatility of fire. But as important as the goal of reinforcement and support appeared in the UK, it was not common in the decision points of the Nigerian firefighters. The most obvious reason being that there are hardly any resources available to call upon even when they are needed (this issue is discussed further in chapter six)

- The goal of finding, or creating access to find the seat of the fire was emphasized more by the Nigerian firefighters (Nigeria=8DPs vs UK=2DPs). The seat of fire is the exact point from which the energy of the fire is being released. Participants explained that fighting a fire without an attempt to see the actual seat of fire is tantamount to “fighting the air”, which is essentially a futile exercise. One of the reasons great emphasis was placed on this particular goal by the Nigerian firefighters was probably because of the need to prudently manage water (which is a scare commodity in the Nigerian fire service). As a result, they can therefore not afford to waste water on the smoke rather than on the actual fire.

- The goal of situation assessment was only mentioned by the Nigerian firefighters (DP=6) and was completely ignored by their UK counterparts. This evaluation is seen more as a priority issue more than anything else i.e. it is assumed that the UK firefighters regard this particular goal as something trivial to report since it is a mandatory requirement for every incident commander

Table 5.8: An example of a situation assessment record showing how an expert in the study responded to changing goals

	Situation assessment 1
Cues	Very large fire involving oil storage; collapsed roof; site of incident very close to residential houses
Expectations	Very intense fire with high potential of spreading further
Goals	Getting access to the building; getting enough water to attack the fire; containing the fire
Decision-Point 1	Asking for reinforcement (Requested 15 additional pumps)
Decision-Point 2	Exterior attack- it is too dangerous to commit crew
	Situation assessment 2
Cues	Fire growing bigger; arrival of 15 additional pumps
Expectations	Presence of additional workforce will result into better control
Goals	Getting access to the seat of the fire; resorting to another option since the initial option of water attack is not working; safety of crew members
Decision-Point 3	Getting specialist appliance to climb higher in order to see the actual seat of fire
	Situation Assessment 3
Cues	Fire still burning because petrol is involved; water unable to put out the fire; pollution of water courses.
Expectancies	Fire may remain uncontained and burn out itself unless a more rigorous strategy is employed
Goals	Reducing environmental pollution from the flames as much as possible; clearing the road for road users to get to work as soon as possible
Decision-Point 4	Decision to request specialist appliance (foam attack)

A direct relationship was found to exist between the cues identified by an expert, the goals they pursued and their subsequent actions (see Table 5.8 for an example of a situation assessment record). As soon as experts identified certain cues, they used their experience and wide domain knowledge to interpret the implications of such cues and then prioritized response goals. This thus implies that goals are mostly context-specific and rarely set *a priori*. This assertion gives credence to one of the most popular decision making theories: *the image theory* (Beach, 1978; 1993). The theory postulates that decision makers often represent information in the form of four images — a set of values and beliefs, the specific goals to which the decision maker is striving, the defined operational plans for reaching the goals, and the anticipated results from implementing the plans. To be able to carry out a task effectively, Beach (1993) argued that these four images must be properly harnessed by the decision maker so as to avoid any form of conflict between or within them. He stressed that *"each plan is an abstract sequence of potential activities beginning with goal adoption and ending with goal attainment"* (Beach, 1993, p.236). The above assertion also seemed to be consistent with existing belief that expertise is largely attached to one's ability to manage shifting goals under time pressure (Shanteau, 1992; Klein, 1997; Wong, 2000; Zsambok and Klein, 1997; Shanteau *et al*, 2002; Salas, 2003).

5.7. CUES

According to Wong (2004), a cue is defined as any stimulus with implications for action e.g. smoke colour, cracks on the wall, odour of flames etc. But it is worthy of note that the cues present in an environment must first be able to generate useful information to the decision maker, who then interprets, processes and translates the implied knowledge into a workable course of action. Hence, even when an incident presents some visible cues, the onus still lies on the decision maker to make sense of them. Attaining effective performance can therefore be jeopardized if the relevant cues are not recognized by the actor in a timely manner. For instance, it is almost useless for a decision maker to spot a cracked wall or a collapsed roof if s/he is then unable to infer the implications of such cues and act accordingly.

Against the above background, this section presents and discusses the critical cues used by expert firefighters across the thirty incidents. It also elucidates the importance of cues and the role they play in making fireground decisions as shown in the excerpts below:

> *For example, if there are lots and lots of smoke coming out of those doors up on the first floor and it was coming out under pressure, I wouldn't put a ladder there and I wouldn't put two people in through there because it's just too dangerous (Jade, 15, Crew Commander UK)*

> *Also because the sympathizers have been trying before our arrival, so far they have not been able to conquer the fire, it means that the fire is not easy* (Sammy, 8, FSO, Nigeria).

A positive relationship therefore seemed to exist between the informational and environmental cues on the fireground and experts' subsequent response actions. Cues guide experts in developing useful action plans, in recollecting similar prototypes from memory and in refining action plans as events unfold.

From the knowledge elicitation process and analyses of the thirty incident reports, the author identified 42 different cues commonly sought by these expert firefighters. These cues were then categorized into five classes depending on the type of information they conveyed to incident commanders (Table 5.9). While some cues presented themselves to officers in clearly visible ways e.g. smoke colour, intensity of fire, crack on the wall, collapsed roof, thickness of the smoke, others were found to be less visible and thus required experts to make use of their senses, previous experience and rich domain knowledge in gaining a deeper understanding. These less visible cues sometimes required good use of somatic awareness on the part of the officers i.e. seeing, hearing, smelling or feeling.

These processes are explained in details in the model developed in the next section.

5.7.1. Classification of cues

(i) ***Search and rescue or safety related cues:*** these cues influence the risk taking behaviour of officers in carrying out their search and rescue tasks of saving lives and properties. This category of cues guide subsequent safety actions and determine if firefighters are still able to accept some level of risk or not. This category of cue raises safety awareness, which is critical for safe performance and ensures that incident commanders carry out safety precautions proactively rather than reactively. Examples of safety related cues include cracks on the wall, potential of roof collapsing, presence of acetylene or LPG cylinders etc. Furthermore, safety related cues help answer the question: how safe is safe enough, allowing officers to decide whether adopting a precautionary approach (i.e. erring towards the side of safety in conditions of high uncertainty) is the safer thing to do.

(ii) ***Cues that indicate the "nature of the problem":*** this class of cue comprises both the visible and perceptual cues from which experts are able to make informed decisions regarding the state of things on the fireground. For instance, the size of a fire or intensity of the blaze (both visible cues) can be used to judge how severe an incident is, while the room temperature (a perceptual cue) can be used to predict the exact time a fire started to burn in a room.

(iii) ***Environmental based cues:*** these are cues generated from the immediate climatic conditions around the fire scene. The cues in this class help to reveal how environmental factors such as wind speed, wind direction, atmospheric temperature could possibly affect task performance — positively or negatively

(iv)***Affective or emotive cues:*** this category of cues emanate from the psychological and emotional states of members of the public, or victims. In order to make sense of the potentially important information that needs deciphering from the people around the fire scene, this class of cue requires that incident commanders possess good emotional intelligence and metacognitive skills. For instance, the amount of outburst (crying and shouting) displayed by members of the public can be a good predictor of the severity of an incident or the potential for disruptive behaviour that could hinder operations.

v) ***Incident command and control cues:*** these are cues that signal if/when a more senior officer should take over command responsibility on the fireground. It must be noted that the most experienced or highest ranking commander on the scene does not necessarily need to take over the command and control of the incident upon their arrival, unless such a commander appears unsatisfied with any of the tactics used by the incumbent incident commander. This group of cues therefore helps in determining whether or not to make such a “take-over” decision, and by so doing, ensure that there is effective leadership and coordination at the incident scene.

CRITICAL CUE INVENTORY (CCI)

1. **Search and rescue cues: safety related cues**
    - Cracked wall (Implication: building is not safe anymore; the chances of collapsing is higher)
    - Walls falling down (Implication: Building is becoming weaker and collapse is imminent)
    - Roof condition (possibility of collapse)
    - Substances present/perceived to be present in a building e.g. combustible materials such as petrol, acetylene cylinders, LPG cylinders
    - Potential of fire spreading
    - Smoke behaviour (flashovers, backdrafts)
    - Location of the seat of fire
    - Location of unaffected properties
    - Type of building (terraced, block of flats, single-story, multi-storied)
    - Entry point (accessible, obstructive)
    - Category of victims trapped (elderly, disabled, mentally challenged)
2. **Cues that indicate the "Nature of Problem"**
    - Size of Fire (The area and distance covered by the fire indicates how serious it is)
    - Intensity of fire (The amount of energy in the fire indicates how serious the fire is)
    - Pattern of flame movement
    - Egress of the flames (through the windows, attics of the house, doors)
    - Smoke color (yellowish rainbow, blue, thick black)
    - Smell/odour of smoke and burning substances
    - Texture of smoke (thick, light, cloudy)
    - Severity of physical damage
    - The nature and extent of injury on victims
    - Room temperature (A room on fire can sometimes be as hot as 1000^{o}C)
    - Type of materials burning or class of fire (metal fire, gas fire, batteries, acetylene)
    - Noise of vibration on the ground (gas fires involving filling tanks)
    - The intensity of heat emitted from the blazing fire to the environment
    - The quantity of water that has been used up in the process (10,000 liters show how serious a fire is)
3. **Environmental-based Cues**
    - Wind direction (is the wind blowing towards or away from the fire?)
    - Wind speed/intensity
    - External temperature/climatic condition (Hot, warm, harmattan, cold)
    - Catchment area (Residential, Factory, Industrial, Rural, City)
    - Location of incident (Rural or Urban area)
    - Distance to water supply (availability and proximity of hydrants)
    - Topography of the street e.g. steep slope, high slope
4. **Affective or emotive cues**
    - Verbal threat from victims (abusive words to firefighters, arson)
    - The shouts for "help" from crowd
    - Level of panic observed in the crowd
    - Cry and wailings from trapped victims upon arrival
    - The number of passersby at the scene of the incident
5. **Cues that inform incident command and control decision**
    - The rank/level of experience of the officer currently in charge
    - The number of pumps deployed (a more superior officer (e.g. a station manager) takes over when the number of on-scene pumps gets to five)
    - The size of the building (building size determines whether sectorization is needed and also determines who is going to be in charge of each sector)
    - Height of the building (e.g. if building is too high beyond the reach of a ladder, then the use of an aerial appliance becomes necessary)

It is important to clarify that the list of cues outlined in table 5.9 is not claimed to be exhaustive, it could still have perhaps been possible to elicit more cues used by experts in the firefighting domain if, for example, other varieties of incidents were reported. But having said this, the number of cues reported in this study appears quite encouraging when compared to what is currently available in the literature, outnumbering even those identified by Klein and his colleague in their seminal work with urban firefighters (Klein *et al*., 1986). The importance of cue elicitation cannot be overemphasized in a complex domain such as firefighting, as demystifying the cues experts rely upon in making their judgments has been shown to play a crucial part in designing efficient decision support systems. These decision support systems, as the name implies, are evidence based tools designed to aid the decision making processes of individuals who operate in complex work environments (Rasmussen, 2005). Thankfully, a number of studies have reported how this cue-based learning approach has successfully been employed in various domains of practice in training less experienced operators (Spence and Brucks, 1997; O'Hare *et al*., 1998; Wong, 2000; Wiggins and O'Hare, 2003; Perry and Wiggins, 2008). For instance Wiggins and O'Hare (2003) developed and then tested the effectiveness of a cue-based training programme which was designed to guide the decision making process of operators in determining whether or not to fly a plane, considering various weather conditions. The aftermath of the cue-based training showed a statistically significant improvement in the performance of operators who participated in the training and those who did not.

The way experts sought and utilized cues in this study was found to contradict the cue-utilization theory (Easterbrook, 1959). The theory suggests that consistently arousing the emotions of task performing individuals using an external stimulus will end up reducing the number of cues such individuals will be able to identify, which will in turn affect task performance. The theory further argues that the more people are exposed to the cues that arouse their emotions, the more likely they are to be distracted away from the main tasks. Unfortunately, there was little or no evidence from this study to support Easterbrook's theory as none of the interview transcripts were found to suggest that experts got distracted through identifying other cues. This includes twelve of the reported incidents (UK= 5, Nigeria=7) which involved low to high level of emotional outbursts, either from members of the public or victims. The current study instead supports the existing notion that the amount of cues identified and processed by experts does not necessarily result to a better or poorer performance; the decision makers must in the end be able to understand the specific cues that will maximize task performance (Wong, 1996; Wiggins and O'Hare, 2003; Hanoch and Vitouch, 2004; Perry and Wiggins, 2008).

The critical cue inventory shown in Table 5.9 seems to suggest that experts across both countries seek more of the cues that define the "nature of the problem" (13/42) as well as the "safety related cues" (11/42), than other cue categories. It might be logical to infer that these two cue categories, regardless of the type of incident, play the most significant role on the fireground in developing and implementing action plans. For example, it is expected that once the nature of the problem is identified (e.g. the size or class of fire) it then becomes relatively easier to develop response plans that would best suit the identified problem (e.g. whether or not to deploy a specialist appliance). Similarly, on the aspect of the safety related cues, it was found that once a cracked or falling wall is spotted by an incident commander, the safety of fire crews automatically becomes of utmost priority, causing the commander to become less and less tolerant of risk-taking in such circumstances. This therefore suggests that experts do not just spend time identifying cues on the fireground, but also understand the implications of the various cues and how each cue is likely to affect the problem at hand (this is discussed in more details in the next section). The work of Perry and Wiggins (2008) illustrates this further. Their study with firefighters compared the type as well as the number of cues generated by two groups of firefighters: experienced station officers (mean years of experience = 22.3) and competent firefighters (mean years of experience = 5.04). The task presented to the participants involved three different scenarios (a single storey house, a single storey office and a furniture warehouse) after which participants were given a cue generating questionnaire that contained all possible cues they are likely to consider. Findings from the study showed that station officers (experts) significantly reported more cues utilized (mean number of cues = 10.10) than the firefighters (mean number of cues = 6.00) as expected. But more interestingly, when the authors classified the types of cues reported by the participants into three different categories i.e. cues related to difficulty of using an entry point, cues related to rescue, and cues related to the safety of crew members — results showed a significant difference between the two groups of firefighters only for safety related cues. The station officers reported more safety-related cues than the competent firefighters in all the three scenarios, but no significant difference was observed for the other two categories (cues related to difficulty of using an entry point and cues related to rescue).

5.8. INFORMATION-FILTERING INTUITIVE DECISION (IFID) MODEL

Following a thematic analysis of the critical decision method incident reports based on the patterns identified across all the incidents (see worked example in Appendix F), it was evident that fire ground commanders in an attempt to manage the complexities generated by an incident concurrently go through stages of information scanning and filtering process, sifting out irrelevant information (noise and distractions) and retaining the useful ones. Although each participant was asked about 22 different questions as part of the CDM protocol, the following questions were particularly important in designing the above model: How did you know that the decisions you made were the most appropriate ones? Where did you get the knowledge for making each of the decisions from? How did you source your information? How long did it take you to make each of these decisions? What cues were you following in making these decisions? What was the most important piece of information that guided your decision making? The last question (i.e. what was the most important piece of information you used in formulating your decisions) was specifically helpful in designing the model as it allowed the researcher to better understand what information mattered most to each participant.

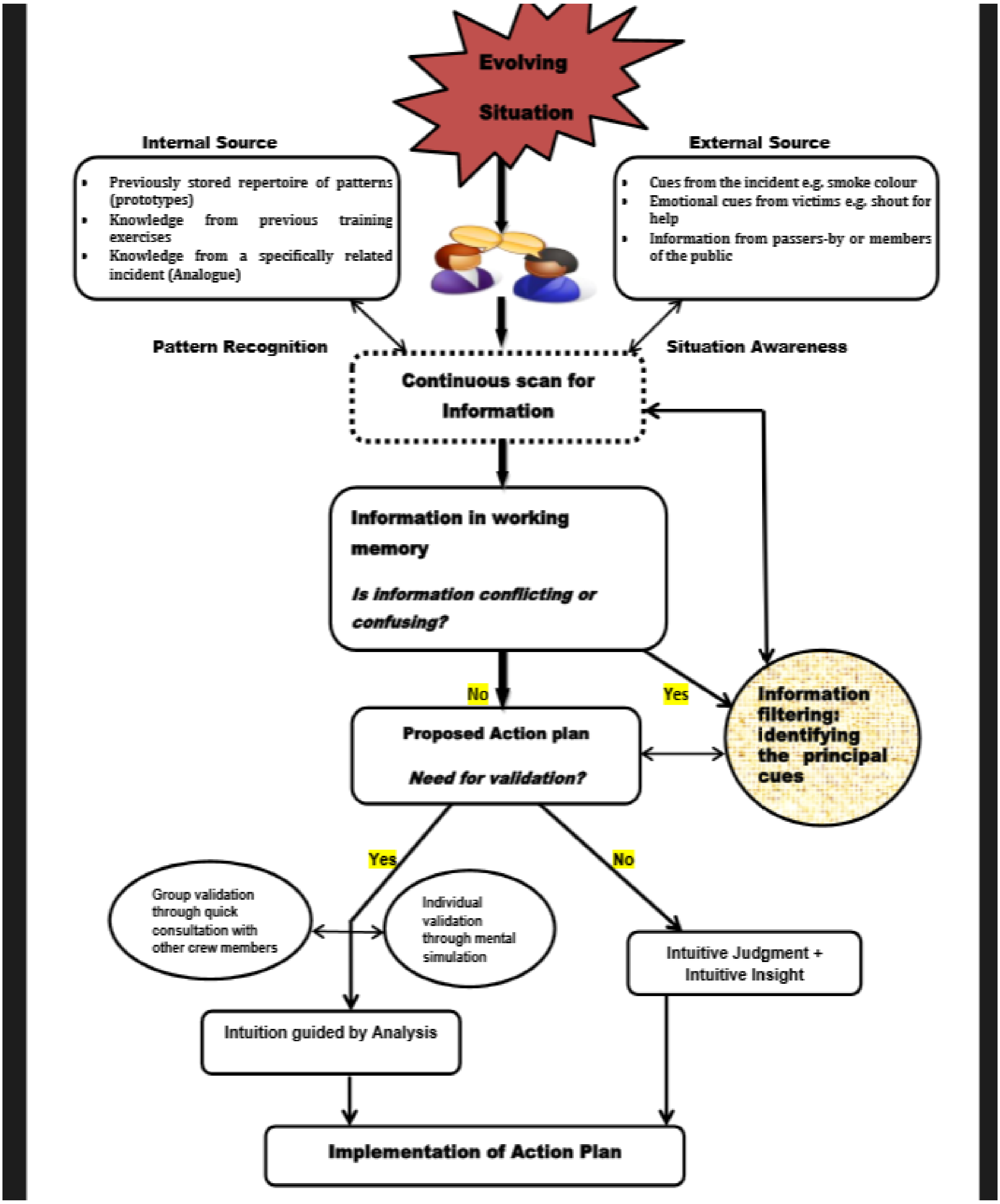

Figure 5.8: Information filtering and intuitive decision model

The model explained:

The model begins with a constantly evolving incident in a dynamic and low validity environment (such as fire-fighting), as opposed to a static environment. This type of environment is characterized with either the presence (or absence) of a range of environmental and informational cues in no particular format, with some cues appearing more obvious than others. Each commander is therefore faced with an important task of making sense of both the visible and the less visible cues and, more importantly, understand their implications for task performance. In addition, the model argues that some of the goals incident commanders pursue on the fireground are not only ill-structured, but also confusing and conflicting (see section 5.6). For instance, participants reported that they are immediately faced with a huge challenge of making sense of the various proceedings upon their arrival at the scene of an incident, which in turn leads to a number of questions being generated: what is burning? Are there people trapped inside? Are there combustible materials in the building? Do we have enough resources to combat this fire? Why are the victims reacting this way? Is the fire going to escalate beyond this level in the next couple of minutes? Are there other hazards around the environment that need to be taken into account? What is the safest way of tackling the fire? How may the topography of the environment affect task performance and what could be done about it? Should an offensive strategy be employed or is it best to go defensive? It is therefore in the quest to search for answers to the above questions that fireground commanders begin to conduct a thorough situation assessment (or what is also called a 360^0 size-up, in the language of firefighters). The model attempts to describe how the expert firefighters were able to cope with at least two difficult cognitive task demands on the fireground: (i) the task of thinking and acting concurrently, making critical decisions amidst incomplete, confusing and conflicting information e.g. investigating the major cause of a fire while at the same time committing the fire crew into the building (ii) the task of identifying the relevant cues, amongst other various available cues on the fireground, that will aid developing workable action plans

The main focus of the model, therefore, is to describe how expert firefighters gather the wide range of informational cues at the fire scene and how such information is subsequently filtered to the point that decision makers are confident of carrying out their proposed action plans without the need for further deliberation. But before proceeding, it seems important to first clarify how some of the terminologies described in the model were used. As earlier stated, a cue in this model is defined similarly to Wong's (2004) definition as any stimulus with implications for action. These include, for example, smoke colour, smoke texture, visibility of flames, proximity of buildings, size of fire, type of building etc. Also, the term "information", as used in the model, represents any *potential* source of knowledge e.g. from external cues, from previous experiences, or from other crew members. The stages involved in the information filtering and intuitive decision model are now discussed below:

5.8.1 Information scanning stage

> *"Even when you don't have the information, you can gain it from experience. You could ask people around for information about a particular location if you are unsure. You could look around for signs, telephone numbers, landmarks upon which you can base your judgments. What color is the smoke? Is it a compartment fire or factory fire? What is the building made of (brick, wood)"* (Adrian, Watch commander, 17, UK)

As part of the CDM probes, participants were asked to explain the various sources of the information they used in making each of the task-related decisions. A thematic analysis of the CDM report revealed five different information sources, including a description of the type of information that was generated from each of these sources. These are discussed later.

The information filtering and intuitive decision model shows that expert firefighters usually generate task related information in two major ways: internal (through pattern recognition) and external (through situation awareness). Information from *internal sources* relates to the set of information that can only be sourced *internally*, by the decision makers themselves. This includes information generated from the internal memory systems e.g. through pattern recognition, previous training exercises, or from a particularly similar incident that has been previously encountered by the officer. Sourcing information internally entails scanning one's memory in search of previously stored patterns and repertoires — in the form of cues, goals, expectancies and actions — with the hope that any of the pre-stored knowledge will match the current problem. Information from *external sources*, on the other hand, includes information directly gathered from the incident, mainly from the events in the task environment. These include, for example, information collected verbally from victims or passers-by, information gathered from observing the behavior of the members of public or victims — in the form of emotional outbursts (e.g. people wailing and shouting for help). Commanders also generate information by making sense of some of the external cues at the fire scene (e.g. smoke colour, fire intensity, cracked walls, smoke texture etc.).

The five informational sources are discussed in detail below:

Source 1 — Experience: Experts often rely heavily on their experience (which is an internal source of information) both for making judgments concerning routine problems and for making creative decisions regarding non-routine tasks. Experience therefore contributes to the pool of information that is stored in experts' memory which they often retrieve with the aid of a powerful tool known as a *schema* (Sweller, 1994; Pollock *et al*., 2002; Paas, Renkl and Sweller, 2004). Experience as an internal source of information is thus similar to the prototypical decision making strategy discussed in section 5.3 above. The interview transcripts show the importance of experience in the attainment of effective performance. Unless less experienced officers are sufficiently exposed to managing real-life fires, the expert participants in this study claimed it is almost certain that these junior officers will struggle when confronted with some of the adverse task constraints that come with managing complex fires. The participants (both the UK and the Nigerian ones) emphasized the need to validate the training and simulation exercises often conducted in the fire service by exposing officers to real-life incidents. The following excerpts illustrate how experts perceive “experience” in the firefighting domain, and why it is regarded as an important source of fireground information:

> *“The technical experience I’m talking about is that as a fireman you would have attended series of fires, and every fire you attend…… there is a saying in the fire service that no two fires are alike — the fire in room A will definitely be different from the fire in room B, though they are within the same premises. So the number of fire outbreaks you attend expands your horizon and technical knowledge about fighting fire”* (Sunny, ACFS, 29, Nigeria)

> *A lot of it is on the job isn’t it? I have gone from really busy stations where we were probably having 4,500, - 5,000 incidents a year to where we are probably about a thousand. So lots of experience, lots of different incidents we would go out to when I was younger* (Willy, 28.5, Watch commander, UK)

> *…but the other side is; its ok being in the training, it's then getting on the ground and doing it — and that is where you get your experience from* (Brown, crew commander, 27, UK)

> …*but with 8 years’ experience that I have, following tankers, fighting fires everywhere, entering well, entering rivers to rescue, fighting fire, gas fire, petrol fire, free burning fire, oil fire. I have attended all. So with those experiences not once, not twice, not thrice* (Kevin, Watch commander, 8, Nigeria)

> *“Nobody sits you down and say when you have this incident you need this, when you have this incident you need that. That is an experience, and you make decisions based on what you think you need for the incident”* (Dickson, 23, crew commander, UK)

The above excerpts, more than anything else, consistently demonstrate the value of gaining real-life firefighting experience, which the participants believe cannot be successfully surrogated with any other form of learning or training procedure. It is perceived that the manner through which experts accumulate and utilize the lessons that were learnt from previous incidents can be explained through the concept of implicit learning i.e. the notion that people learn all through their lifetime, from good and bad experiences, and sometimes without even knowing how and when such learning took place (Fessey, 2002; Eraut, 2004; Billet, 2010).

Source 2 —Training: In solving complex fireground tasks, the participants also reported that they often rely on some of the knowledge they had acquired from previous training exercises, particularly the incident command training. The incident command and control training arguably accounts for one of the major differences in the level of competence displayed by a supervisory manager (i.e. crew commanders or watch commanders) and that displayed by an ordinary firefighter (both in the UK and Nigeria). This is due to the fact that such training is usually not applicable to ordinary firefighters since they are rarely involved with management responsibilities on the fire scene. The training, which the majority of the participants claimed to serve as the foundation upon which subsequent knowledge is built, covers more advanced learning themes such as decision making, leadership, breathing apparatus (BA) entry procedures, fire investigation, sectorization, team management, situation assessment, emotional intelligence etc. The following excerpts describe the relevance of effective training in the fire service and how the knowledge derived from such training exercises is often transformed into a useful source of "just-in-time" information at the fire scene:

> *"….. you would have command training, particularly how we set up the command functions. You know from the training you've had that if you have 20 pumps there, your command structure would look like this e.g. operational commanders then sectorized and each part of the fire is controlled by one person, and that person is supported by a safety commander"* (Patrick, Assistant chief fire superintendent, 32, Nigeria) *.*

…..the basis of my decisions was…. "Initially it is training; what I have been taught and told" (Dickson, 23, Crew commander, UK)

"…….[I gained knowledge] in the course of my training, because we were taught many other subjects apart from fighting fire, we were taught the chemistry of combustion, building construction and how the materials used in building behave when they are affected by fire" (Jack, 30, Chief Fire Superintendent, Nigeria)

"Yes, I received this training to head the watch, because without these training I won't even know what to do. Management wants to know whether you are capable of heading a watch before giving you the responsibility" (Kevin, 8, Watch commander, Nigeria)

I went for a course in Lancashire, and I think it is one of the most important courses I have ever had. We were taught stuffs different from the normal house or car fire. We were given scenario that requires complex thinking and unusual scenarios as well. It was incident command training, a really advanced training. Ordinary firefighters are not qualified for such training because they do not get involved in command and control things (Isaac, 13.5, crew commander, UK)

Nonetheless, despite acknowledging training as an important source of information, participants also went further to identify some limitations associated with this informational source, which they claimed appears "generic" most of the times.

So command training is very important. In terms of actually putting out a large fire you get some training on that, but only theory training…..you can't set fire to build buildings for training (Patrick, Assistant chief fire superintendent, 32, Nigeria)

> *But we have done training for small industrial unit, things like that, how to deal with them, what to expect to find in them; so we have done training to suit that, but as every incident is different, training is like a generic training that gives you a basic knowledge to then adapt to suit what you are doing, which is basic for fire services- You are given training, then you adapt to suit* (Dickson, 23, crew commander, UK)

The above excerpts therefore suggests that regardless of the length or quality of training experts have acquired, they must be able to adapt what they have previously learnt to suit a current problem, using their experience. It therefore looks like training still remains largely insufficient in the absence of experience.

Source 3 —Team Collaboration: Another important source of information which incident commanders reported was through *team interaction*, where ideas are exchanged and communicated amongst the various officers at the fireground, particularly the more experienced members of the team. The firefighting job, being multi-faceted in nature, requires a wide range of knowledge, skills and technical know-how, therefore suggesting why it is almost impossible for officers to work in isolation. The participants identified various aspects of firefighting that requires the application of specific type of skills and expertise which no single officer can claim to totally possess. For example, managing a complex fire requires technical knowledge e.g. operating fire engines and other fire appliances; knowledge on health and safety e.g. understanding safe approaches to rescue and evacuation; knowledge on entry control procedures and the scientific functioning of breathing apparatus; knowledge on managing chemical substances e.g. managing incidents involving hazardous materials (HAZMAT); knowledge on the use of current fire equipment e.g. recognizing when and how to use a wide range of specialist appliances at the fire scene (helicopter, foam tender, aerial appliances, high volume pumps, ground monitors, cold cut cobra equipment etc.), knowledge of carrying out fire investigations and managing crime scenes, sometimes in collaboration with other emergency responders.

Even though fireground commanders are required to possess some of the knowledge mentioned above (albeit on a broader scale) while undertaking the incident command training, they still often rely on the frontline officers in carrying out the “hands-on” fireground tasks. Also, in some circumstances, the incident commanders rely on information provided by the frontline firefighters as the basis for making other informed decisions (especially when fire crews have been committed into a building with their breathing apparatus). Hence, either way, fireground operations call for effective team interaction and teamwork. In illustrating this, one of the participants (Anderson, 28.5, Watch commander) claimed it is simply an “act of foolishness” for him (as a senior officer) to neglect the pool of knowledge he is surrounded with and try doing everything on his own. The excerpts below also reiterate the importance of team interaction and group communication:

> *…… fireman is a very practical down to work lesson and we spark ideas off each other. So If I was to say I'm the best man, it's only my decision because I tended to ignore the other 13 people that are there. If the 13 people have got 20 years of experience each that's 260 years of experience that your…….so if you stand up to say I need help here….. You've got another 200 to 300 years of experience around you, so you will be very foolish not to tap into that knowledge* (Willy, 28.5, Watch commander, UK)

> *Since I'm part of a team……. I was able to test my 'theory' against other experienced people; and as a consensus we agreed that it would work. It was my judgment and mine alone, but you always test the theory if you had the time, and I did, and it worked* (Patrick, ACF, 32, UK)

Source 4 — Situation assessment/Situation awareness: One of the first things incident commanders do upon arriving at the scene of an incident is to assess the situation, something called “sizing up” or “look see” in the firefighting language. All the participants admitted that they heavily rely on cues and information generated directly from observation as the basis for making critical decisions on the fireground. Since the assessment is usually carried out personally by the incident commander, the information accruing from such assessment is often trusted more than that from other sources as it deals more with "personal knowledge" (knowledge by acquaintance). Although the terms "situation assessment" and "situation awareness" are sometimes used interchangeably in the literature, they are treated as separate but inter-related concepts in this study. Whilst situation assessment deals with the aspects of "looking" or "sizing up" (in the words of the participants), situation awareness is more concerned with making sense of the cues that were identified from carrying out the former. In other words, identifying cues on the fireground through situation assessment can be said to be a relatively easier task, but understanding the implications of such cues for task performance is what remains challenging and hence a feature of expertise. In line with the above, therefore, situation awareness can be regarded as the by-product of situation assessment since it is by looking that an awareness of a situation can eventually be generated. The following excerpts illustrate the role of situation awareness in the search for information on the fireground:

> *When I went in to my initial…..we call it* 360^0 *size up, I need to see myself. We call it 'look-see'. In this case, what I was looking out for was: one, what is the actual emergency, what is going on? Two, are there any other hazards around that person that I have to take into account prior to me deploying any crews* (Brown, 27, crew commander, UK)

> *"……just observation. You know one of the qualities of a good fireman is to be observant. Through observation I noticed how the whole situation was"* (Adam, 30, ACFS, Nigeria)

> *When I arrived I met my colleague, he was running in the other direction. I said to him: what are you doing? He said I'm going to ask for 12 pumps, and I said what for, and he said we need water, and I said make it 15* (Patrick, ACF, 32, UK)

> *“Immediately we got to the place, I surveyed with these eyes to see the surrounding, it is the eyes that tell the brain what to do, and the brain acts accordingly” (Mike, ACFS, 28, Nigeria)*

The above excerpts show that experts first strive to become aware of a situation before attempting to implement any action plan. Situation awareness therefore provides experts with the ability to differentiate between the cues that are transient signals and those that are false signals. In order to be situationally aware, scholars have previously suggested that actors must be able to see what they are trained to see; they must be able to see the right things, look out for signs and have a good perception of signs e.g. smoke escaping from under the eaves, melting rubber between clip-lock walls, cracks in concrete walls and the colour, texture and density of the smoke (Ingham, 2007; Endsley and Garland, 2000; Klein, 1993; Hoffman *et al*., 1998).

Analysis of the above excerpts further suggest that situation assessment is only likely to answer the question of what resources are needed, whereas situation awareness answers the more important question of how much is needed. According to the expert participants, although most ordinary firefighters can also easily recognize the need to request additional resources at the scene of an incident, the more challenging task lies in knowing the exact amount of resources that are required. The ability to do the latter is part of what differentiates the ordinary firefighters from the incident commanders as it requires a higher level of situation awareness and resource management. In the fire service (both in the UK and Nigeria), over-estimating or under-estimating the amount of support needed is often seen as bad incident command practice, assumed to be predicated upon a poor sense of awareness on the part of the incident commander.

Source 5 — Information from victims and passersby: This is another important source of information for incident commanders. Information gathered from members of the public could potentially serve as a rich source of information to firefighters, especially when such information is coming from more reliable sources e.g. house owners or first witnesses. There were instances from the incident accounts where the firefighters reported that the vital information they needed to make important decisions was eventually supplied by the victims or passersby. Also, in addition to providing firefighters with important information, members of the public can also provide useful assistance to fire crews in handling some of the manual tasks e.g. carrying charged hose or lifting heavy equipment (this is common in Nigeria). The following excerpts aim to shed more light on the above discourse:

> "*You know when you listen to comments, you will be able to know whether the fire is being caused by an arsonist, or by carelessness, or through ignorance, you know all these things. We depend on people's comment"* (Marvin, 30, Station commander, Nigeria)

> *"I also got information from people, onlookers and those living around there, the information I got from them helped"* (Jack, 30, CFS, Nigeria)

> *Also the owner of the building, in a very short space of time, he gave me a really clear…..this is how big it is, this is a pit there, there is an inspection pit, we've got a can of waste oil and some other oils, fuels and lubricants and small cans of…..there might be a few cans of diesel in there, lots of tools, there's three phase electrics in there and at the back there's got two cylinders the little one and the big one and upstairs there's got this one big cylinder LPG, so in a very very short space of time he gave me lots of information* (Terry, 27, Group commander, UK)

Nonetheless, some of the participants emphasized the importance of verifying the authenticity of the information generated from this source by ensuring it is mapped against one's previous experiences and with the current proceedings. One of the explanations provided by participants regarding the need to treat information from passers-by with care is due to the fact that members of the public (non- firefighters) are most times emotional at the sight of a fire, and therefore subjective in the way they report their evidence.

Although it is true that both the UK and the Nigerian firefighters rely on information from members of the public, differences were found to exist in the manner in which both groups of experts collect and manage information from the “non-firefighters” (members of the public). In Nigeria, for instance, firefighters sometimes get to the scene of incidents quite late, most times for reasons beyond their control (e.g. being held up in traffic or delays encountered in the attempt to fill up fire engines with sufficient water). As a result of such delays, members of the public are therefore necessitated to commence response efforts even before the arrival of the firefighters. This practice of “public intrusion”, sadly, was reported by the Nigerian firefighters as one of the most difficult aspects of task performance as it often slows down the subsequent response effort. Firstly, attempts to extinguish the fire by unauthorized members of the public sometimes escalate the fire, making it more challenging for the fire crews to eventually manage upon their arrival. Secondly, members of the public may react emotionally to firefighters, hurling abusive words at them, sometimes attacking them physically. Thirdly, members of the public sometimes try to take advantage of the chaotic environment in order to steal or loot valuable assets. This sometimes leads to a situation in which a fire scene eventually turns out to become a crime scene. The following excerpts illustrate the experience of some of the Nigerian firefighters in dealing with members of the public at the scene of an incident:

> *Yes, pressure from the sympathizers. In fact if not for the presence of the policemen, they will not allow you to do what you want to do. Some will even try to steal (Sammy, 8, FSO, Nigeria).*

> *We asked police officers that were around to help us control the crowd that were present at the place and to send them far away to avoid explosion from their use of the GSMs. I have been telling them and they were not cooperating, and we were few (four in number) and we cannot control the crowd. When we are working they are used to watching us, not until we call on the police to drive them out (Mike, 28.5, ACFS, Nigeria)*

The UK firefighters, in contrast, do not seem to be facing this challenge of "public intrusion" at the scene of incidents. The reason for this cultural difference is both societal and organizational. In terms of society, it is usually seen as a normal practice as well as a legal obligation in the UK that people exit a building once a fire alarm goes off. In terms of organizational, firefighters in the UK make use of cordons (one or more, depending on the nature of the incident) to keep passersby at bay from the actual scene of the incident. Once the hazard zones have been cordoned off, firefighters are then able to carry out their tasks more effectively without any form of disturbance or intimidation from members of the public or any further need to worry about their safety.

5.8.2 Information filtering and identification of the principal cues

The process of information search described above results in the generation of multiple cues from the multiple sources listed above. This implies that elements in the working memory are also increased automatically, mainly to the detriment of the decision maker. It is at this point that information filtering becomes essential in the attempt to reduce the number of elements (or cognitive load) in the short term memory of the decision maker. For the purpose of clarity, information filtering is defined as the cognitive ability of discriminating between relevant and irrelevant information in ways that give room for further intuitive decisions to be made under time pressure.

After experts explained their various sources of informational cues on the fireground, another CDM probe involved asking them to identify a single cue which they considered most crucial for each of the decisions made. The aim of the question was to identify the most important informational cue that aided expert judgment. The initial assumption was that certain cues are more likely to better explain what is happening than others. Findings confirmed this to be true: out of the 42 cues reportedly used by experts across the thirty incidents, only 9 were considered as the most important. The author referred to these sets of cues as the *principal cues*. All the participants shared at least one strategy they use in knowing which of the cues were more relevant; with the most dominant strategy being that of identifying the particular class of fire or the type of material burning. The list of the 9 principal cues is:

- The class of fire involved (whether Class A, B, C, D, E, and F etc.), and the colour of smoke generated
- The type of materials present in the building and around (e.g. acetylene, carbonaceous substances, electronics)
- The intensity of the fire
- The work the building is used for (e.g. garage or mechanic workshop) and
- The cause of the fire (Arson, electric spark, lightening)
- The psychological states of victims
- Cracks spotted on the wall of a building
- The layout of the building (this is to aid in identifying access routes)
- Presence or absence of individuals in a burning building (e.g. trapped victims, disabled individuals, elderly persons)

For instance, once the class of fire involved is recognized, experts are then able to intuitively determine the next course of action such as to decide on the most appropriate fire-fighting medium that would best tackle the fire e.g. hose reel or main jets, the amount/type of resources to request, the most appropriate firefighting strategy to employ (i.e. offensive or defensive) etc. Also, identifying the particular class of fire that is burning allows experts to engage and occupy their present thoughts mainly with information regarding that class of fire (Table 5.10). Information relating to other classes of fire is thereby screened out and pushed to the sub-conscious “window” in order to keep working memory load reasonably low. This finding is seen to support existing belief that experts are used to selecting one option at a time rather than concurrently comparing amongst various alternatives — a process Klein (2008) termed *serial selection of options*.

Table 5.10: Classes of fire and their description

Class	Description
A	Fires in ordinary solid combustible materials such as paper, wood, clothes etc.
B	Fires involving flammable liquids such as petrol, kerosene, oil, paint
C	Fires involving volatile gases such as natural gas, propane, butane
D	Fires involving combustible metals and Alloys such as Aluminium, Lithium, Zinc etc.
E	Fires originating from electric sparks, short circuits, naked and transparent wires etc.
F	Fires involving molten fats or tars.

Below are data from the CDM reports showing that incident commanders do not only source for relevant information but also allow such information go through a filtering process before developing an action plan:

> *"Essentially, when I went in, I was confused at first as to why the woman set a fire and put it on the floor. Is it because she is on drugs, is it because she's got psychiatric problems, is it because she's angry with somebody, has she been drinking, is she going to harm my crew. She might have a knife; she might have a weapon….. all these things were the things going through my mind in making judgment…………. the most important piece of information from my point of view is the threat of burning the building down" (Adrian, Watch commander, 17, UK)*

> *"The thing is, you are looking at the fact that there is a lot of smoke coming out and you can tell what the colour of the smoke. [I know you might think it's funny] but you can tell if it's a car fire, you can tell if it's a house fire, you can tell if it's paper or wood……so you know from that grey yellow smoke that it's a house fire"* (Willy, 28.5, Watch commander, UK)

Members of the public; when you arrive at an incident members of the public would tell you lots of information very very quickly, and it's up to you as the incident commander to take the useful pieces of that information and discard the bits that may not be……. (Jade, 15, crew commander, UK)

"On getting there, people around will give you information; you will be hearing them say this is what caused it....... through that we now gather our information……….. the smoke/flame is also an important source of information. When the smoke is white/light then the fire is not dangerous. But when you see the smoke deep and dark, it means the fire is too dangerous" (Kevin, Watch commander, 8, Nigeria)

Arguably, one of the greatest strengths of the information filtering stage as described in the model is that it allows the level of uncertainty associated with a particular incident to be reasonably reduced. Lipshitz & Strauss (1997) defined uncertainty as a sense of doubt that delays action. The authors also identified five sources of uncertainty incident commanders often need to combat at the scene of an incident: missing information, conflicting information, confusing information, noisy information and unreliable information. Through information filtering, therefore, the decision maker is left with less and less options to choose from thereby making the working memory space freer in performing other non-routine tasks. However it is important to emphasize at this juncture that "irrelevant" cues do not necessarily mean "useless". They are only termed irrelevant because they do not fit the purpose of the current task at the time. As suggested by other scholars, extra care must be taken during the information filtering process so as to avoid screening away important cues (Oppenheimer, 2003; Klein, 2003; Spender, 2008). It is suspected that experts may place "irrelevant information" into the sub-conscious realm as potentially useful possible options they could subsequently consider, if need be. This then allows them to focus on the relevant information at the conscious level.

5.8.3. The decision making phase (Validation and/or implementation of proposed action plans)

As shown in the model (Fig. 5.8), once the information filtering process is deemed complete and the relevant information obtained, incident commanders then proceed to determine whether or not there is a need to validate the information regarding the proposed action plan. Validating the potential action plan before implementing it strives to ensure that all missing gaps are filled and that all potential causes of post-decision regrets are envisaged and prevented. The decision to validate, the rigour and the time spent in the validation process were all found to depend on certain factors, such as the amount of time pressure commanders are faced with, the stakes involved in the incident, the composition of the team and the quality and authenticity of the information at the disposal of the commander. For example, the validation process is not likely to be too rigorous if the information at the incident commander's disposal is from sources judged to be highly reliable (e.g. information coming directly from first witnesses) or if the team is made up of more experienced officers who do not need much detailed explanation to understand their tasks

It is suggested in the information filtering and intuitive decision making model that the overall validation process usually takes one of two major forms: (i) mental simulation — where the commander projects the status of the current environment into the future, spotting potential pitfalls as well as opportunities (ii) quick consultation with peers — which occurs when a commander needs to "pick the brain" of other team members before implementing an action plan. Two of the participants specifically reported that they are sometimes forced to test their ideas against the ideas of other experienced team members, mostly under conditions of high uncertainty or conflicting goals. These two validation processes as shown in the model are termed "intuition guided by analysis", which appeared at decision points where experts indicated they did not follow their first impression at the exact time it came to their mind. However, it is important to clarify that the validation stage in this model should not be confused with the extreme analytical thinking mode described in the intuitive-analytical continuum model (see Hammond *et al*. 1987). Instead, the validation process described here is similar to what Hogarth (2003) termed imposing “circuit breakers” and what Cohen *et al* (1996) called conducting a “quick test”.

The decision makers on the other hand reported that they proceed to implement their proposed action plans once they are satisfied with the quantity and quality of information they have at their disposal i.e. when there is no need to validate. One of the cues that triggers the decision to act instantly is when officers experience some level of congruity between information retrieved from memory (internal sources) and that obtained from current proceedings (external sources). Thus, in the absence of conflicting or confusing information in working memory, commanders begin to experience what Sinclair and Ashkanasy (2005) called “a sense of confidence that precedes intuitive judgement”

5.8.4. THE IFID MODEL DISCUSSED

The model presented above, the information filtering and intuitive decision model (IFID), attempts to describe how the experienced firefighters who were interviewed in the study reported managing a critical fire incident. Since most of the cues on the fireground rarely appear in forms that are clearly defined, especially at the initial phase of an incident, incident commanders were often found to be faced with the important task of collecting, filtering and processing multiple informational cues from various sources within a limited timeframe. In carrying out these tasks, the participants explained that they try to initiate a problem solving process using certain amount of information as a starting point, and then subsequently rely on additional information to refine and clarify their understanding of the problem along the line. For example, using the “class of fire”, which is one of the principal cues identified above, experts usually try to focus on the cues that are directly related to the particular class of fire currently burning (since each class of fire will require applying different tactics). For instance, while class A fire can easily be extinguished using ordinary water, class B & class C fires would normally require more advanced chemical substances such as foam compacts. This information filtering process i.e. the ability to differentiate between the cues that trigger actions and those that are not very relevant is therefore seen as an important contribution of the IFID model. It is logical to infer that most of the irrelevant cues (distractions or noise) that compete with the relevant ones mostly appear from the effort of the memory to remember everything that happened from previous incidents all at the same time. The basic maxim emphasized in the IFID model therefore appears thus: *whilst having too little information about an incident could be quite risky, having too much information, on the other hand, could prove counter-productive*. This implies that a point is reached when acquiring and computing more information becomes detrimental to the outcome of a decision.

Interestingly, the concept of “less is more” which is regarded as one of the most interesting discoveries in the last 100 years of research in the field of judgment and decision making was found to support the underpinning philosophies of the IFID model (Hertwig and Todd 2003; Hogarth and Karelaia 2007; Hilbig *et al*. 2010; Marewski *et al*. 2010; Katsikopolous 2010). The proponents of the concept use the phrase “less is more” to suggest that making accurate intuitive decisions is very possible under conditions of less information processing, computation or time. The extra unnecessary information (which includes, for example, other classes of fire not related to the class of fire currently burning) has been termed “noise” as they tend to add to the pile of uncertainty if not screened out of the working memory. Klein (2003) defined noise as irrelevant data that competes with, or strives to overlap the important data or cues. According to him, noise contains its own cues and patterns that tend to intersect and sometimes even override the real cues and patterns. These intersections eventually result into more complications, as more and more possible ways of interpreting the problem start to emerge. Similarly, Weick (1993) identified noise as a real threat to accurate sense-making as it may prompt erroneous signals or irrelevant data, thereby increasing the possibility of explaining away the relevant and important cues. From the point of view of developing training curricula, the main challenge here for less experienced officers lies in knowing which information is relevant and which is noise.

In addition to the “less is more” principle, the IFID model also fits well with the cognitive load theory, which suggests that the inability of the human memory to store a large amount of information is not necessarily a disadvantage since it can then facilitate remembering the more important and up-to-date information, sorting out the irrelevant and outdated ones by forgetting them (Ackoff, 1989; Sweller 1994; Pollock, Chandler and Sweller, 2002; Paas *et al*. 2004). This way, decision makers are able to maximize their short-term memory — which by definition has a very limited capacity. In essence, eliminating irrelevant information (or possible sources of distraction) from working memory will allow experts to focus on the more relevant information, thereby freeing more mental energy for other aspects of task performance.

A number of models have been developed in the field of cognitive psychology to describe how actors make decisions, with each model focused on one or more macro-cognitive elements e.g. situation awareness, sense making, teamwork, pre-planning etc. (Klein 2003; Endsley, 1995; Lipschitz and Strauss, 1997; Cohen *et al*. 1996). For instance, the recognition primed decision (RPD) model, a prototypical decision making model in the naturalistic decision making community, holds that proficient decision makers are mainly "recognitionally skilled" i.e. are able to recognize familiar situations from the repertoire of patterns stored in their memory — which were accumulated over years of deliberate practice (Burke and Henry, 1997; Hatano and Inagaki, 2000; Charness *et al*., 2005). According to Klein (2008), these patterns are what eventually help decision makers to recognize the most relevant cues, provide expectancies, identify the main goals to be pursued, and then suggest the most plausible action plan. Simply put, the RPD model suggests that experienced officers mostly rely on patterns recalled from previous experiences (in the form of cues, expectancies, goals and actions) in solving current problems. However, in their study aimed at investigating how actors make decisions in novel and time pressured environments, Cohen *et al* (1996) identified one of the limitations of the recognition primed decision model. The authors drew attention to the possibility of rare or novel situations occurring that could altogether defy existing knowledge — an insight that eventually propelled them to develop another useful cognitive model, which they termed the recognition/metacognition (RM) model. Thus, in contrast to the RPD model which suggests that proficient decision makers often rely on recognized patterns in solving current tasks, the R/M model argues that decision makers must, in addition to being recognitionally skilled also be metacognitionally skilled.

Whilst it is important to emphasize the role of experience in making intuitive decisions as with the RPD (see Fig 2.3) and the RM models (Fig 2.4), it is equally important to describe how experts are able to manage the multiple sources of informational cues on the fireground. It appears from the current study that the incident commanders, regardless of their ability to recognize previous incidents, are often faced with the crucial task of identifying the most relevant informational cues as well as discriminating between the relevant and irrelevant (noisy). On this note, the IFID model purports that the human memory not only serves as an organ for storing all forms of information that individuals have encountered in the past, rather it also serves the crucial purpose of providing them with more relevant and up-to-date information exactly when needed. Hence, in contrast to the recognition primed decision making model (Klein et al. 1988) and the recognition/metacognition model (Cohen *et al*. 1996), the IFID model goes further to highlight the principal cues used by experienced officers in filtering the multiple information they are often bombarded with at the scene of an incident (see section 5.8.2).

Another important contribution from the IFID model lies in its attempt to clarify the role of intuition in analytical thinking. Although it is believed that analysis/deliberation is conceptually different from intuition, the model suggests that intuition still plays a key part in making decisions leading to whether or not to deliberate on a proposed action plan. For example, in two of the reported incidents that required some deliberation, the expert participants agreed they had already developed an action plan in mind, but only needed a little bit of more thinking time before acting. Further analyses of the two incidents showed that the additional thinking time was required (in retrospect) either because higher stakes were involved or because certain information remained unclear to the officers. The key thing to note here, therefore, is that experts seem to know when to reflect on a particular action plan and when to implement instantly. This finding supports existing claims that intuition complements analysis in certain circumstances and also that experts, in contrast to novices, seem to understand the boundaries of their skills and know when their intuition is likely to betray them (Dunning *et al*., 2003; Shynkaruk and Thompson, 2006). Kahneman & Klein (2009) put it this way:

> "*True experts, it is said, know when they don't know, and non-experts (whether or not they think they know) certainly do not know when they don't know" (Kahneman & Klein, 2009, p.524)*

The model also aligns with the overwhelming evidence in the literature suggesting that effective managers frequently draw on intuition and analysis as separate 'inputs' when making critical decisions, switching decision styles as conditions warrant (Hammond *et al*., 1987; Goldstein and Gigerenzer, 2002; Hogarth, 2003; Klein, 2003; Tanner, 2006; Evans, 2008; Epstein, 2010).

Furthermore, the IFID model aims to provide additional insight regarding the role of intuition in creative decision making. Notwithstanding the remarkable progress that has been experienced in recent years in studies involving intuition, Dorfler and Ackerman (2012) who built on the initial work of Polanyi (1962) remained quite critical on the extent to which most scholars emphasize the use of intuition in judgment making at the expense of its use in creative thinking. Dorfler and Ackerman (2012) challenged this notion of a one-sided application of intuition, calling for more empirical evidence in investigating the creative role of intuition. Analysis of the 134 decision points between the two groups of experts (as shown in Fig. 5.7, section 5.5) provided additional evidence to suggest that intuitive insight and intuitive judgment represent two different but related routes to intuitive decision making. The former relates to decisions made during unusual circumstances that require improvisation (creative decisions), which is only possible through insight (Polanyi, 1962) whereas the latter, intuitive judgment, relates to decisions made through pattern recognition — in which case a decision maker will assess an ongoing situation and then match the cues, goals and actions against the repertoire of patterns stored in the memory (Perry and Wiggins 2008; Keller *et al*., 2010). Hence, although the creative use of intuition appeared to be significantly less prominent than its use in judgment making, there are reasons to believe that problem solving on the fireground involves both intuitive insight and intuitive judgment.

Finally, since the IFID model describes how experts cope with one of the greatest challenges of managing complex incidents i.e. the ability to overcome the snare of diverting cognitive resources away from the main task amidst multiple task demands, a link seems to exist between the model and some of the psychological errors actors are likely to face in a task environment. Previous findings have shown that many of the psychological anomalies that result in poor judgment often emanate from people's inability to effectively process the amount of information in working memory. For example, Kahneman (2011, p.95) used the term *mental shot gun* to describe a situation in which people's intention to solve a particular problem evokes another task which is not only irrelevant but also detrimental to the main task. Mental shot gun hence results in slowing down the decision making process as it tends to generate some form of decision-conflicts, or what Festinger (1957) termed cognitive dissonance.

Furthermore, Gasaway (2013) identified another potential error decision makers often suffer while making decisions under time pressure — the *normalcy bias*. Normalcy bias is mostly invoked when the brain encounters something far beyond its bounds of understanding, reasoning and comprehension. In such circumstances the brain begins to fabricate new realities by blocking out the true ones and replacing them with vividly imagined ones. Therefore modelling what experts do as described in the IFID model and teaching such to novices, is envisaged to be an effective way of improving the intuitive decision making skills of novices. It is thus hoped that the IFID model, through training, will serve the purpose of mitigating occurrence of psychological anomalies in the less experienced officers while making time-pressured decisions.

5.9. PATTERN RECOGNITION AND INTUITION

As discussed in section 2.7, seven characteristics of intuition have been identified in the extant literature i.e. intuition:

- is spontaneous
- involves holistic processing of thoughts
- is rooted in tacit knowledge
- neither follows nor breaks the rules of logic
- involves unconscious and effortless processing of information
- frequently accompanied by emotions, and that
- intuitors often show a sign of relief after making an intuitive judgment.

However studies have also shown that the aforementioned characteristics can be summarized into two major schools of thought (Shirley and Langan-Fox, 1996; Sadler-smith and Shefy, 2004; Hodgkinson *et al*., 2009). The first consists of a body of knowledge that maps intuition to experiential knowledge and expertise, gained through accumulated years of experience and then retrieved through pattern recognition (Baylor, 2001; Liptshitz *et al*., 2001; Charness *et al*., 2005; Plessner and Czenna, 2008; Ericsson *et al*., 2007; Salas *et al*, 2010), while the second category consists of scholars who believe that sensory, emotional and affective elements are a crucial aspect of intuition (Epstein, 1994; Shapiro and Spence, 1997; Sinclair and Ashkanasy, 2005).

While ample evidence was found in the current study to support intuitive characteristics that correspond to the first school of thought (see Table 5.12), little or no evidence was found to support the notion of intuition that fits into the second category. The table below shows a compilation of excerpts that define intuition from the point of view of the participants. Participants used various terminologies and phrases to describe an intuitive decision making process, none of which was found to be associated with emotions or mood.

Table 5.12: A content analysis of participants' view of intuition

PSEUDONYMN	TERMS USED TO DESCRIBE INTUITION	LINK TO EXISTING DEFINITION IN THE LITERATURE
UK FIREFIGHTERS		
NATH	As soon as possible, ……decisions made in seconds (p9,Q31)	spontaneous
PATRICK	It is a product of looking, feeling and seeing (p28, Q27)……..you consider and assess options at the same time as opposed to doing it in a stepped way (p25, Q14)	Holistic processing of information
DICKSON	…….. doing something instantly and adapt that to suit [the situation] as you get more information (p49, Q26)	spontaneous
TROY	Once you've made that decision it's not to say that you haven't instantaneously looked at the options, in split seconds the options are there and you know that that's the right way to do it, don't ask me how, you just do (Q18, p221)	spontaneous, tacit knowing
WILLY	Subliminally, you are doing it without realizing you're doing it, and you do the kind of things….when I had the last fire that was like this, this went better or that went better (Q10, p232)	Unconsious processing, tacit knowing, experiential
JADE	….again that's experience gained through 15 years of firefighting, through seeing lots of different fires and seeing how fire behaves (Q10, p256)	Experiential
DARREN	…..So how you actually make those decisions is through primary experience and secondary experience; so stuff that you have actually experienced yourself and stuffs you've learnt from other people, you've learnt from manuals, from training exercises (q12, p196)	Experiential
NIGERIAN FIREFIGHTERS		

KNIGHT	……on getting there, when I saw the sign it did not take me 10-20secs because before dropping down from the vehicle I had already known what to do (p105, Q19)	Unconscious processing, spontaneous
ADAM	…..when you get there, your brain will just tell you let's do it this way……you don't have to waste time (p114, Q18)	Unconscious processing, spontaneous
MARVIN	…..as you are approaching your brain will be working….you make decisions in 5secs, it shouldn't be more than that….even before your vehicle stops, as a good officer you might have assessed the type of fire you are facing (p133, Q19)	spontaneous, Unconscious processing
JACK	….it did not take long to make any decision because the decisions come freely; because I have got the training and the experience is there (p152, Q24)	spontaneous, unconscious processing, Experiential
SUNNY	…….it easily brings to my mind what I did before, and what didn't work……you gain more knowledge from your past experiences (p160, Q16)	Experiential
MARGARETH	Experience! These are the things you do every day, you have these issues every time and you discover that without doing it in a particular way, you will get injured (Q9, P290)	Experiential

The excerpts in table 5.12 seem to provide additional evidence to strengthen existing beliefs that intuition used a valid form of knowledge. The table also shows that intuitive knowledge represents the type of knowledge that guides professionals through what needs be done, without necessarily knowing how they knew. The evidence provided here is therefore seen to contradict the assumptions of the cognitive experiential self-theory (Epstein, 1998) as well as the conclusions reached by Sinclair and Ashkanasy (2005). These authors' main argument has been that intuitive knowledge often "uses emotions as a conduit", yet none of the experts in this study were found to attribute intuition to "feeling" but rather to "knowing". This opposing view of intuition (emotional vs non-emotional) is unsurprising considering the different epistemological positions from which the various studies derive. The current study adopted a naturalistic approach to the assessment of intuition, whereas the above two studies attempted to capture intuition from an experimental and theoretical approach respectively.

Since all the expert participants agreed that dealing with a current problem requires making use of previous knowledge and experiences, the concept of pattern recognition thus appears to be a logical way of explaining where intuitive knowledge comes from. Findings in Table 5.12 show that intuitive knowledge is the type of knowledge developed through consistent and repeated experiences that have been unconsciously linked together. Hogarth (2003) has previously used the term *mere exposure effect* to explain how people store past experiences in their memory as they respond and adapt to multiple stimuli from their environments over time. A number of cognitive psychologists have also used the term “pattern” — which they defined as a set of cues that is often “chunked” together — to describe the repertoire of knowledge experts often build over time (Crandall and Gretchell-Leiter, 1993; Klein, 2003; Perry and Wiggins, 2008).

However, it is important to emphasize that developing a reservoir of meaningful patterns in the memory do not just occur circumstantially, it takes years of dedication and hard work (Driskell *et al*., 1994; Hoffman, 1987; Wong, 2000; Hayashi, 2001; Feldon, 2008; Ericsson *et al*., 2007; Kahneman 2011, p.238). For example, studies of chess masters (e.g. Chase and Simon, 1973) have shown that at least 10,000 hours of dedicated practice is required in attaining the highest level of performance (which is equivalent to playing chess five hours a day for about 6 years). The more patterns people acquire over their years of active practice the more likely they are able to match a new situation to one of the pre-stored patterns. This is the principle that helps expert fire officers, for instance, to see a smoke colour and intuitively predict that toxic chemicals are burning (Okoli *et al*., 2015).

5.9.1 Principles of pattern recognition

Although the term “pattern recognition” is not new in the field of cognitive psychology and expertise studies, it was still deemed necessary in the current study to investigate how the concept is utilized in the firefighting domain. The research was particularly interested in understanding the underpinning “principles of pattern recognition” from the point of view of the experts themselves, and to evaluate such understanding against the current application of the term in the literature. As part of the CDM interview protocol, participants were therefore probed in-depth as to whether or not managing the incident they narrated reminded them of previous incidents. In addition, each of the participants was asked to explain exactly how their knowledge of past incidents was remembered and then replicated in solving the current tasks. A thematic analysis of the CDM data across the thirty incidents subsequently generated five main themes that were found to be closely associated with how pattern recognition works for expert firefighters.

1. The number of templates chunked in experts’ memory is a function of the number of incidents they have attended and the level of experience they have gained from solving both routine and non-routine tasks

As earlier stated, the more experienced officers are often called upon to take over incident command responsibility as an incident escalates, which is the norm in both countries. This ultimately implies that competence in firefighting is mainly defined by the number of non-routine tasks a particular firefighter has managed throughout their career, as opposed to routine tasks. It is therefore not surprising that Shanteau et al. (2002) in their important paper entitled “Performance based assessment of expertise” made a strong case for the inclusion of “problem-type” as an important variable in discriminating between routine and adaptive experts.

All the participants in this current study agreed that their ability to recognize previous incidents and recall them correctly is explained by the fact that they have attended many “serious” fires in the course of their career as firefighters. Hence, this study agrees with existing claims that both the length of active service and the quality of experience people gather in the process are crucial to building what Chase and Simon (1973) called *chunks,* or *templates* by Gobet and Simon (1996), or *patterns* according to Klein (2003)

Across a wide range of domains in the naturalistic decision making literature such as sports, medicine and midwifery, education, aviation, military, ambulance and firefighting, studies have confirmed a positive relationship between actors' years of experience and their level of competence (Benner and Tanner, 1987; Klein and Thordsen, 1988; Crandall and Gamblian, 1991; Orasanu and Connolly, 1993; Flin, Slaven and Stewart, 1996; Wong, 2000; Johnson and Raab, 2003; Ross *et al*., 2004; Tissington and Flin, 2005; Kermarrec and Bossard, 2014). Specifically these studies have shown that experts tend to outperform novices mainly because they possess a wider range of domain knowledge which they leverage upon in making creative or knowledge based decisions

For example, Chase and Simon (1973) in their early study on chess hypothesized that experts can rapidly recognize key features of a problem using their perceptual and cue discrimination skills. The authors tested this hypothesis in an experimental study involving expert and novice chess players and eventually developed a well-established theory known as the chunking theory (Chase and Simon, 1973). The chunking theory purports that experts store a large amount of information in their long term memory, usually as a single entity which they then rely upon to direct their plans and moves (Gobet, 2005). In two different tasks presented to the two groups of chess players (chess masters and novices), the authors found that the former were able to memorize and reconstruct a chess position better than the weaker novice players. Simon and Chase (1973) linked such exceptional performances to the fact that the chess masters had acquired a larger amount of chunks than their novice counterparts, leading therefore to the conclusion that about 50,000 long term memory chunks are required to reach the level of performance of chess masters.

2. The Templates in experts' memory form a framework for thinking (Schema-based network)

According to the expert participants, decision making on the fireground does not, for the purpose of effective task performance, support recalling anything and everything. Instead incident commanders are expected to rely only on the relevant cues from the proceedings of an incident in order to trigger the pattern recognition process (these are the "principal cues" discussed in the model in section 5.7). Interestingly, the memory triggering and recalling process has been shown to be possible mainly through the operations of one of the most powerful cognitive networks in the memory — the *schema*. Virtually everything human beings see, hear or even think about is critically dependent on schematically organized information that is stored in long-term memory (Cooper, 1998; Pollock *et al*., 2002; Paas, Renkl and Sweller, 2004; Cowan, 2008).

For example, expert mathematicians are able to intuitively understand how a/b=c is transformed into a=cb because their algebraic schemas tell them so, without the need to impose any extra cognitive load on their working memory. In addition, schemas are what make it possible that only a single tree and not thousands of leaves and branches that make up the tree is remembered; that only a sentence rather that the individual words or numerous letters that make up the sentence is remembered (Sweller, 1994; van Merrienboer and Sweller, 2005). In essence, schemas strive to increase the amount of information that can be held in working memory, despite its limited holding capacity. This is possible because each schema, no matter how complex, often appears as one single element in the working memory (see Gobet, 2005 for details on chunking theory). This therefore implies that schemas not only organize and store knowledge for future use, they also help to significantly reduce working memory load; acting as a "central executive" that provides vital information that is required to perform the current tasks (Pollock, Chandler and Sweller, 2002)

How then does the organization of this schema influence the pattern recognition process? It is important to note that everything firefighters have learnt and experienced is stored in long term memory, which includes information about the classes of fire, equipment, water supplies, fire chemistry and behaviour, first aid, human behaviour, sectorization, entry control procedure, inter-agency response and so on. It is therefore by easily recognizing and understanding the implications of a particular cue through the schema-based arrangement that a decision maker is likely to be able to respond more promptly. Since the human working memory by its very nature cannot process many elements at a given time, it probably holds that firefighters are able to intuitively recognize the most plausible cues, goals and actions plans because of their well-organized schematic framework for thinking. All the participants agreed that they would normally know what to do, depending on the particular type of fire encountered. This supports the idea that they perhaps have different schemas for fighting different types of fires: house fires, petrol fires, factory fires, fires from road traffic collisions, chemical fires etc. For example, one of the experienced officers (Paul, ACFS, 32, UK) provided a useful framework from his analysis, stating that:

- *"Previous incidents contribute to a template*
- *[The] template is in your head and forms a framework for thinking*
- *You call upon this instinctively*
- *The number of templates depends on your level of experience*
- *Most of the incidents you go to must fit into at least a [single] template*
- *Post-incident briefing helps identify strengths and weaknesses in strategies, providing learning points for future incidents"*

(Paul, Assistant Chief Fire Superintendent, 32, UK)

Expertise also lies in knowing which of the schemas to combine in the event of encountering novel situations.

3. The manner in which skills were learnt and committed to memory determines the quality and fluency of the pattern recognition process

The CDM reports showed that pattern recognition is only realistic when learning has actually taken place. In other words, the ability to recall events from memory did not seem to occur because experts merely observed how their superiors previously managed a particular task. Rather, it is envisaged that proper learning occurred and that the lessons learnt were properly committed into a memory space in ways that subsequently enhanced ease of recall.

The participants identified two key areas where opportunities for learning can be created for the frontline officers. First, through post incident debrief (see also last point from Paul's excerpt above). Dedicating quality time to discuss what went right or wrong after an incident was reported as a useful way of establishing learning points for officers, particularly the less experienced ones. The main point here is that learning points would only be registered in the memory space if the stakeholders involved in the learning process are made to be aware of what was learnt in the first place. Second, by admitting that mistakes are a part of the learning process, thus increasing the error margins for the novice learners (albeit in a controlled manner). Four of the highly ranked participants in the UK admitted to learning most of the key aspects of the job during their early days as crew commanders. They claimed it was some of the mistakes they made back in those days that eventually made them stronger and better on the job. The excerpts below illustrate this point better:

> *I can make a mistake and say, I'm sorry I made a mistake it's not right, whereas when you are new or inexperienced you don't want to be seen making mistakes and you can't accept making a mistake. And most times learning from your mistakes is what counts. If you don't accept that you made a mistake you can't learn from it because you don't think you made a mistake* (Dickson, 23, Crew commander, UK)

To say I have not made mistakes would be the wrong thing, I'm one of those people that think you have to make mistakes to learn and I'm not frightened of making mistakes whereas a lot of my people are. A lot of my peer groups don't volunteer to be the person that's on the spot, whereas I put myself on the spot. And you can criticize me but don't go too far because tomorrow you'll be on the spot. (Lambert, 26, Watch commander, UK)

The above excerpts therefore suggests that it would be extremely difficult or even impossible to recall anything meaningful in the future unless an individual has first registered previous events in the memory as they happened at the time they occurred, deliberately learned from them and committed the learning points into the memory space.

4. Pattern recognition process (I): Current tasks > existing repertoire of patterns ⟶ Addition of new templates ⟶ Adaptive expertise

Incident commanders are often faced with two possible scenarios on the fireground. First, when the task constraints and knowledge required in managing a current incident exceed existing knowledge in the long term memory. This typically includes situations where no pre-stored pattern or templates seem to match proceedings of an event, or situations where recognized patterns appear insufficient for solving a current problem. A few instances were found across the CDM reports where officers encountered incidents that were beyond their routine knowledge for which they were compelled to switch from rule-based or adaptive decision making strategy to creative problem solving (see section 5.5). Furthermore, evidence from the creative decision points showed that adaptability and flexibility are two of the most effective requirements in developing creative insights. Hence, in instances where pattern recognition seemed to be flawed, incident commanders must possess the ability to combine bits and pieces of information from different incidents to make a whole — a process Kaempf, Wolf and Miller (1993) termed *story building*. For example, to develop a workable action plan an officer could pick insights from the schema for “search and rescue”, another from the schema for “fire behaviour” and another from the schema for “technical procedures”.

Story building thus appears to be more useful when there is a need to cope with incomplete or confusing information, allowing decision makers to connect different lines together in order to predict how events might have come about (for details see Cohen, Freeman and Wolf, 1996). For example, to construct and test the validity of a story regarding, for instance, the possible cause of a fire, an incident commander might want to know what substances were last brought into the building, where combustible materials are located in the building, what the building is used for, whether or not the building has previously experienced any fire outbreak.

As shown in the equation above, this creative ability requires making knowledge-based decisions, hence is a hallmark of adaptive expertise. The good news is that experts are able to contribute to their existing templates after successfully constructing and implementing a story into a workable action plan. For example, Brown (27, Crew commander, UK) reported a massive factory fire incident involving also the crucial task of managing a victim who had suffered severe burns. Brown explained that whilst he has previously managed several factory fire incidents as well as incidents that required resuscitating people with severe burns, he had never managed any incident involving both conditions at the same time. Through the insights drawn from managing those two incidents the officer was therefore able to create a workable action plan of splitting his crew into two — with one carrying out a firefighting task and the other a rescue and salvage task

5) Pattern recognition process (II): Existing repertoire of patterns > Current tasks ⟶ strengthening of templates ⟶ Routine expertise.

This second equation explains instances where experts are able to recognize most of the elements in the current environment and act accordingly using the rule-based or adaptive decision making strategy. Incidents of this category are usually less cognitively demanding than those described in the first equation since pre-stored knowledge in experts' memory is enough to proffer workable solutions to the task constraints. The process here may be likened to a magnetic attraction, with the schema-based network attracting the relevant cues and ignoring others.

For example, Sammy (crew commander, 8, Nigeria) reported a battery explosion incident at a warehouse and explained how managing the incident brought to his memory previous gas fire incidents he had managed. In the current incident, the officer immediately requested breathing apparatus as soon as he remembered (from one of the previous incidents) how he almost fainted for inhaling toxic chemicals (Note: a breathing apparatus is regarded as a specialist appliance in Nigeria unlike in the UK). Also, Paul (Assistant chief fire, 32, UK) narrated how he recalled from one of the previous incidents the need to use a foam tender to fight the current fire instead of using ordinary water. The current incident was a massive petrol storage fire in which the wastes and oil debris from the fire kept flowing back and polluting the river course — making response effort extremely ineffective.

As shown in the equation above, the ability to make decisions based on knowledge derived solely from pattern or similarity recognition is arguably a feature of routine expertise since no creative problem solving strategy is required. In these circumstances (as with the above two examples), the officers only end up *strengthening* existing templates as opposed to adding new ones.

5.10. DIMENSIONS OF TACIT KNOWLEDGE

Building on the early works of Polanyi (1962, 1966), Tsoukas (2003) employed the analogy of a triangle in contextualizing tacit knowledge. In his analogy, Tsoukas (2003) likened the first end of a triangle to the *subsidiary features* (i.e. informational and environmental cues), the second end to the *focal target* (i.e. the main goal pursued by an actor) and the last end to a *knower* who connects the other two ends. It was on this note that Polanyi affirmed that no knowledge is possible without the integration of the *subsidiary features* and the *focal target*; he therefore referred to all knowledge as *personal* and all “knowing” as *action*. In describing his reaction when faced with difficult situations on the fireground, one of the officers reported thus:

> “*It was an unusual incident, but something inside you takes over where you go into a mode of professionalism, and it comes because you’ve been doing it for that long and [using] the training and the knowledge and experience [you have acquired], you go into a firefighter mode”* (Brown, 27, Crew Commander, UK)

The “firefighting mode” mode described here is similar to the operations of tacit knowledge, which has been conceptualized in most part of the current thesis as the act of knowing without knowing how (Polanyi 1962; Nonaka, 1994; Hanabuss, 2000; Fessey, 2002; Horberry and Cooke, 2010). Tacit knowledge represents the type of knowledge that is difficult to verbalize, or a component of expertise that is highly resistant to surface articulation even by the experts themselves (McCaffrey, 2007; Eraut, 2004; Maqsood, Finegan and Walker, 2004). It comprises a spectrum of conceptual, visual or sensory information that must be effectively utilized in order to make sense of something.

Since the current study was mainly focused on eliciting tacit knowledge from expert firefighters, it became imperative to specifically search for evidence of this type of knowledge across the entire incident reports. The entire CDM transcripts were carefully read and specific words, phrases or sentences related to “knowing-what” “knowing-how” and “knowing-when” were coded. The content areas (from the transcripts) where experts attempted to explain or justify the basis of their actions/inactions, using phrases such as “I did this because I know…..” or “you know that…..” were also coded. Some of the CDM probe questions were more directly related to tacit knowledge elicitation e.g. how did you know the action you took was the next thing to do? What knowledge did you use in making those decisions and how was it obtained? What do you think novices would have done differently? What cues did you rely on in making those decisions? In other cases, information regarding experts’ tacit knowledge were seen to emerge from other probe questions that were not directly related to tacit knowledge e.g. what goals were you pursuing at each decision point? Were you being creative or were you just following some set of rules?

Overall, eight themes emerged from the CDM analysis, which is hereafter termed the *dimensions of tacit knowledge* for ease of reference (Worked examples of thematic analyses attached in Appendix F)

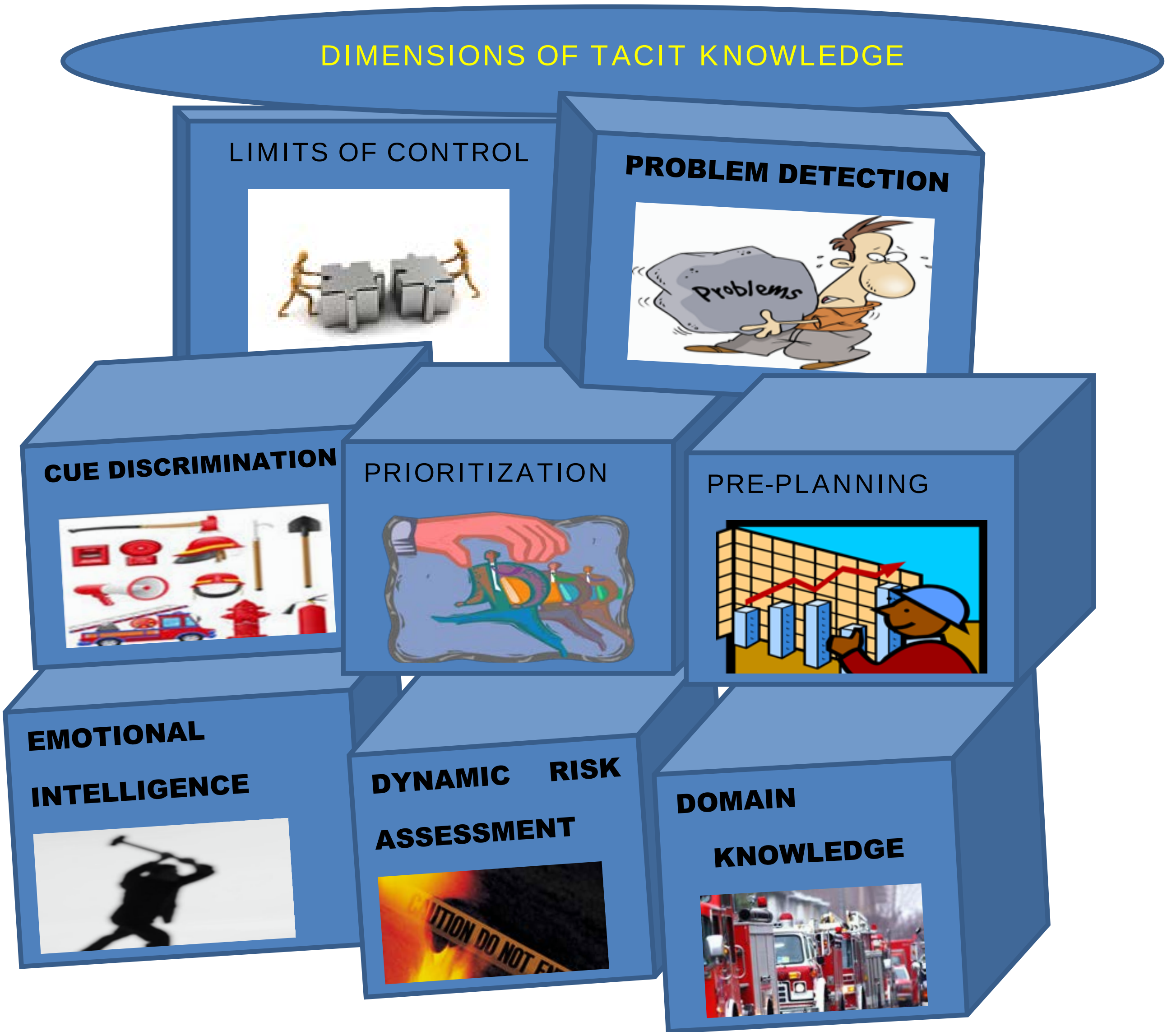

Figure 5.9: Attributes that define experts' competence (tacit knowledge) in the firefighting domain

1. CUE DISCRIMINATION

Cue discrimination is an aspect of tacit knowledge that deals with the ability to identify subtle differences and/or similarities between various cues. Since it is not all the available cues on the fireground that are eventually needed for making task related decisions under time pressure, commanders are often faced with a crucial task of focusing on the more relevant cues. However, this act of selecting the relevant cues from amongst other available cues ultimately requires having a good understanding of the various cues associated with each class of fire and being able to discriminate between and within the different cue classes. For example, experienced officers by virtue of their cue discrimination skills seemed to understand the difference between the colour/texture of smoke that is oozing out from a fuel fire (class B fire) and that from a carbonaceous fire (class A fire). They also seemed to be aware of the pattern of flame movement for a fire at the different stages (growing stage, developing stage and decaying stage)

Why is cue discrimination regarded as a crucial aspect of expertise? There are at least five reasons for this:

- The speed with which a particular cue changes over time could be quite slow but yet consistent. Hence, failure to make sense of such subtle transitions, as early as possible, might end up proving costly.

- The cues may be very similar to each other to the extent that diagnosing them becomes a bit challenging (e.g. a backdraft and a flashover). In fact, incident commanders might sometimes need to integrate a number of smaller “clues” to be able to see what is actually happening

- It is important to note that cue discrimination goes beyond mere identification of cues to include, more crucially, the ability to compare and contrast between closely related cues. Professional competence is therefore measured by being able to identify both the cues present in a task environment as well as the missing cues.

- (iv)The background of the task environment could be noisy and distractful, thereby making it difficult for the commanding officer to focus on the most relevant cues required for carrying out the right tasks.

- The incident might become so complicated that too many cues increasingly begin to command the attention of an incident commander, increasing the short-term memory load in the process

But how do experts develop this cue discrimination ability? Previous studies have shown that developing the ability to discriminate between cues is mainly possible because of the well refined perceptual skills experts have developed over many years of consistent practice (Gobet, 2005; Ericsson *et al*., 2007; Klein, Pliske, Crandall and Woods, 2005; Perry and Wiggins, 2008). For example, in an empirical study with firefighters aimed at identifying the rules experts rely upon in determining roof "squishiness", Calderwood, Crandall and Klein (1987) found out, interestingly, that no visible rule existed for the experts in making such a judgment call. One of the experienced fire-fighters interviewed in the study asserted that "you simply have to keep standing on a number of squishy and un-squishy roofs until you are able to know the difference between them".

2. PRIORITIZATION

If one visualizes the firefighting domain as one in which experts are expected to make accurate decisions under time pressure and sometimes amidst confusing and incomplete information, it becomes easier to appreciate the importance of task prioritization in attaining effective performance. For most serious fires, the first 10mins into the incident is usually the most crucial time as it is when the energy in a fire appears to be greatest. It is at this timeframe, also called "the golden hour" in the medical literature (see Annibale and Bissinger, 2010) that most of the crucial decisions are made, which implies that doing nothing is never an option in such circumstances. Experienced firefighters often strive to attend to the most urgent tasks first, especially in more complex fires where a misplaced priority could prove disastrous. Task prioritization therefore emphasizes the importance of getting the *timing* of events right since implementing action plans prematurely can jeopardize the chance of success while also delaying actions unnecessarily can cause irreversible damages to both lives and properties. Knowing “what” to do is hence not always as important as knowing “when” to or knowing “which” to do first. In some of the reported incidents, the participants showed that they understood the principle of task prioritization based on their perception of which task required more urgency e.g. firefighting vs evacuation tasks. Experts also seem to know how to prioritize resources i.e. they understand which appliance needs requesting first e.g. an aerial appliance or foam tender

Furthermore excerpts from the interview transcripts showed that experts were always willing to prioritize the saving of human lives over properties in almost all circumstances:

> *“Your initial risk assessment has to be quick. You need to concentrate on the most pressing need. Hence the decisions to ask for more help from police and other investigation comes after you have made your initial decisions within that first 10minutes” (Brown, 27, Crew commander, UK)*

> *“Let’s say this building is on fire now, after making a roll call that some people were trapped inside, we will make sure that that life is saved before even fighting the fire – to save life first (the life of the victim). So we save lives first, before fighting the fire” (Adam, 30, CFS, Nigeria)*

> *“Then we got there we discovered that it is a very heavy fire, so we had to ask for more hands and an appliance from another station turned out to the place and we were able to extinguish the fire. We did the damping down, we were able to do that, and we tried to make up our equipment” (Margareth, 11, FSO, Nigeria)*

> *"And in this case, the priorities were saving lives. But to do that, we also have to do something about the fire because the fire was starting to prevent us from carrying out our own life saving processes. You can sometimes ignore the fire and rescue the people but sometimes you can't and this was one of the incidents where you couldn't ignore the fire, you had to fight the fire and also rescue the people at the same time"* (Lambert, 26, Watch commander, UK).

It can therefore be inferred that some of the decisions experts found somewhat challenging were not necessarily because they lacked knowledge on the actions to take, but mainly because they had to get the timing of events right i.e. going either offensive or defensive exactly at the right time, requesting extra resources exactly at the right time, conducting a fire-break exactly at the right time etc.

3. PRE-PLANNING

It is no longer new that managing and coping with time stress is one of the most difficult aspects of task performance on the fireground, especially when higher stakes are attached to an incident (Borodzcicz and van Heperen, 2002; Clancy *et al*., 2003; Boin and 't Hart, 2007; Jenkins *et al*., 2010). In such circumstances, it become extremely important to develop strategies that will allow overall response time (thinking time + implementation time) to be significantly reduced. One of the common ways through which experts often attempt to more effectively manage time is by *pre-planning*, which simply means planning or thinking ahead of time. Through pre-planning experts are able to draw a mental picture of possible action plans in advance of time such that thinking time at the scene of incident is eventually reduced, allowing more mental energy to be channeled towards actual task performance.

Analyses of the CDM data showed that firefighters in the UK pre-plan by ensuring their breathing apparatus sets as well as other personal protective equipment (PPE) are worn while *enroute* to an incident scene. Similarly, findings also revealed that incident commanders (in both countries) sometimes start apportioning tasks to their crew while *enroute* to the scene of an incident, using the information they have gathered from a caller as a reference point. The CDM reports also showed that when fireground commanders perceive the need to perform a relatively time consuming task (e.g. ventilating a building, breaking walls or roofs), they often strive to make all the necessary arrangements in advance of time through pre-planning. This includes ensuring that the hoses are fully charged and that adequate water is available.

The excerpts below shed more light on the role of pre-planning in the fireground decision making process:

> *"Because of the nature of the topography of the area, the nature of the incident as described, and obviously the knock-on effects of getting people at 3.30 in the morning, moving around to a place of safety and all that that entails, I knew that this would be a very complex incident, particularly as there were acetylene cylinder confirmed to be involved. That was all what I was thinking about on the way for that 10mins" (Troy, 27, Group commander and flexi-duty officer, UK)*

> *"When you are in the vehicle, your turn-out slip has told you little of what is happening there, i.e. if it is a building on fire or a car on fire. And as an experienced officer you will be addressing your men on what to do right down from the vehicle. The moment you alight from the vehicle, an officer in charge would first come down, he would just survey round under some seconds" (Young, 28, CFS, Nigeria)*

But how does pre-planning enhance intuitive decision making? Drawing insights from the data/frame sense-making theory (Klein *et al*. 2006) it is suggested that decision makers, upon receiving an initial information about an incident (e.g. from a caller) tend to develop a *frame* — something that serves as a reference point for developing an action plan. For example, in one of the incidents reported in the study, Troy (Group commander, 27, UK) explained how he concluded the incident was a serious one after receiving a call from the control room requesting him to turn out to the incident as a flexi-duty officer. The experienced officer immediately began to develop potential plans while driving down to the fireground. The initial information experts receive about an incident often generates *expectancies*, which explains why people can initiate an action plan even with only little available information and then adjust as they obtain additional information.

It is however important to mention a potential danger of pre-planning (the process of generating expectancies) i.e. the fact that it can sometimes lead to fixation — a situation where officers are tempted to hold onto their pre-conceived ideas (expectancies) by all means, rationalizing and normalizing their proposed plans even when there is potential evidence of weaknesses in such plans (Turner, 1976; Weick, 1993; Roux-dufort, 2005; Feldon, 2007). Furthermore, the source of information from which expectancies are developed was also found to be an important factor. For example, the outcome of a pre-planned action could be erroneous if the information that was used to generate such a plan was based on false alarms (e.g. emotional outbursts from callers) rather than on legitimate signals.

4. DOMAIN AND TECHNICAL KNOWLEDGE

Experienced firefighters must possess a wide range of domain knowledge, which includes, for example, knowledge on fire behaviour, fire combustion, fire chemistry, smoke behaviour, building construction, handling of firefighting appliances, water behaviour, ventilation, hose and hosereel, sectorization. Understanding how the fireground environment operates as well as the potential problems that could possibly arise from such operations is undoubtedly an important requirement for expertise. Incident commanders are therefore not only expected to know when appliances are working properly (e.g. a pressure pump) but also when/why they are malfunctioning. In addition, a good fire-ground commander must also be able to balance and negotiate resources effectively as events unfold.

Following a thematic analysis of the CDM reports, below is a list of some elicited knowledge areas as they apply to the firefighting domain:

- Building behaviour: Understanding building construction and architecture e.g. wall cracks, roof collapse
- Fire behaviour: Understanding fire growth and movement, and how fire reacts to combustible substances
- Smoke behaviour: Understanding smoke color, smoke texture and smoke density
- Fuel behaviour: Understanding how fuels reacts to fire and being aware of the substances that mostly increase fuel volatility
- Water behaviour: Understanding the properties of water as an extinguishing agent
- Weather behaviour: Understanding the impact of weather condition (e.g. wind) on task performance. For example, knowing that extremely windy conditions can affect performance by making the fire spread quicker, and that non-windy conditions on the other hand can affect performance by making the smoke in the environment static and thereby causing difficulty in communication
- Human behaviour (meta cognition): Understanding how the members of public would react to the sight of a fire and how individual firefighters are likely to behave under stress
- Information technology and communications: Understanding how fire equipment is being set-up, how their efficiency can be best maximized and how they are being dismantled.
- Multi-agency involvement: Understanding who to involve in a response effort and how the activities of the various agencies can be better coordinated

The excerpts below show how experts are able to combine some of the above variables to demonstrate their understanding of fireground tasks, equipment and the environment:

"At those point I'm looking at it, I know, I've got a measure that if I've got a house on fire, just a normal standard house with nobody in it, I can do that with 2 trucks, 9 people, 2 fire engines, no doubt, that is a bog standard measure, I know that. If I've got a car on fire I can deal with it with one fire engine. So there are basic measures" (Dickson, 23, Crew commander, UK)

"So if the wind is blowing to your side you must use spray, but if the fire is going far and you think the spray cannot cover the distance, you can then use jet to extinguish" (Steve, 9, FSO, Nigeria)

So in some cases when I turn up to a fire and the flames are flying out of the window, everybody thinks it's really dangerous; but actually for us we can see what is dangerous; potentially everything is visible to us. But if we come to a place with black thick smoke where the smoke is not ripping out of the windows, that potentially could suddenly go while we were in there [this is what is really dangerous], whereas a fire that is already burning is burning before we got there we can deal with it because it's going to get no worse (Dickson, 23, crew commander)

5. DYNAMIC RISK ASSESSMENT

Dynamic risk assessment appeared to be an interesting component of experts' tacit knowledge, generally covering aspects of officers' behaviour on what is risky/not. According to the expert officers, two things could potentially happen if the risk assessment process is not properly conducted at a fire scene: people could either become excessively risk averse or become overly confident and wanting to take all manner of risks. It is important to note that dynamic risk assessment is not just limited to assessing and identifying risks within the immediate environment, but also making sense of assessed risks and projecting their implications to future states. Dynamic risk assessment on the fireground is therefore both a now and a then process that utilizes information about a current state both in solving existing problems and in making future predictions.

In suggesting the potential errors novices might have possibly made at each decision point, the expert firefighters explicitly identified risk assessment as one of the most difficult aspects of task performance and areas of vulnerability for novices. As shown in the excerpts below, the participants claimed that the difficulty for novices mostly lies in the area of striking a balance between what is tolerable and what is not.

> *Less experienced officers might not have spotted the water courses were being polluted. They might have also want to commit crews into the building, which is not a good idea. I did not commit crew into the building because it was clear to me from the outset that the risk outweighs the benefit (Patrick, 32, ACFS, UK)*

> *"The mistake that would have come in here is that probably, they [the less experienced officers] would not have punctured the wall because of the risk that is involved; they will just stay outside and continue to fight the fire. And that also would be dangerous because the fire will continue to burn and continue to spread"* (Sunny, 29, ACFS, Nigeria)

> *…… one thing they hadn't ascertained, the initial crews, was what other hazards were in there. So I knew that it was a vehicle workshop, I knew the building. I knew it has got an inspection pit, I knew it got lots of things like old oil, waste oil, all sorts of things. I also knew because I asked the guy what's upstairs and he told me there were two cylinders up there not acetylene but liquid petroleum gas.* (Troy, 27, Group commander, UK)

One other interesting thing that emerged from this section concerns experts' disposition towards risks. As shown in the excerpts below, the participants seemed not to be intimidated from taking risks (albeit taking calculated risks); rather, they see risk taking as a huge part of their job, claiming the firefighting job, in practice, is far from being excessively risk averse :

> *"The reason why I said a lot of people might not agree with me is that the situation was such a long stay, and it was a long time to keep emergency resource there for a welfare issue. However, there was a risk of fire if I didn't take that decision" (Adrian, 17, Watch commander, UK)*

> *"The first thing is to enter, if you enter and fail, then you try to do another thing. It is not wise to fight a fire from outside at all; you must get to the seat of fire, no matter how serious it is. In fact if someone is trapped inside the fire, and you are unable to fight the fire where that person is trapped, we have equipment that we wear (fire jackets), so we wear to enter and rescue the person" (Sammy, 8, FSO, Nigeria)*

> *"I thought it was OK for the two guys to go in without having back up. So it's a good decision, they had water, so they had the means of putting it out" (Willy, 28, Watch commander, UK)*

Surprisingly, however, some of the UK participants were found to be particularly critical of the risk culture employed in the UK fire service, arguing that the culture seems to be encouraging a risk averse behaviour amongst firefighters:

> *"The decision to leave crews inside the building initially, I could have been criticized for that, and I was very mindful of it, that was very much like do or don't I……I don't like the fire service for the way…..I think we can be quite risk averse…..and I don't like that….I try not to be risk averse, I think we are the fire service we are there to take risks for the greater benefit, albeit not recklessly"* (Darren, 17, Group commander and flexi-duty officer)

> *"One of the controversies was that the crews weren't that comfortable in being that close to cylinders that were potentially involved in fire. I explained to them as a HAZMAT officer as well….. it was hard saying for me to say I risk assessed this, it's fine, if we don't do this that fire is going to come through here, it's probably going to blow the cylinders and it's going to go out to the street. So that was the calculated risk that I took".* (*Troy, 27, Group commander and flexi-duty officer, UK)*

The above supports the underpinning principles of the risk thermostat model (Smith, 2003), which posits that effective risk management entails getting a balance between potential losses and gains associated with risk taking, such that one is not neglected over the other. In the words of Adam Smith:

> *a "one-sided concern for reducing accidents without considering the opportunity costs of so doing fosters excessive risk aversion — worthwhile activities with very small risks are inhibited or banned. Conversely, the pursuit of the rewards of risk to the neglect of social and environmental "externalities" can also produce undesirable outcomes" (Smith, 2009, p.1)*

It can therefore be inferred that what an individual expert firefighter judges as safe (or unsafe) is mostly a function of their risk taking attitude, which is in itself largely shaped by their level of experience. This explains why the concept of dynamic risk assessment has mostly been associated with experiential knowledge since no definite rule exists to indicate the amount of risk that is expected to be taken (Tissington and Flin, 2005; Clancy, 2011; Okoli *et al*., 2015). The competence assessment framework that was developed in this study (see table 7.1) strongly advocates the need to train novices in becoming more balanced in their risk taking attitude. This implies teaching them how to take *calculated risks* as opposed to being too risk averse or being overly reckless.

6. PROBLEM DETECTION

Problem detection has been defined as the ability to recognize that events may be taking an unexpected or undesirable turn, hence, potentially requiring some form of intervention (Klein *et al*., 2005). The ability to detect problems earlier on in an incident ultimately requires seeing the bigger picture and identifying early warning signs, even if those signs yet appear casual, under-developed or microscopic and difficult to make sense of. Many crisis management scholars have suggested that the majority of the "small" disruptions which eventually turn out to become critical problems are rarely self-evident at the beginning (Turner, 1976; Reason, 1990; Smith, 1990; Fink, 2002; Elliot and Smith, 2006; Boin, 2006). Expertise therefore rests on an officer's ability to recognize from vague, ambivalent and contradictory signals, that something out of the ordinary is developing, which might negatively affect task performance. In essence, this aspect of tacit knowledge helps ensure that any gap(s) in a potential action plan is detected in advance.

The excerpts below shed more light on the importance of problem detection, showing how experts were able to pre-empt potential problems and act accordingly to prevent their escalation:

> *"I walked down, looked for the officer in charge, at the same time I saw these guys trying to mobilize a firefighting jet in between this house and the next door neighbour's house on an alleyway; to try and take it round the back to fight the fire from the back because that's where the main seat of the fire was. Now I haven't taken over, I haven't even seen the incident commander at that point but I intervened at that point because I know No we won't do that. …….. (Troy, 27, Group commander and flexi-duty officer, UK)*

> *"….and also we were cooling the cylinder because we want to prevent the fire from spreading" (Atkinson, 8, FSO, Nigeria)*

“We had to fight the fire from the rear [so as to block damages] because it was spreading towards the rear from the front …..also because the wall may fall upon any of the officers if we fight from the front” (Knight, 8, FSO, Nigeria)

On this note, the competence assessment framework developed in this study (Table 7.1) suggests the need to include, as part of their training curriculum, tasks that will help less experienced officers improve their ability to detect early warning signs. This includes being able to spot the presence of combustible materials in a building; to detect access difficulties to a building early enough; to identify the need, and develop strategies that can help resolve the problem of water supply, especially in rural areas etc.

7. LIMITS OF CONTROL/BOUNDARIES OF SKILLS

One of the easily overlooked aspects of tacit knowledge, yet a crucial skill for survival, is that of understanding the boundary of one’s expertise. Irrespective of their level of competence or previous success records, expert firefighters are still sometimes faced with certain circumstances, mostly external, that can appear difficult to control e.g. ensuring a timely availability of specialist appliances, working against harsh weather conditions such as wind speed or intense heat etc. Hence, understanding the limits of what one is able to control, especially under time pressure, will help ensure that precious moments are not wasted in experimenting things that might eventually not work.

The CDM transcripts revealed two main areas where experts showed good understanding and awareness of their limits of control:

(i) Their willingness to admit that an event has escalated beyond their boundary of expertise and therefore requires intervention from more superior officers. The participants interviewed in this study were rarely ego-centric in surrendering the command and control of an incident to their superior officers if need be, suggesting therefore that experts seemed to understand the limits and boundaries of their expertise. This was found to be the case in two situations that proved extremely difficult to control — the two officers in question (Marvin, 30, Station Manager, Nigeria; Dunham, 13.5, Station Manager, UK) naturally passed the baton of leadership to their superior officers (fire chiefs in both cases) as the incident escalated.

(ii) Showing the right character — admitting to defeat where and when necessary i.e. knowing exactly where to "cease fire". The excerpt below shows, for instance, how a severe school fire defied all possible tactics, despite being supervised by a district fire commander, forcing the officer to completely withdraw his crew from the building. The fire was caused by a lightning strike, concurrently creating multiple fires in three different parts of the building. The officer and his crew eventually allowed the building to burn itself down after attempts at saving the building proved futile. The incident commander reported thus:

> *I've got to make that call [withdrawing the crews from the building], but it's my judgment as to when to make that call. And I just have to stand back and say I have lost this one, even with the resource I've got the fire is beyond our ability to put it out, it's in too many places, it's spreading too quickly because fire was everywhere (Darren, 17, Station Manager and district commander, UK)*

Over the years, organizational and behavioural psychologists have attempted to understand why individuals usually find it difficult to admit defeat even when there are signs suggesting that all hope is lost (Bazerman and Watkins, 2006; Roux dufort, 2005; Smith, 2000; McRaney, 2011; Kahneman, 2003; Dunning *et al*., 2003). The quest to understand this aspect of human nature generated some new insights and provided useful explanations to some of the cognitive biases and illusions that drive ego-centric behaviour in humans. One of these psychological biases that inflate people's belief in themselves is *the illusion of favourability*, which suggests that people have an unrealistic positive view about themselves in both absolute and relative terms. In absolute terms, people tend to highlight their positive abilities and discount their weaknesses, and in relative terms people believe they are more honest, smart, capable, intelligent, and insightful than others (Messick and Bazerman, 1996). Another psychological bias that tends to distort human reasoning is *the illusion of optimism,* which holds the view that people are unrealistically positive about the future relative to others (McKenna, 1993). That is, people overestimate the likelihood that they will experience “good” future events and underestimate the likelihood they will experience the “bad” ones. Finally *the illusion of control* shows how people often attempt to exaggerate the extent to which they can control random events (Turner, 1976; Kahneman, 2011; Gasaway, 2012). Although it is sometimes advisable to think positively about one’s self (McKenna, 1993), when these tendencies become extreme they can lead to illusions that, while gratifying, can also distort reality and bias decision making.

Acknowledging one’s inadequacies, especially in unpredictable or unforeseen circumstances should therefore not be seen as a sign of weakness, contrary to common belief. In fact, scholars have shown that knowing what one can/cannot do can be a useful tool for managing overconfidence and thus a hallmark of expertise (Messick and Bazerman, 1996; Kahneman and Klein, 2009; Hallinan, 2011).

8. EMOTIONAL INTELLIGENCE

Over the past decades, Peter Salovey and John Mayer have been two of the leading experts on the subject of emotional intelligence (Salovey and Mayer, 1989; Mayer and Salovey, 1993). They defined emotional intelligence as the ability to monitor one's own feelings (or emotions) and those of others, using that as the basis to guide subsequent actions.

The participants emphasized the importance of emotional intelligence in managing complex fires, stating that although the concept is relatively unpopular in the fire-fighting domain it remains a crucial virtue that must be possessed by all incident commanders. The majority of the participants claimed that whilst the less experienced fire-fighters might not necessarily fall short in the area of technical knowledge, they are more likely to struggle in terms of managing not only their own emotions, but also that of other crew members and/or the members of the public. A range of keywords phrases from the interview transcripts informed the coding process for this particular aspect of tacit knowledge. These include: doggedness, confidence, ability to cope with pressure, dogmatism, being considerate, being energetic, being compassionate, calmness amidst turbulence, and being brave.

More specifically, findings showed that emotional intelligence is quite important in managing cases such as arson and for dealing with some difficult members of the public (as mostly found in the Nigerian setting). For example, Adrian (27, Watch Commander, UK) explained how the arson case he managed was made possible mainly because of his emotional intelligence. See excerpt below:

> *"I think what could have easily been overlooked is the condition of the woman. The incident might have been left without any support, or it may have been dealt with without adequate compassion"*

Also, in another incident that involved an urgent need to salvage a victim who had suffered about 30% burns, the commander (Brown, 27, Crew Commander, UK), from the point of view of emotional intelligence, explained that:

> *"If you did not have your training and experiences you would have "froze". A man screaming on the floor and the kids are looking down at you; you would have frozen. But once you have been put up to that high level of stress, you know how to deal with it. And what happens being a firefighter — everything around you is going mad, and people are looking to you because they think you are the rock. So if you show any sign of weakness then that will be reflected on your crew, that will be reflected on people around you; you have to give people hope; and that is what we do by standing tall"*

The above excerpt also shows that emotional intelligence (or the ability to "stand tall" amidst chaos), just like other metacognitive processes such as sense making, situation awareness, critical thinking, team decision making, gets better as people acquire more experience.

5.11. Chapter Summary

The chapter began by presenting the demographic characteristics of the thirty participants, which includes useful background information about, but not limited to the participants' level of education, training and certifications acquired and the number of stations served in. Differences were found between the age distribution of the UK and Nigerian participants, with the former having a higher mean value and lower standard deviation. The chapter also showed how the participants personally perceived the job of firefighting, with particular interest on what makes the job a complex one. A content analysis of the CDM data revealed seven different criteria that defined experts' perception on what a “challenging” and/or a “memorable” incident was. Interestingly, participants did not necessarily define a memorable incident on the basis of recency; rather other variables were seen to influence the decision of each participant to narrate the particular incident they chose to report.

In examining one of the most important objectives of the study i.e. to identify the dominant decision making strategy often employed by fireground commanders in solving complex tasks, a categorization construct was adopted that was similar to that used by O'Hare *et al*., (1998) in their study with expert water rafting guides, aviation pilots and emergency ambulance dispatchers. Each decision point was coded as “option comparison”, “deliberated”, “analog” or “prototype”, depending on the source of knowledge applicable to experts at each decision point. Findings from the study showed that majority of experts' decisions fitted into the prototypical or pattern recognition strategy across both groups of participants (UK= 88.4%, Nigeria=84.6%), suggesting that the officers were mainly assessing the current situation against the prototypes they had stored in their memory. The interview excerpts also provided additional evidence to suggest that the ability to recognize patterns is one of the greatest hallmarks of expertise, which is also dependent on the number of incidents that had been attended and the lessons learnt from them.

The decision points from the study were also analyzed using existing theoretical constructs, with each decision point coded as “standard” “typical” or “creative”. Findings showed that experts utilized at least one of the three problem solving strategies when resolving complex tasks, depending on the nature of the incident. The vast majority of decision points across the entire incidents were found to fall within the “adapted to suit” (typical) category, accounting for 62.3% and 64.6% of the UK and the Nigerian decision points respectively. The above findings gave credence to existing notion that experts know the boundaries of their skills and when to apply or switch between the three strategies as events unfold. Analysis of the various decision points also provided further understanding regarding the sequence of conversion that exists between the application of rule, skill and knowledge based decisions. For example, rules and procedures were often invoked when performing recurrent (routine) aspects of tasks, since expected outcomes are basically similar from problem to problem. But in situations where expected outcomes vary from problem to problem (non-routine tasks), decision-makers tended to depend less on rules/procedures, relying more on their prototypical and creative ability.

Furthermore, the knowledge elicitation process and analyses of the thirty incident reports generated 42 different cues commonly sought by the expert firefighters, which were then categorized into five classes based on the type of information they conveyed to incident commanders. While some cues presented themselves to officers in clearly visible ways e.g. smoke colour, intensity of fire, crack on the wall, collapsed roof, thickness of the smoke, others were found to be less visible and thus required experts to make use of their senses, previous experience and rich domain knowledge in gaining a deeper understanding.

The chapter also presented and discussed a decision making model — the information filtering an intuitive decision model, which describes how the expert officers were able to cope with multiple informational sources on the fireground and yet able to make fast decisions in most cases. The model described how expert firefighters were able to gather the wide range of informational cues at the fire scene and how such information is subsequently filtered to the point that decision makers are confident of carrying out their proposed action plans without the need for further deliberation. In addition, the IFID model provided additional insight regarding the role of intuition in deliberation and in creative decision making.

The chapter concluded by presenting and discussing eight dimensions of tacit knowledge that emerged from the CDM data across the thirty incidents: cue discrimination, pre-planning, prioritization, domain knowledge, dynamic risk assessment, problem detection, limits of control and emotional intelligence.

CHAPTER 6
ANALYSIS OF THE CONTEXTUAL (CULTURAL) DIFFERENCES BETWEEN THE UK AND NIGERIAN FIRE FIGHTERS AND THEIR IMPACT ON TRAINING AND INSTRUCTIONAL DESIGN

6.1. Introduction

As previously stated, one of the objectives set out in this study was to examine how expert firefighters (both in the UK and Nigeria) made difficult decisions while managing complex fireground tasks. The initial assumptions were that the difference between the two groups would predominantly lie in the aspect of the firefighting technology employed by each of the group and that experts across both groups would make fireground decisions that are only appropriate to their respective task environments (context-based decisions).

The aim of this chapter is to discuss the key cultural differences that were identified from the two study areas, both at individual (firefighter) and organizational (fire service) levels. Although some of the key differences between the two groups have been discussed in the previous chapter, these are again collectively summarized here for ease of recall. Following a summary of the key cognitive differences that were found to exist between the UK and Nigerian firefighters, a discussion regarding the contextual factors that are perceived to have facilitated the cultural differences is then presented. This discussion is structured into four themes: cultural context of the firefighting equipment and resourcing, cultural context of the approaches to training and perceived training needs, cultural context of the firefighting tactics, and cultural differences in governmental and environmental influences.

As a caveat, however, it is worth mentioning that the intention of the analysis in this section is not to use any of the two fire services as a benchmark, but rather to compare and contrast, where applicable, some of the operational and cultural differences that were found to exist between the two groups, from the point of view of the participants.

6.1.1. The relationship between culture and shared cognition within a community of practice

Research on national culture and its impact on organizational performance is not new, but can be dated back to the work of Hofstede who examined the cultural differences of individuals from across over forty countries between 1967 and 1978 (Hofstede, 1983). Hofstede's main proposition was that the way people think is often conditioned by the core values underpinning their national culture, meaning that the subject of national culture can no longer be relegated to the rear when it comes to understanding how people behave within their community of practice. On this note, Hofstede (1983) defined culture as the collective programming of the mind that is taught to other members of the group as the right way of doing things. Hofstede provided some useful analogies regarding how difficult it is to change people's existing cultural mind-set, unless one first detaches them from their culture.

Culture within the context of this study is understood as the symbolic and learned social processes that generate and sustain shared norms and values between members of a social group (Schein, 2004). It represents not only national or ethnic cultures, but also the easily "taken for granted" procedures that have become part of an organization's daily routines. As noted by Nonaka (1994), individuals often *internalize* the moral values of their organizations as they undergo socialization with other members within a community of practice (Lave and Wenger, 1991).

Ample evidence exists to suggest that knowledge in itself, and therefore shared cognition within a group, cannot be separated from the context in which it was created (Nonaka, 1994; Alavi and Leidner, 2001; Maqsood, Finegan and Walker, 2004; Nonaka and von Krogh, 2009). This implies that both the creation and sharing of knowledge is often deeply embedded in temporal contexts, which include the environmental conditions, cultural overtones, and social circumstances that underpin people's actions (or inaction). In the knowledge creation theory the term "context" is often referred to as "ba" — a shared space where knowledge is created based on the interactions and relationships that exist in a group, often between actors, agents and structures (see Nonaka, 1994 for example). Ba, which is similar to the concept of “community of practice” (Lave and Wenger, 1991), can be physical, virtual, mental or any combination of these (Nonaka and Toyama, 2007). Hence, an attempt to measure knowledge between two or more groups is likely to pose some challenges, since knowledge in itself is strongly bound to culture. It can therefore be implied that different “bas” exist for both the UK and the Nigerian firefighters. For example, building on the principles of organizational knowledge creation theory, Erden, von Krogh and Nonaka (2008) examined the quality of group tacit knowledge based on the gaps they identified in the literature pertaining to how individuals and groups often utilize tacit knowledge.

6.1.2 Some similarities, but some differences

The interview reports in the current study generated a total number of 69 and 65 decision points for the UK and Nigerian firefighters respectively and analysis of the decision points revealed, perhaps, some unexpected similarities in the decision making and problem solving strategies of the two groups. For instance, analysis of the decision points showed the following estimates between the UK and the Nigerian firefighters respectively: 7.2% and 7.7% of the entire decision points were found to be made deliberatively; 88.4% and 84.6% were prototypical decisions; 4.3% and 7.7% were based on analogs; 23.2% and 26.2% fell under the standard category, and 62.3% and 64.6% of the decisions were adaptive (see sections 5.4 and 5.5). Whilst these statistics can be said to pose some form of surprise, it can also be argued that the findings seemed logical when one considers that the decision points were actually analysed against the distinct environments in which the decisions were made. Analysis of the qualitative transcripts also showed considerable similarities in the way experts from the two groups made decisions. The two groups of experts, for example, both seemed to understand what cues like wind, temperature, cracked walls and collapsed roofs meant, as well as their implications for task performance (see section 5.7)

Despite these similarities, considerable differences were also found across the interview reports between the two groups of experts. These are summarized below:

In terms of the leadership style used on the fireground (command and control), some difference was found to exist between the two groups (see pp. 176). The Nigerian fire service tends to be more hierarchical, on average, than its UK counterpart and mainly allows the highest ranking officer present at the scene of an incident to take over command and control. In the UK, the decision is mostly based on the circumstances surrounding an incident. While the most experienced of the officers (in terms of length of service) have the right to leadership responsibility in theory (in the UK), there are instances where these superior officers allow other lesser ranked officers who have gained the best situation awareness to take over overall incident command responsibility. It can then be argued that the UK fire service tends to lean towards what has generally been termed *situational leadership* (see Bass, 1990 for an overview). Situational leadership is based on the notion that no particular leadership style fits all situations, meaning that leaders have the obligation of finding the most appropriate balance between their individual and group competencies on one hand, and the current proceedings of an incident on the other hand. For example, a leader might decide to adopt an autocratic style under time-pressured situations and then become more democratic when stakes become less (Bass, Avolio and Atwater, 1996). The Nigerian fire service, in contrast, seems to be more autocratic in its leadership style, with little or no room for flexibility.

Another aspect of cultural difference that emerged from the study was in terms of the goal pursued by officers within the two groups. Although a range of firefighting goals were identified and discussed (see Table 5.7, pp. 210-211), that of “reinforcement and support” was found to be significantly lower for the Nigerian officers (Nigeria=4DPs vs UK=15DPs). Owing to the nature of firefighting, there is little doubt that more resources often need to be called upon as an incident escalates. However, as popular as the goal of “resource reinforcement and support” appeared in the UK, it was not very common amongst the Nigerian firefighters. This can be explained on the notion that there are hardly any resources available to call upon even when they are needed (this issue is discussed later in this chapter).

Analysis of the entire set of decision points also revealed interesting cultural differences between both groups of experts. For instance, a list of decision points that were peculiar to the Nigerian firefighters but not reported by any of the UK firefighters is outlined below (see appendices A and B for full list of decision points):

- Conducting situation assessment upon arriving at the scene of an incident
- Going back to the nearest fire station to replenish water supplies
- Taking the nearest available route to the scene of an incident
- Using breathing apparatus — while the use of breathing apparatus is seen as a legal requirement as well as a mandatory obligation in the UK fire service (HM Government, 2008), the Nigerian officers uses it only in “exceptional” circumstances
- Crawling into a building (only) with a charged hose to fight a fire
- Laying two lines of hose (This is an important decision often made when there is an urgent need to extinguish a fire from more than one direction. Whilst this decision was mentioned 5 times by the Nigerian firefighters, none of the UK experts considered it worth mentioning).

Another key difference between the UK and the Nigerian experts emerged in an attempt to examine whether options actually existed (See Table 5.5. pp. 193). While six of the participants believed that “options chosen were not necessarily the best, but were the best available to the officers at the time”, this was not found to be the case for the UK experts. The Nigerian firefighters, in hindsight, believe they could have made better decisions if they had the right resources at the time the decisions were made.

In the next section, the contextual factors that were perceived to have underpinned the aforementioned cultural differences are discussed under four themes:

6.3. Cultural context of firefighting equipment and resourcing

Just like their UK counterparts, the Nigerian firefighters believe they have a duty of care to members of public, in terms of saving lives and valuable properties. Based on this understanding, they often strive to mitigate and prevent the escalation of fire incidents as much as they possibly can and with the resources available to them. However, as earlier hypothesized, a major concern that was raised by all the Nigerian firefighters relates to the poor condition of the equipment they operate with. They claimed that the fire crews are sometimes limited in their operational performance due to a lack of modern infrastructure that is able to match the challenges of the 21st century fires.

Based on personal observations and from analyses of the interview reports, a few differences were identified in the ways that both groups of firefighters often carry out their routine tasks on the fireground, with particular reference to equipment (see Table 6.1 below)

Table 6.1: Analysis of the approaches to firefighting between the UK and Nigeria fire services

Fireground practices	Modes of operation	
	UK	Nigeria
Protecting officers from inhaling smokes, toxic and poisonous substances	• The use of computerized breathing apparatus set	• Use of handkerchiefs (face towels)
Committing crews into a well alight building (offensive firefighting)	• Breathing apparatus sets • Entry control board and identification tallies	• Use of face masks • Spraying water on firefighters to cool the heat around them
Protecting officers against excessive heat and physical injuries	• Fully kitted PPEs (helmet, fire-boots, touch lights, fire-jackets, and whistles). • Fire breaks (excessive release of water to the unaffected areas)	• Spraying water through the hose to reduce the amount of heat around the fireground
Gaining access to high rise buildings	• Hydraulic platforms • Fire helicopters • Dry riser systems	• Use of ladders and hook ladders
Ensuring constant supply of water	• Fire engines are connected to hydrants	• The use of two or more fire engines for water

	• High volume pumps (HVPs)	security • Going back to stations to replenish fire trucks
Communication between incident commanders and control department	• Wireless radio communication	• Mobile phones
Managing crowd and creating hazard zones	• Use of inner/outer cordons • Use of hazard tapes	• Reliance on security agencies to help control crowd

In the UK, for example:

- High volume pumps (HVPs) can effectively pump about 7,000 litres of water per minute, thereby making sufficient amount of water available for firefighting. It can also be used to remove water from a flooded area at the same rate, which corresponds to emptying an Olympic sized swimming pool in just 3 hours.

- A "Dry riser" is a system of pipe work and valves that enables water to be delivered for fire-fighting purposes to all floors in high rise buildings.

- Breathing apparatus sets i.e. self-contained respiratory protective equipment are used for interior attacks and are mainly designed to protect firefighters.

In contrast, the Nigerian firefighters often arrive at fire scenes relying solely on water in the fire trucks as hydrants do not currently work in the country. They either do not exist at all, or do not run where they do exist due to poor water networks (see excerpts below). Hence within the Nigerian context where water availability is quite challenging, securing and managing water effectively during response operations appear to be one of the main goals for incident commanders. In meeting this crucial challenge, incident commanders often strive to deploy more than one vehicle at a time to fire scenes. Once water in one fire engine is exhausted, it goes back to the nearest fire station for replenishing and another fire engine is engaged. However, in the event of a massive fire that requires constant water supply (e.g. when there is need to run multiple streams of water), incident commanders mostly tend to opt for water vendors. These water vendors enter a short term contract with the officers to supply all the water needed for firefighting and are then paid in return.

The excerpts below illustrate the above points more clearly:

> *We come for replenishing, that is one of the problems around here. But if there are water hydrants around there, the best thing is just to couple our hose and other equipment into the hydrant and start to fight fire. You know here cannot be compared to where you are talking [overseas], like here now, even though they have the hydrants there, are they flowing? Is there water inside? If the hydrants are there and the water is not coming in there, it's nothing. But what we do here for now is that if there is fire incident, there is more than one vehicle that will attend, and they noticed that the water is not enough, they will come back to the station to replenish the tank, and go back. That is the system we are using* (Adam, CFS, 30, Nigeria)

> *No hydrants available, if water finishes we have to come back to the station and then fire cannot wait for you. The tanker can only take 15,000liters of water. Look at Ilorin we have only 2 stations, if fire happens in like Oloje, do you think the house will not burn down before we get there? That is why when we get there we face problem, people will be stoning us. They will be fighting us* (Kevin, 8, Watch Commander, Nigeria).

As earlier stated, all the Nigerian participants decried the lack of up-to-date firefighting equipment, which they see as a huge blow to the Nigeria Fire Service compared to what is available overseas. In lamenting this situation, one of the officers explained that:

> *If at all now we have something like 12-20 storeys of building on fire, we in Kwara State don't have access to those buildings, we can only get far as*

much as our ladder can carry us. In fact, if any building is above three storeys, believe me, we don't have anything to do on it (Young, FSO, 8, Nigeria)

The Nigerian participants identified the following equipment as the most needed in the Nigeria fire service:

- Turntable ladders
- Aerial ladders for high rise buildings
- Breathing Apparatus sets
- Aerial planes
- Hydraulic platforms
- Hose layers
- Automatically coupled hose
- Automatic line divider
- Water tenders
- Foam tenders
- Modern fire engines (e.g. Pump ladder rescue, Turntable ladder)
- Brigade response vehicles (BRVs)

Figure 6.1: A face mask that is worn in place of breathing apparatus set

Figure 6.2: A rubber boot worn in place of fire safety boots

There is ample evidence indicating a significant difference in the level of firefighting equipment and resource capabilities between both countries (see Table 6.1, Fig 6.2 & Fig 6.4). However, an interesting cultural insight emerged from the analysis of the transcripts that seemed to transcend resource capability. A cultural bias against the use of breathing apparatus was identified amongst some of the Nigerian firefighters, which was traceable to the information they were given at the fire training school. One of the officers reported that although they were told the importance of using breathing apparatus sets when fighting massive fires, they were also advised on the need to constantly ensure they breathe in natural air:

> *Sometimes you may not have BA; you have one handkerchief [face towel] to cover your nose…..You see in any fire we are always advised to use BA; but what we learnt is that to use BA, you will not feel comfortably or enjoy free air like this* (Sammy, 8, FSO, Nigeria)

Are these two alternatives (i.e. using BA sets and breathing in natural air) not meant to be mutually exclusive? Breathing apparatus is purposely designed to supply oxygen to operators so as to support their breathing while performing tasks under stringent conditions of excessive heat, smoke. It also serves the purpose of protecting its wearers from inhaling dangerous combustible substances. In none of the UK incidents did any of the officers enter a well-alight building without their breathing apparatus sets. An important question remains whether or not the Nigerian officers would be inclined to use breathing apparatus sets if made available to them?

6.4. Cultural context of firefighting tactics

Differences were found between the UK and the Nigerian firefighters in terms of the firefighting tactics that are employed on the fireground, particularly with how fire crews are being committed into a well-alight building. Essentially, the Nigerian firefighters adopt a tactic which they termed the “practical firemanship method”. This method was shown to have been taught to these firefighters as an acceptable template for entering a well alight building. The method was explained in detail by one of the participants:

> *We believe that thick gas, those toxic gases, would rise up leaving a less dense one underneath. You will be able to breathe in that one [the less dense gases] so that it would not affect you much. Now you go in with your hose fully charged, but you open it little, as that water is coming out from the nozzle, it’s coming out with some oxygen, it is that oxygen that you will have to inhale in order to sustain you while going in. But as you are going in, you will be quenching the little fires you meet on your way while. You also have to make sure that you will be using the back of your hand to clear the ground as you go into the building. You don’t crawl with your palm on the ground, if this palm should touch a livewire, that officer would be electrocuted – because the blood nerves is concentrated on this palm more than the back of the hand. If you touch a livewire with the back of your hand it will only shake your hand so that you can easily manoeuvre the danger. That is how you will now enter and fight that fire from your crawling till you believe you can now see clearly you will now stand up (Francis, 28, CFS, Nigeria)*

The above excerpt seems to suggest, *inter alia*, the extent to which the Nigerian firefighters are willing to improvise in the bid to make up for inadequate resources. Since the officers cannot afford to be passive they devise strategies with which they enter a building — mainly by relying on water coming out of a charged hose as a source of oxygen. One might therefore be forced to ask how risky this method is to the officers. How risky is it to rely on water from a charged hose to supply oxygen in a well alight building? How risky is it to touch live wires with bare hands? How risky is it to be under the stringent conditions of a burning building unprotected and without the aid of breathing apparatus sets?

The excerpts below show how some of the Nigerian officers reported carrying out their firefighting tasks in a well-alight building:

"…..for you to stay within a smoke-logged environment you have to cease your breathing. And don't forget, it's not as if we don't have equipment that we can use, but there is timeline for the equipment. If you go in with BA, under 10mins you will exhaust the BA content, and you have to come out. But for you to be there to work for about 10-30mins and more, you have to cease your breathing and that is where the issue of having a supporting crew pouring water on you comes in, so that if you don't have your BA somebody will be giving you fresh water, directly on you in shower form" (Sunny, 29, ACFS, Nigeria)

"And secondly what make us to lie down is that there was a thick smoke. And also we use this face mask but it is the manual one. So we use this manual one but we still see that this manual one will not prevent our nose from this smoke so we have to lie down. But it is because of this smoke that makes us to use this system because we can call it a layman's system" (Steve, FSO, 9, Nigeria)

The above excerpts suggest that the Nigerian officers are culturally used to fighting fires without the use of breathing apparatus sets, personal protective equipment or entry control procedures. It could thus be argued that the firefighting tactics employed by the Nigerian officers are largely contributing to their increased propensity to risk taking, which from the perspective of the UK firefighters might be classified as reckless risks. A few studies which have examined the operational procedures of firefighting in Nigeria have also shown that the Nigerian firefighters often expose themselves to high risks (Esinwoke, 2011; Cobin, 2013).

In the UK, in contrast, the fire service seems to have a well-defined procedure for entering a well-alight building, generally known as entry control procedure. One of the UK officers showed that every incident commander or entry control officer (where appointed) is obliged to follow this procedure to the letter:

> *"It was very much a rule that we have a person and another person with an electronic board and they monitor the firefighters that are deployed to the building, it's a very safe system and we wouldn't deviate from that at this fire because there was no need to" (Jade, Crew commander, 15, UK)*

The officer explained that three levels of entry control often exist on the fireground:

> *"the rapid deployment, where BA wearers need to be in a building very quickly; stage 1, which is the normal level of control and then stage 2 which is the increased level of control. Stage 2 applies more to larger incidents that are going to last a lot longer. Stage 3 is usually not common and what essentially should be a stage 3 is called main control, which applies to huge incidents with lots of BA e.g. big buildings, a large hospital or a big factory" (Jade, Crew commander, 15, UK)*

In the event of switching to a more offensive attack as shown in the above excerpts, firefighters are only allowed to enter an engulfed building with the aid of their breathing apparatus (BA) sets. The BA wearers are also required to be committed into the building in pairs (mainly for safety reasons). This is then followed by setting up BA boards which allow the movement of all the officers fighting from the interior to be easily monitored. The entry control officer must therefore work closely with the overall incident commander to ensure that the risk versus benefits of keeping firefighters in the building is continuously assessed. This requires also that escape routes are clearly mapped out and well understood by the committed crews in the event of unforeseen circumstances, such as an explosion. Hence with more advanced technology and with the quality of training received, some risks are better controlled and managed by the UK firefighters.

Fig. 6.3: A smashed windscreen by infuriated members of the public following the late arrival of the fire crew

Further on the issue of tactics, the harsh environment where the Nigerian firefighters operate sometimes makes it difficult for effective firefighting to take place. Many of the participants reported they are often faced with distractions from members of the public who want things done their own way. These members of the public often get overly aggressive and hail abusive words at the firefighters and sometimes even stone them. It is common in Nigeria to stone the fire crews if they, for example, arrive to the scene of an incident late or are unable to control a fire (Fig 6.4. shows a smashed windscreen by some enraged public members). Such irrational and intimidating behaviour from members of the public therefore poses an important question to the Nigerian fire brigade i.e. why can't the officers just like their UK counterparts try to "cordon off" unwanted individuals from the immediate fire scene? This simple but important strategy will almost certainly turn out to be an effective way of curbing this menace, as it will allow the officers to concentrate on their task without fear of being verbally or physically abused.

6.5. Cultural context of the approaches to training and perceived training needs

In the UK, officers are reassessed on their skills every two years to ensure they are up-to-date (see excerpt below). During this reassessment process, firefighters are put through some refresher courses on different subject areas such as First Aid, breathing apparatus and entry control training, HAZMAT training etc. Analysis of the CDM reports also showed that all the UK participants have other qualifications and certifications, in addition to their firefighting certificates. These include specialized training as a BA instructor, HAZMAT adviser, First aider, NVQs, road traffic collision instructor, hydraulic drive operator, as well as training in areas such as fire investigation, building construction, fire behaviour etc.

> *"They are quite extensive, wide range of trainings. You do a continuous training and compulsory as well. We look at ourselves every time. We have a set programme of training that we have to achieve as operational. e.g. you have to have a breathing apparatus training, first aid training. As a manager as well you have management training; how to deal with incidents, how to deal with people, and how to deal with staff. And all these trainings are continuous, you are continuously developing yourself" (Adrian, 17, Watch commander, UK)*

Unfortunately, the Nigerian firefighters do not have the opportunity to go through further training or retraining, a situation that most of the officers attributed to a lack of support from government to fund and support training. Apart from Margareth, 11, FSO, who just completed a health and safety training, none of the Nigerian participants reported to have acquired any additional certifications aside the three they had obtained after training school (basic firefighting certificate of competence, ordinary certificate of competence and advanced certificate of competence).

There also seemed to be inherent weaknesses in the range, quality and the design of training received by the Nigerian firefighters. For example, participants stated that some fires are not realistic to fight in Nigeria as they have not been trained to fight such fires:

> *We need to be trained on how to fight chimney fire. Hospital fire is also very dangerous, I would personally stay outside, because of life support equipment in the hospital, they are highly flammable……… We were not taught how to refill fire extinguishers, how to do smoke detectors. More support, knowledge update, new equipment on how to fight fire are needed* (Atkinson, Watch commander, 8, Nigeria)

In a personal interview with the training commander of one of the states in Nigeria, the officer appeared to be sceptical about the approach to training in the Nigerian context, claiming that the training they receive is mostly too generic:

> *"In the overseas, the training are sectional, either you go on BA, or rescue, or how to fight fire, but in Nigeria here, we combine all subjects to make one. So we are jack of all trades master of "plenty" (Marvin, CFS/Station manager, 30, Nigeria)*

Another officer, although acknowledging the fact that officers train regularly in the service as expected, mourned the antiquated training procedures currently used in the service. He argued that the Nigeria fire service is still backward when they ought to be moving with the pace of time and technology:

> *By the time we joined fire service, even if there is a cooking gas fire it's not rampant as what is happening now because people were not using gas to cook then. There are many vehicles now more than before, so as things are*

going, the fire service has to be developed so that we move with time. That is why I cannot say that we've had enough knowledge to combat what may happen in future? NO! Because times are changing, so we have to be moving with time too (Young, CFS, 28, Nigeria).

Figure 6.4: A newly purchased BRV with extremely low pressure. The station manager (right) claimed he was not informed prior to the purchase of the vehicle

One of the CDM probe questions in the current study was aimed at eliciting the particular training that would have helped the officers perform their tasks better (in hindsight). The goal of the question was to identify core training needs for the fire service of both cultural groups. To this effect, all the UK participants claimed that the training they had received prior to the incident was sufficient in performing their tasks and that they cannot think of any additional training they would have needed. This is not very surprising considering the quality of training the UK firefighters often receive as part of their daily job routine. The author of the current study has had numerous opportunities to physically observe some training and simulation exercise sessions in some fire stations in the UK (see Fig. 6.5 and Fig. 6.6)

Figure 6.5: A search and rescue and BA training exercise in the UK

Figure 6.5: A road traffic collision exercise in the UK

In contrast, the Nigerian firefighters, regardless of their positions, stressed the need for additional training. They collectively identified some key areas where training or retraining is mostly required:

- International training and courses (certifications)
- Fire investigation training (FI)
- Wider level of training to cover other classes of fire such as palm oil fires, metal dust fires, gas fires
- Fire tender training
- Advanced operational training
- Refilling fire extinguishers
- Fixing smoke detectors
- Managing unusual incidents e.g. Chimney fires, hospital fires (highly flammable substances)
- Fighting fire in a confined space
- Crowd control

6.6. Cultural differences in governmental and environmental influences

The final theme that emerged from the cultural analysis relates to the role of Government in the fire service. The Nigerian firefighters all claimed that the Government has failed in its responsibility to show concern for them personally and for the service at large, especially considering the fact that it is in the public sector. These officers believe they constantly lack support from the government, both on welfare issues and with the nature of the technology available to them. As shown from the excerpts below it was clear that one of the main problems facing the Nigerian fire service, from the point of view of the participants, is the level of negligence shown by the government:

“But in Nigeria fire service is not recognized; until it happen before they can remember fire service is there – without happening they cannot remember fire service in our country” (Kevin, 8, Watch Commander, Nigeria)

“The BA is one of the effective equipment of firefighters, but in Nigeria, let me say in Kwara State, we don’t normally use the ones we have in Kwara State because you know our Government are not ready to finance. There are many in the fire engine, but we don’t normally use it. If you use it and the air that is inside get exhausted, who will refill it? So the Government are not ready to do such things” (Ryan, FSO, 8, Nigeria)

“Have you ever seen where a graduate would say I would work as a firefighter? You can’t hear it because the condition of the service is so poor, despite the risk of the job, it is not well catered for in many parts of the state” (Francis, 28, CFS, Nigeria)

“The Nigerian fire service also looks to be suffering from low manpower as staff turnover tend to be high. It looks like the job is not attractive to a lot of people…….we have little equipment but there are no personnel; we have shortage of personnel to even make use of the equipment. Most of the fire trucks since when they have been parked have had no movement…. If there was good equipment you know we will perform better than this” (Steve, 9, FSO, Nigeria)

Figure 6.7: A typical classroom in a Nigerian fire training school

However, aside from the governmental support the Nigerian officers claimed they lack, another issue that was consistently flagged up was the poor coverage of the fire service across states. This means there is a very limited number of fire stations that are available to serve the populace. For example, only 3 fire stations currently exist in Kwara State, one of the states that was covered in the study with a population of over 2.5 million people and 16 local government areas. In another study area, Lagos State, which is the largest commercial city in Nigeria with a population of 17 million people and 20 local government areas, only has 14 fire stations. In fact, as was reported by the participants, most states in Nigeria cannot effectively cope with multiple fire incidents happening at the same time. This is not only because of the limited number of fire stations available, but also because of the wide distance between the fire stations. For instance, when asked what he and his crew would do should another incident be reported somewhere else while on their way to an incident, the chief fire superintendent at Offa station, Kwara state (Young, 28, CFS, Nigeria) explained he can at best drop-off one experienced firefighter to attempt to manage the new incident, while the rest of the team proceeds to the initial scene. He explained that with only one fire engine and six firefighters available to serve the whole Offa town and its environs, there is only very little anyone could do.

He admitted that, ideally, in such circumstances he is supposed to inform the control room at the headquarters to turn out another appliance. Unfortunately, this, he noted, is impossible as it takes about 1.30hrs to drive from the Headquarters to his own station.

In the UK, on the other hand, there seems to be a wider coverage of fire stations across cities and towns represented in each county. For example, there are currently 102 well equipped fire stations across the 32 boroughs in London, including one independent river station, and 38 fire stations in the West Midlands (which has a population of 5.6 million people). These stations are also furnished with modern firefighting equipment, based on the author's personal observation and his involvement with a few simulation exercises with the fire crews as a volunteer (see Fig 6.5 and Fig 6.6).

6.7. Chapter Summary

This chapter reported the findings that emerged from a comparative analysis between the UK and the Nigerian fire service, based on evidence from the interview transcripts. The differences between the two cultural groups were structured along four themes, namely cultural context of the firefighting equipment and resourcing, cultural context of the approaches to training and perceived training needs, cultural context of the firefighting tactics, and cultural differences in governmental and environmental influences. In general, findings showed that while the UK fire service appeared to be significantly more advanced than its Nigerian counterpart in the aspect of technology, there was more to the cultural differences than technology. The firefighting tactics employed by the Nigerian officers were found to be completely opposite those used by the UK officers. The practical firemanship method that was taught to the Nigerian officers as an improvised way of fighting building fires is arguably a high risk method when compared with the entry control procedure often employed by the UK officers. Evidence was also found to suggest that the Nigerian firefighters are often sceptical about using breathing apparatus and would rather prefer inhaling natural air. In addition, excerpts from the study showed that the Nigerian firefighters were largely unsatisfied with the quality of training received and the nature of the equipment at their disposal. As a result, a range of training need was identified from the point of view of the Nigerian participants.

Whilst the training outputs developed from the UK experts is believed to be useful for the future incident commanders in the UK, the need and opportunity for training was mainly found to exist with the Nigerian officers from the evidence presented above.

CHAPTER 7
THE COMPETENCE ASSESSMENT FRAMEWORK AND THE IMPLICATIONS OF KNOWLEDGE TRANSFER FROM EXPERTS TO NOVICES

7.0. INTRODUCTION

As discussed in chapter 4, one of the strengths of the critical decision method is that in addition to its wide use for eliciting experts' knowledge it also provides an opportunity to identify training needs for novices. For the purpose of this study, the wide range of knowledge elicited from the thirty expert firefighters (both in the UK and Nigeria) was compiled and developed into an instructional framework, which was termed *the competence assessment framework*. In context of this study, an instructional design model is a framework for developing lessons that (i) increases and/or enhances the possibility of learning (ii) encourages high level of learner engagement

Instructional design theorists have shown that the overall aim of knowledge elicitation is to provide a framework or guidelines through which knowledge could best be exchanged and/or transferred from superior officers to the less experienced officers (Pollock *et al*., 2002; van Merrienboer and Kirschner, 2007; Hoffman and Millitello, 2008). Such interactions often create an opportunity to design appropriate instructional curricula, thus providing "potential experts" with a focused and extensive index of experiential knowledge (Van Merrienboer, 1997; Wipawayangkool and Teng, 2014). With the aid of such training protocols and the lessons learnt from them, the schemata (action scripts, repertoires and mental models) of the less experienced firefighters can then be developed until they are able to support non-recurrent tasks or attain automaticity in the tasks they are already familiar with (Van

Merrienboer, Clark and de Croock, 2002; Feldon, 2007; Ericsson, Prietula and Cokely, 2007)

Having identified a range of cognitive skills and knowledge utilized by experts earlier in chapter 5, this chapter is focused on evaluating how novice firefighters might be able to benefit from the elicited knowledge outputs and possibly propel their learning curve towards attaining expertise. The chapter begins by presenting and discussing the competence assessment framework, which is a compilation of the skills and knowledge elicited from the thirty interviewed experts. Thereafter, the implications for learning the elicited knowledge, and more specifically how it can be transferred to novice firefighters is discussed, drawing on the extant literature and also from evidence provided by the interviewed experts. The chapter then proceeds to propose the four component design (4C/ID) model as a useful learning framework. The rationale for choosing the 4C/ID over other instructional design models is discussed extensively for the benefit of training facilitators or instructional designers who might wish to utilize the identified expert knowledge for training purposes (particularly the Nigerian fire service where training curricula currently seem to be poorly designed or not existing). Two learning theories that have been widely used in the field of educational psychology — Vygotsky's zone of proximal development and the theory of situated learning/communities of practice are explored as theoretical basis for the proposed 4C/ID model. The chapter then concludes by proposing possible ways of assessing novices, drawing on Miller's (1990) assessment framework and other relevant assessment mechanisms in the cognitive load theory literature.

7.1. THE COMPETENCE ASSESSMENT FRAMEWORK (CAF): A SYNTHESIS OF ELICITED EXPERT KNOWLEDGE

Fire training colleges, staff and manpower development centres as well as incident command training schools (both the UK and Nigeria) all conduct at least one form of assessment that helps them verify the competence level of potential incident commanders i.e. prior to a promotion exercise. By so doing, these bodies are faced with the crucial tasks of discriminating amongst candidates in the final selection process, providing effective learning strategies that must also motivate and engage the learners, as well as evaluating the adequacy of existing training programmes.

Analysis of the CDM transcripts across the entire incidents generated eight categories of expert knowing, which were collectively termed *dimensions of tacit knowledge* (See section 5.10 for details). This elicited expert knowledge thus aided the development of the competence assessment framework shown in Table 7.1.

Following the nature of the present day crisis, it is almost certain that competence needs to be measured across a wider range of parameters, with more emphasis on tacit knowledge. The framework is hence based on existing claims that competence is best defined by tacit as opposed to explicit knowledge (Polanyi 1962; Anderson, 1989; Hannabuss, 2000; Bontis, 2001; Eraut 2004; Ritter *et al*., 2007; Nonaka and Krogh, 2009; Wipawayangkool and Teng, 2014).

Table 7.1: The Competence Assessment Framework

Dimensions of Tacit Knowledge	Levels of Assessment			
Cue discrimination	Knows	Knows how	Shows how	Does
• **Ability to differentiate between smoke colors and their implications**				
• **Recognizing the class of fire involved (class A – F)**				
• **Perceiving the smell e.g. gas fire, electrical sparks**				
• **Physical damage**				
• **Ability to make sense of the substance burning in a building**				
• **Understanding where to position fire resources based on surrounding structure (e.g. if there are houses around)**				
Domain knowledge	Knows	Knows how	Shows how	Does
• **Fire behaviour and combustion**				
• **Understanding how different building types affect fire-fighting e.g. high rise buildings and the use of a dry riser**				

• Understanding smoke behaviour				
• Knowledge of Water properties				
• Understanding fuel behaviour				
• Understanding how climatic factors (e.g. wind direction, temperature) affect task performance				
• Using the most appropriate Fire-fighting medium (e.g. fog method, spray, main jet, main jet + hose reel)				
• Knowing the class of fire involved (class A-F)				
• Knowledge of the different available fire equipment and their use (e.g. crane, hose reel, main jets, ladder, cold cut cobra, dry riser, ground monitors)				
• Setting up command structure for 20 pumps • Understanding how to source for water in difficult conditions e.g. rural areas				
• Cooling combustible gases using hose reel				
• Laying hoses under time pressure; knowing when to run two or more lines of hoses				
• Making sense of when to take over as incident commander				
• Laying ladders using a building as reference point.				
• Entry control procedure (Rapid deployment, stage 1, stage 2)				
Prioritization	Knows	Knows how	Shows how	Does
• Task sequencing (which task should come first?)				
• Requesting resources on the basis of their urgency • Knowing how many lines of hose to create • Resource mobilization from other stations				
Emotional Intelligence	Knows	Knows how	Shows how	Does

• Perceiving the emotions of other team members				
• Reasoning with the emotions of other team members				
• Understanding the emotions				
• Managing the emotions of other team members • Personal traits (self-awareness, self-will, confidence)				
Risk Assessment	Knows	Knows how	Shows how	Does
• Pre-assessment/Pre-planning e.g. planning and distributing tasks in advance				
• The ability to take "calculated" risks amidst task constraints e.g. looking for the seat of fire				
• The ability to spot important hazards clearly and timely.				
Creativity & Improvisation	Knows	Knows how	Shows how	Does
• Creative decisions				
• Ability to gain access to building within tight space				
• Ability to source for water in rural areas with less hydrants				
• Ability to generate other workable options				
Limits of control/Safety awareness	Knows	Knows how	Shows how	Does
• Ability to identify task constraints				
• Understanding when to employ an offensive/defensive strategy				
• Recognizing the boundaries of safety				
• Knowing exactly when to seek support from other team members				

As the name implies, the competence assessment framework was mainly designed to serve as a useful tool for assessing performance in the firefighting domain, particularly in novices. One of the strengths of the framework is the fact that it is conceptualized as a descriptive (naturalistic), as opposed to a prescriptive model — meaning that the assessment criteria identified in the framework were directly drawn from real-life fire incidents that were directly reported in the study.

In their study involving professional competence in the health sector, Epstein and Hundert (2002) identified a lack of consensus in the literature regarding how professional competence has mostly been defined and criticized some of the current assessment tools used in the medical profession, some of which were claimed to have neglected essential aspects of professional practice such as interpersonal skills, professionalism, lifelong learning, and the integration of core knowledge and skills into clinical practice. Following the gaps identified between theory and practice, Epstein and Hundert (2002) proposed a more integrative definition of professional competence as:

> *"the habitual and judicious use of communication, knowledge, technical skills, reasoning, emotions, values, and reflection in daily practice for the benefit of the individual and community being served" (Epstein and Hundert, 2002, p.226)*

Building on the above research, the competence assessment framework developed in Table 7.1 aims to advance the definition of professional competence by incorporating important dimensions of expert (tacit) knowledge. As shown in the framework, learning tasks can be developed across the various knowledge dimensions. For instance, novices could be trained on how to identify and discriminate between a wide range of cues on the fireground, which includes for example, the ability to recognize possible smoke colours for the different classes of fire. The framework also proposes assessing novices across four different levels depending on the learning task that is aimed at (possible methods of assessment are discussed later in section 7. 7)

It is however important to mention that the framework is only presented as a generic assessment tool, one in which facilitators can build upon and adapt to suit their various training needs.

7.2. THE IMPLICATIONS OF TRANSFERRING EXPERT KNOWLEDGE TO NOVICE FIREFIGHTERS

Although no direct definition for the term “complex skill learning” seems to exist in the literature, this study builds upon existing research (e.g. Wulf and Shea, 2002; Kirschner and van Merrienboer, 2007) to define it as the type of learning that: (i) cannot be mastered in a single session i.e. one that requires a series of training and practice sessions until learners are able to transfer what was learnt during training to real task performance (ii) requires understanding of how to integrate and coordinate a range of implicit and explicit knowledge, including the constituent skills required to perform domain tasks.

Five important factors that are perceived to enhance the effectiveness of learning the elicited expert knowledge are discussed below:

1. The training curriculum must be developed to ensure a good balance between desired learning expectations and learners’ mental load

Recent studies on complex skills learning have shown that it is almost impossible to design any effective learning instructional framework without ensuring an optimum balance between learning contents and the cognitive capabilities of the learners (Sweller, 1994; van Merrienboer and Sweller, 2005; Paas, Renkl and Sweller, 2004; Kirschner and van Merrienboer, 2007). This is the main doctrine of the cognitive load theory (CLT) — a theory developed in the 1980s that uses interactions between information structures and knowledge of human cognition in the design of training curricula (see for example van Merrienboer and Sweller, 2005). This body of research typically attempts to evaluate the operational dynamics of both working memory and long term memory, based on the principle that working memory can store about seven elements but can only utilize 2-4 of those elements at any given time (Gobet, 2005; Cooper, 1994; Tulving, 2002; Kahneman, 2011).

In terms of developing an instructional design for the fire service, this study points the attention of training facilitators to two major ways through which working memory load of the less experienced firefighters could be affected during training. These are: intrinsic cognitive load (the amount of element interactivity that is present in learning tasks) and extraneous cognitive load (the particular means through which learning tasks are taught to the learners). In this context, an element is referred to as *"the amount of information that must be processed by a learner as a single unit in working memory"* (Pollock, Chandler and Sweller, 2002). It is therefore important to note that intrinsic cognitive load cannot easily be altered as it depends on the number of *elements* (inherent in the learning tasks) that must be processed in working memory (Van Merrienboer & Sweller, 2005). Tasks with low element interactivity impose low intrinsic cognitive load since, for a task to be understood and learnt, only a limited number of elements will need to be processed in working memory. Tasks with high *element interactivity* on the other hand tend to pose more learning difficulties because they contain elements that cannot be fully understood in isolation, thereby imposing an additional load on working memory (Cooper, 1994; Anderson, 2002).

In contrast to intrinsic cognitive load that is directly inherent within learning tasks, extraneous cognitive load is comprised of unnecessary loads that are imposed on learners, which are not useful for learning. However, unlike intrinsic cognitive load, extraneous cognitive load can be altered by using effective instructional interventions. For example, by using a combination of auditory (information presented in spoken form) and visual diagrams, as opposed to presenting all learning contents in written form, working memory load on learners can be reduced since mental load would then be shared between the visual and auditory processors (Kester et al., 2006). For the purpose of designing learning tasks for firefighters it is therefore important to note that extraneous load must be lowered as much as possible for learning tasks with high intrinsic load (e.g. carrying out rescue and firefighting tasks). However, if intrinsic load is low then a high extraneous load might not be too harmful since the total cognitive load would still be within working memory capacity.

2. Overconfidence in novices must be effectively managed by ensuring they devote ample time to learning complex skills

Learning complex skills certainly requires that a reasonable amount of time is invested in the learning process. Starting with the work of Chase and Simon (1973), it now appears well established that attaining expertise or developing a reservoir of patterns will definitely take years of dedication, hard work and active practice (Driskell *et al*., 1994; Hoffman, 1987; Wong, 2000; Hayashi, 2001; Feldon, 2008; Ericsson *et al*., 2007; Kahneman 2011, p.238). For example, studies of chess masters (e.g. Chase and Simon, 1973; Gobet 2005) suggest that at least 10,000 hours of dedicated practice is required to attain the highest level of performance (this is synonymous to about five hours play/day for six years).

Studies on expertise have shown that novices are by their very nature quite "energetic" and "enthusiastic" and hence eager to climb the ladder of expertise, but sometimes in ways that are rather too ambitious (Baylor, 2001; Dunning *et al.,* 2003; Gasaway, 2013). This eagerness, if not well managed, can however lead them to begin to downplay the rigours involved in complex skill learning. The term *Dunning-Kruger effect* has been used to describe this situation (Kruger & Dunning, 1999; Dunning *et al*., 2003), akin to what Hannabuss (2000) termed *unconscious incompetence*. In their experimental study involving a group of inexperienced subjects, Dunning and Kruger (1999) found that unskilled individuals significantly over-rated their skills — also known as illusion of superiority (Messick and Bazerman, 1996; Kahneman, 2011).

In short, the Dunning-Kruger effect indicates that unskilled individuals often:

- Tend to over-inflate their own level of skill;
- Fail to recognize genuine skill in others;

- Fail to recognize and admit the extent of their inadequacies;
- Recognize and acknowledge their lack of skill and inadequacies if their limitations were eventually revealed to them e.g. through additional training

The current study therefore suggests that the less experienced firefighters should ideally first be allowed to obtain adequate training before being tasked with incident command responsibilities; this way, their level of overconfidence is also controlled implicitly. Either under-rating the complexities of managing real fires or over-rating one's level of skills can prove catastrophic, particularly considering the amount of stakes associated with the task of firefighting. In the words of one of the participants:

> "*Making people gain experience without training them first could be counter-productive in the end*" (Jade, 15, Crew commander, UK)

Allowing pseudo-experts (inexperienced officers who claim to be experts) to manage complex incidents might result in them endangering their lives and those of others, particularly when faced with tasks for which they were not trained. In addition, such individuals might also find it quite difficult to acknowledge or learn from superior officers that have more experience. This situation appears mostly applicable to the Nigerian firefighters as it seems necessary to address the firefighting tactics these Nigerian officers currently adopt (see evidence provided in section 6.4.)

3. Tasks must be learnt within the most appropriate environments

It has been argued that the environment people find themselves in often plays a significant role in shaping what/how they learn (Hogarth, 2003). A number of scholars have attributed one of the main causes of learning difficulties to the fact that training facilitators sometimes fail to consider the appropriateness of the *environment* where actual learning takes place, as well as the type of relationship that exist between the learners and their instructors (Van Merrienboer, 1997; Hannabuss, 2000; Fessey, 2002; Eraut, 2004; Billett, 2010).

For the purpose of developing training curricula in the fire service, it is therefore suggested that officers who from the outset desire to develop specific skills (e.g. the use of hydraulic vehicles, managing road traffic collisions, incident investigation, managing incidents related to arson etc.) should be allowed to gain practical experience directly from the most "appropriate" stations. The word appropriate in this context refers to fire stations that are popular for performing the activities that are associated with the desired skills. Each station area or *patch* (in the firefighting language) is slightly different and thus has slightly different balance of risks. This is why fire stations are strategically located and positioned at specific catchment areas based on the "problem" that seem peculiar to that area (this is the case both in the UK and Nigeria).

The implication of the above proposition is that officers will then need to be rotated across different fire stations for learning to be effective. To justify this assertion, all the participants (both in the UK and Nigeria) agreed that moving from one station to another provided good learning experience as well as an opportunity to acquire new skills. For example, one of the senior officers (Sunny, 29, Assistant chief fire superintendent, Nigeria) reported that working across stations often help officers cross-breed ideas more easily, since it then becomes easier to see how officers at other stations are likely to approach things.

For example, Willy (28, Watch commander, UK) who has served in eight different stations (see Table 5.1) reflected on his multi-station experiences. The officer was able to recall the peculiarity associated with every station where he had previously served, highlighting the specialized skills he learnt across the stations:

- *"Station 1 was a very deprived area so you get a lot of house fires and rubbish fires which is associated with that".*
- *"Station 2 is a specialist station you did a lot of motor way RTCs, you also did a lot of rescues, and because it had all the big equipment rather than the stuff we carry on the fire engine you actually went out to big accidents".*

- *“Station 3 another deprived area in Birmingham, lots of anti-social behaviour so that’ll be really good for experience”.*
- *“Station 4, again because it’s quite an affluent area anything that happened there is always going to be…..in station 4 everything was a job, you went to big houses, expensive houses on fire”.*
- *“Station 5 is another deprived area, busy road you know the A45, so a lot of road traffic accidents (RTAs) there”.*
- *“Station 6 lots of high rise, lots of skit lifts and bins basically being in the city”.*
- *Station 7 here is quite varied, again quite a deprived area lots of anti-social behaviour”*

……..so if you want to put all of these together you get a massive amount of [experience]….I mean some of these stations had aerials so you get the experience on the hydraulic platforms, experience on all the different…. so you have incident support, command units, breathing apparatus.

The majority of the participants, particularly the UK ones, who had served in at least one fire station all agreed that working across various stations contributed positively to their development as firefighters. The main reason attributed to this was that every fire station is peculiar in its own way and perhaps known for a specific type of event, which will in turn require gaining particular skill sets. In Nigeria, it is quite difficult to work across stations as there are only a few fire stations in most of the States.

4. The tolerability of error must be properly defined during training sessions

While declarative knowledge can be acquired by simply being told, procedural knowledge is gained by doing (Anderson *et al*., 1995). Evidence has shown that people seem to learn better and thus gain more confidence when allowed to be involved in actual task performance i.e. “learning by doing” (Eraut, 2000; Fessey 2002; Billet 2010; Schon, 1983). It is however important to ensure that this “do it yourself approach” is considered alongside the reality that learners are liable to make mistakes, especially when the tasks involved are relatively complex. Training facilitators must therefore specify from the outset the “margin of error” that is tolerable, based on what is realistic in real-life. The excerpt below also suggests that firefighters often learn by acting and then learning from their mistakes when things go wrong. The key emphasis is on learning:

> *So I don't mind that, and I think the training is about making mistakes and I don't think if I put myself forward in training to make a mistake I should be penalized for that, I should be applauded for that otherwise nobody else would ever put themselves forward; and I think that is where the fire service is missing the trick because if you put yourself forward and it goes wrong then people would tell you about it and they will make an issue out of it. Sometimes you don't make an issue of it because the lesson is already learned. (Lambert, 26, Watch commander, UK)*

Hence, although competence in any work domain is enhanced when performers are *confident* in carrying out their tasks, it appears that confidence, as well as the motivation to act is unlikely to increase unless learners are given a considerable level of support and allowed to perform with some degree of "freedom" (King and Clark, 2002; Matzler, Bailom and Mooradian, 2007). This is why learning, for less experienced personnel, is seen as the amount of support their superior officers are willing to give them during training (Vygotsky, 1967; Sweller, Van Merrienboer and Paas, 1998; Alias and Gray, 2005). Learning to other less experienced individuals also means the type of relationship that exists between the learners and their coaches; whether mutually supportive, critical, factional or hostile (Kirschner, 2002; Eraut, 2004; Billett, 2010)

The effectiveness of any training exercise in the fire service is thus believed to lie in knowing exactly when to increase or reduce the level of support provided to learners. While it is encouraged to sometimes allow learners to perform tasks that are slightly beyond their *zone of proximal development* (discussed below), this tendency must be well monitored to avoid eroding their motivation, and consequently distorting their confidence (Eraut, 2000; Wulf and Shea, 2002). To this, management has an important role to play in understanding the relationships that exist between instructional designs and the cognitive capacity of the learners.

5. Learners must be encouraged to invest in deliberate practice

A wide range of studies have shown that one of the most effective ways of learning new skills is by doing the "unusual" i.e. focusing on the aspects of tasks one cannot already perform proficiently (Wulf and Shea, 2002; Charness *et al*., 2005; Ericsson, 2006; Zimmerman, 2006; MacMahon *et al*., 2007; Schempp *et al*., 2007). Deliberate practice is therefore a sustained effort to practice tasks that are currently beyond one's level of competence — stretching beyond the limits of one's comfort zone (Mitroff, Shrivastava and Udwadia, 1987; Driskell, Cooper and Moran, 1994; Vygotsky, 1997; Ericsson, Prietula and Cokely, 2007). Broadly, deliberate practice involves two kinds of learning: (i) improving upon an existing skill and (ii) extending the range of one's skills.

In their research on complex skill learning, van Merrienboer, Clark and de Croock (2002) noted that true experts are known for diverting their attention and effort to mastering other non-automatic constituent skills once automaticity has been attained on certain skills. Through deliberate practice individuals are thus able to develop task specific expertise, much faster than having to wait many years to gain experience on the task. However, it is crucially important to emphasize that deliberate practice requires quality coaching, mentoring and time investment. Continuous deliberate practice and not just conventional practice is the key to becoming an expert. For example, in their study with expert golf instructors Schempp *et al*. (2007) stated explicitly that playing golf for fun will not make one a world class golfer but that deliberate practice has the potential to do so.

In the next section, two theories that underpin the recommended learning framework (i.e. the 4C/ID framework) are discussed in turn:

7.3. ZONE OF PROXIMAL DEVELOPMENT: VYGOTSKY'S ANALYSIS OF LEARNING

The concept of the zone of proximal development (Vygotsky, 1967) was originally developed to link the actual learning process with the mental conditions of learners. Vygotsky identified two developmental levels: the *actual developmental level* and the *zone of proximal development* and argued that learning can only be fully maximized if the discrepancies that exist between these two levels are clarified (Vygotsky, 1978). Vygotsky's main line of argument was that the conventional way of assessing students' competence e.g. by focusing excessively on the already established mental functions is somewhat incomplete. This traditional assessment measures (e.g. through tests or examinations), according to Vygotsky, seems only able to evaluate students' mental abilities on the basis of what they can do on their own (Vygotsky, 1997), ignoring what they can do with the support of others (e.g. support from their teachers, or collaboration with other peers). The key insight from Vygotsky's framework for this study is therefore that what learners can do with the support of others is essentially the best indication of their state of mental development when compared to what they can do on their own.

Vygotsky's idea has transformed the original beliefs of traditional assessment by demonstrating that an essential feature of complex skills learning lies in its ability to create the *zone of proximal development*, which he defined as the distance between the actual developmental level (which is defined by one's ability to solve problems independently) and potential developmental level (the ability to perform tasks under adult guidance or in collaboration with peers). It highlights those psychological functions that have not yet fully matured but are in the process of maturation i.e. functions that are currently in the embryo hoping to mature tomorrow. In the words of Vygotsky, these functions are best described as the *"buds"* or *"flowers"* of development rather than the *"fruits"* of development (Vygotsky, 1978, p.86).

In order to better understand the zone of proximal development and how it relates to learning and instructional design, Vygotsky (1978) emphasized the role of *imitation* in the learning process. Successfully imitating the basis of experts' competence allows students to perform a variety of tasks that exceed their own individual capabilities. Learners are given the opportunity to achieve more with the support and guidance of the more experienced persons than they would normally have achieved unsupported (Chaiklin, 2003; Kozulin, 2003). The whole idea is that what a learner can do today with the help of others s/he would possibly be able to do independently tomorrow. Applying this concept to complex skills learning therefore encourages instructors/facilitators to take into account both the matured processes i.e. cycles that are already completed as well as those that are currently in their developmental stage i.e. the psychological processes and formations that are just beginning to develop.

7.4. SITUATED LEARNING, LEGITIMATE PERIPHERAL PARTICIPATION AND COMMUNITIES OF PRACTICE

Building on the work of Vygotsky, Jean Lave and Etienne Wenger in the early 1990s proposed a new model of learning, particularly for the workplace. The authors developed what can best be described as an instructional approach to learning — situated learning (Lave and Wenger, 1991). This conceptualization of learning is strongly rooted in ethnographic and anthropological perspectives to learning, suggesting that students are more inclined to learn by actively participating in the actual learning experience. Essentially, situated learning is about creating meaning from the real activities of daily living in a way that learning occurs relative to the teaching environment. This should be informal through social interaction, rather than by a planned or mechanistic process of cognitive transmission. For Lave (1993), learning is not necessarily a process of socially shared cognition that subsequently results in the internalization of knowledge by an individual, but rather *"a process of becoming a member of a sustained community of practice (Lave, 1993, p.65).* This probably explains ongoing initiative of the UK fire service in which most fire stations across some parts of the country have been labelled *community* fire stations

Lave also noted that:

Developing an identity as a member of a community and becoming knowledgably skillful are part of the same process, with the former motivating, shaping, and giving meaning to the latter, which it subsumes" (Lave, 1993: 65)

Although Lave & Wenger (1991, p.42) did not provide a precise definition for the term "communities of practice", they attempted to explain what it is not. The authors noted that a community of practice is not a *"primordial culture sharing entity"* (p. 98) and that the use of the term "community" does not necessarily mean co-presence neither does it connote a well-defined, identifiable group or socially visible boundaries" (p. 98). Rather communities of practice typically mean "*participating in an activity system about which participants share understandings concerning what they are doing and what that means for their lives and for their communities"* (Lave and Wenger, 1991, p.98). Even in relatively routine or unskilled work domains, this particular theory of learning argues that a considerable level of interaction is still needed to get a job done (Lave, 1993). These interactions, division of knowledge labour — what Wenger, Erber & Raymond, 1991 called *transactive memory* — and the common understanding through which people appropriate a task were said to be the key elements that sustain a community of practice (Wenger, McDermott and Snyder, 2002). Erden, Von Krogh and Nonaka (2008) emphasized the tightness of the relationships that often exist amongst members of a particular community, suggesting that the group actually thrives through sustained mutual engagement on a common enterprise that subsequently creates a common repertoire.

In describing the nature of the interactions that take place as well as the quality of shared cognition amongst the members of a community, Hoadley (2012, p.288), citing the work of Orr (1996) on Xerox photocopier repairmen, described a situation in which knowledge was co-constructed by technicians who did not have to rely on manuals, standard operating procedures, or what they had been taught formally. Instead these performers, through the construction and sharing of stories and through joint problem solving, were able to come to understand far more about how to repair copiers than the manuals could provide. The type of innovation and learning depicted in the above scenario therefore seems to contradict the more instructivist approach in which experts or researchers would generate knowledge that is subsequently transmitted to learners. In contrast to the traditional approach to learning which often occurs from abstract, out of context experiences such as lectures and books, situated learning suggests that learning most effectively takes place through the relationships between people, by which learners are able to connect prior knowledge with authentic, informal, and often unintended contextual learning (van Merrienboer, Clark and de Croock, 2002, p.43). Within the community of practice, the role of a student changes from being a beginner to an expert as they become more active and immersed in the social community. This therefore suggests that the social community matures and learns through collaboration and sharing of purposeful, patterned activity (Green, 2006)

Lave and Wenger (1991, p.53) in their seminal work also used the phrase *legitimate peripheral participation* to describe the process of knowledge generation, application, and reproduction that constantly take place in communities of practice. Through legitimate peripheral participation, learners enter a community and gradually pick up its practices. At first, the “newcomers” may participate in less demanding ways, but over time, they take up a great deal of the identity of group membership and centrality, and more and more of the central practices of the group (Floding and Swier, 2012, p.193)

The salient points that can be gleaned from the above learning theories for the purpose of this study is that novice firefighters will likely attain expertise much faster and more effectively if allowed to learn within a “community of practice” as opposed to learning individually — what Lave and Wenger (1991) called the cognitive approach to learning. Whilst it is impossible to undermine the role of self-learning in the fire service, especially as firefighters (the Nigerian ones in particular) are still being examined through the traditional methods of assessment such as written examination, collaborative learning remains largely influential.

7.5. THE FOUR COMPONENT INSTRUCTIONAL DESIGN FRAMEWORK: A PROPOSED INSTRUCTIONAL DESIGN FRAMEWORK FOR THE ELICITED EXPERT KNOWLEDGE

While a number of approaches to learning within the professional settings have been discussed in the literature (e.g. the Integrated task analysis model, the guided experiential learning approach; see Clark *et al.* 2006 for an overview), some have been shown to be flawed in their design (Merrill, 2002). Some of the shortcomings that were inherent in most of the instructional design models available in the early 90's were attributed to a lack of alignment between learning objectives, the knowledge and skills required to achieve those objectives, and the task-mental capacity ratio required to perform the desired tasks (Merrill, 2002; Sarfo and Elen, 2007). Following this knowledge gap, Van Merriënboer developed an instructional framework in the late 90's which has since proven effective in enhancing transfer of knowledge and complex skills especially to novices (see van Merrienboer, 1997; van Merrienboer and Kirschener, 2007; Sarfo and Elen, 2007; Kirschner and van Merrienboer, 2007). The 4C/ID was primarily designed as a framework for learning complex skills in programmes ranging in length from several weeks to several years. The 4C/ID is therefore logical in the sense that learners are made to grasp their learning tasks at an optimal pace i.e. without under-utilizing or overloading the cognitive capacity of learners (Anderson, 1982; van Merrienboer, Clark and Croock, 2002).

The four component instructional design model is favoured as a learning framework in the current study for at least four reasons:

(i)The model builds on the assumption that for learners to be able to understand a task in its entirety, tutors must present such a task in its full complexity, incorporating as much as possible the key task constraints that are typical of the domain of practice. Thus, the design of whole task practice is the focus of the 4C/ID model, which it achieves by systematically progressing from a simplified version of a learning task to more complex versions (Van Merrienboer, 1997). This practice contrasts other traditional design models that tend to decompose complex tasks into chunks that are learned separately and then compiled together to form a whole (see Pollock *et al*., 2002 for details). The 4C/ID model discourages such a fragmented approach to complex skill learning e.g. “You won’t understand this now but it will really be important to you later”. According to Merrill (2002), decomposing complex skills for ease of learning has a tendency of making learners lose sight of the relationship between various aspects of the skills being taught (Wulf and Shea, 2002; van Merrienboer and Kirschner, 2007)

(ii) The 4C/ID framework pays a close attention to how learners execute specific aspects of a task (problem-centred approach) as opposed to assessing performance on a broader level (outcome-centric approach). The word *problem* is used in Merrill’s (2002) perspective to describe a wide range of whole-tasks that are representative of those that are likely to be encountered in the real-world. The 4C/ID, on this note, contrasts with other traditional learning tools where the main focus is often centred on achieving positive outcomes with little or no interest in the learning process. Also, *immediacy of performance* is possible with the 4C/ID as instructors could ask learners to immediately repeat either a whole task or some aspects of a task that were not carried out in conformity with experts’ expectations. By setting up repeated tasks for learners, automaticity is achieved and novices are able to solve task related problems more intuitively i.e. with minimal mental effort; this way, important feedback is not left to a debrief session. The 4C/ID therefore utilizes a “process” based feedback (you did it wrong) than an “outcome” based feedback (you got it wrong), implying that learners are more likely to discover exactly what went right/wrong in the course of task performance (Klein, Moon and Hoffman, 2006)

(iii) The 4C/ID makes a clear distinction between supportive information (which is presented to learners prior to practice e.g. fire manuals) and just-in-time or procedural information (which is presented to learners during practice to help perform recurrent aspects of tasks). In a study aimed at teaching novices how to troubleshoot electrical circuits, Kester *et al* (2006) found that cognitive load was quite high when both supportive and procedural information were presented to learners prior to task performance, but lower when supportive information was presented before task practice and procedural information during practice.

(iv)The 4C/ID ensures that coaches are able to tailor learning tasks to focus on specific areas of weaknesses in novices, thereby allowing instructions to produce “learning with understanding” (Gobet, 2005). To achieve this, the 4C/ID encourages variability in some of the tasks presented to learners, particularly as single problem case tasks have been shown to be insufficient in developing cognitive skills in most complex work domains such as firefighting (Anderson, 1983; Sweller, Van Merrienboer and Paas, 1998). The 4C/ID model therefore allows learners to acquire both abstract knowledge (for creative problem solving) and concrete knowledge (rule-based or codified knowledge).

7.6. APPLYING THE FOUR COMPONENT INSTRUCTIONAL DESIGN MODEL AS A LEARNING FRAMEWORK

The main assumption of the 4C/ID instructional framework is that the environments where complex skills are learnt are described in terms of four interlinked components (4C): *Learning tasks, supportive information, just-in-time information, and part-task practice*.

7.6.1 Learning tasks

Learning tasks are real, concrete and meaningful whole-task practices that are structured from simple to complex versions and aid knowledge acquisition in learners. They typically encourage inductive learning, allowing knowledge and skills to be induced from concrete experiences (see Fig 7.1 below). By so doing, learning tasks serve the purpose of supporting non-recurrent aspects of tasks (schema construction) while also facilitating the development of automaticity in the recurrent aspects of the tasks (rule automation). The competence assessment framework developed in this study (Table 7.1 above) contains more than 40 distinct learning tasks that can be designed for novices, based on perceived training needs.

Any training programme aimed at learning complex skills utilizes, more often than not, a sequence of learning tasks as its backbone (Vanmerrienboer, Clark and Croock, 2002). These learning tasks are essentially performed in a real or simulated task environment and provide whole-task practice, as opposed to fragmented learning tasks. The learning tasks are also designed in a way that the learners are confronted with all constituent skills that make up the whole complex skill. It therefore becomes important to ensure that learning tasks are designed to engage learners in activities that require them to work directly with the constituent skills, knowledge and attitudes. Merrill (2002) pointed out four levels of analysis that must be included when designing whole task practice for complex learning:

- The problems to be solved
- The tasks to be performed by learners in solving particular problems
- The various operations associated with each of the tasks, and
- The actions that must be implemented in carrying out the operations.

Merrill (2002) suggested that every instructional design must strive to engage learners at these four levels of performance.

Task classes: With the four component instructional design model, task classes rather than individual learning tasks are what determine the sequence by which training programmes are organized (see Fig 7.1 below). Since learners cannot easily be bombarded with highly complex learning tasks at the inception of a training session, learning tasks are therefore categorized into distinct task classes, from simple to difficult. Once the task classes are defined, the learning tasks are then developed for each class in increasing level of difficulty. Hence, by progressively increasing task problems the skills of learners gradually improve until they are able solve complex problems (Merrill, 2002). Furthermore, sequencing task class also ensures that “details” which are not relevant to a particular learning task are not presented to learners until when needed. Instructional designs that do not put this sequence into consideration have been shown to yield negative learning outcomes in terms of performance and learners’ motivation (Sweller, 1994; Eraut, 2004).

It is worth mentioning that all tasks within a particular task class are equivalent since they can be performed using the same body of general knowledge (i.e. mental models and cognitive strategies). When learners begin work on a new task class, it becomes crucial to reduce extraneous cognitive load by giving adequate support to the learners. The amount of support provided to learners however reduces between learning tasks that belong to same task class as learners acquire more expertise — this process has been termed “scaffolding” (Wulf and Shea, 2002; Merrill, 2002; Van Merrienboer, Kirschner and Kester, 2003).

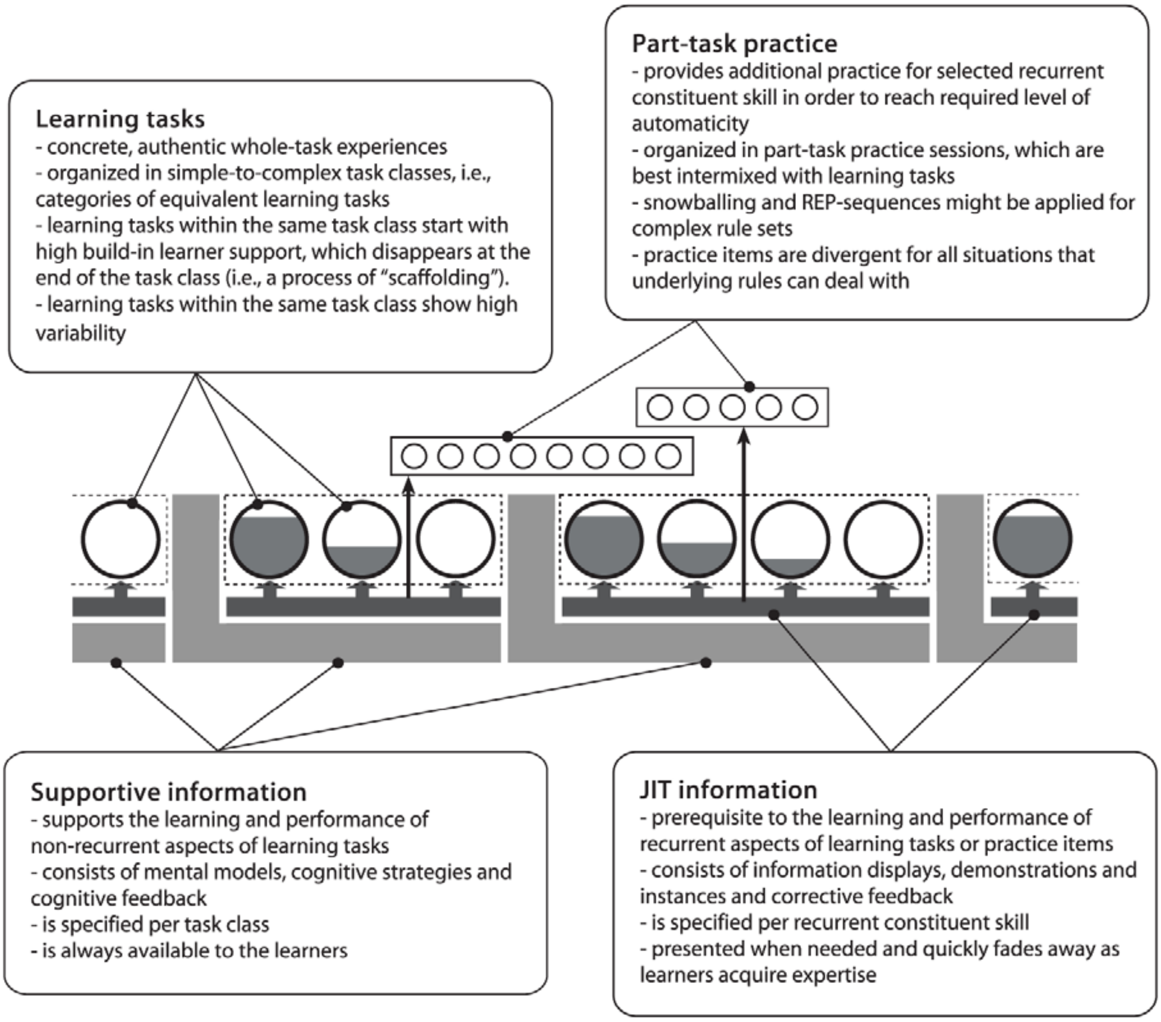

Figure 7.1: The four component instructional design model (Van merrienboer, Clark & de Croock, 2002)

7.6.2. Supportive information

This is the second component of the 4C/ID model and represents information supplied to learners to assist them carry out the non-recurrent (or non-routine) aspects of a task. Non-recurrent tasks are tasks that require higher cognitive reasoning or problem solving skills i.e. tasks for which behaviour varies from one problem situation to another. Supportive information, without which it is almost impossible to carry out learning tasks, stipulates how to approach problems in a domain (cognitive strategies) and how the domain is organized (mental model). It is what trainers usually call "theory", and is often presented to learners in cases, books, seminars, worksheets and so on. The main function of supportive information is to enhance schema construction; hence, it is presented in such a way that learners are able to apply prior knowledge as they acquire new information. By presenting supportive information to learners, they are essentially being made to encode such information in long term memory (through elaboration) which can then be recalled and activated in working memory when needed for task performance (Van Merrienboer, Kirschner and Kester, 2003).

Since supportive information is relevant to all learning tasks within the same task class, it is presented to learners prior to the commencement of a new task class and made available throughout the learning duration. Presenting learners with supportive information prior, as opposed to during an exercise is judged to be more productive as such information often contains high element interactivity (total amount of information that requires processing) which might increase the chance of cognitive overload. Expecting trainees to make sense of supportive information while also attending to problem tasks has been found to be detrimental to learning, from a number of studies (Pollock *et al.,* 2002; Van Merrienboer, Kirschner and Kester, 2003; Van Merrienboer and Sweller, 2005) — what Sweller (1994) also termed the *split attention* effect.

7.6.3. Just-in-time information

In contrast to supportive information, procedural information is embedded in rules, explicit knowledge, procedures and standard operations, and required by learners to perform recurrent aspects of the task. They are presented in bits to learners as "how to" instructions i.e. direct, step-by-step instructions that specifies to learners how to perform routine aspects of behaviour (e.g. process worksheets). The general consensus is that the more learners perform recurrent aspects of tasks, the more they are able to acquire automaticity over time (Paas and van Merrienboer, 1994). Thus, procedural information is presented to learners exactly at the point when such information is needed to perform a task, after which it is then allowed to fade away for subsequent tasks. It has been demonstrated that learners do better when informal support is made available exactly at the point needed than when provided prior to the task, especially for routine tasks (Vanmerrienboer, Clark and de Croock, 2002). Since just-in-time information is presented during task performance, it therefore implies that it is presented to learners in a "ready to use" form, with less element interactivity (see Kester *et al*. 2004 for details).

7.6.4. Part-task practice

Part task practice provides opportunity for learners to repeatedly practice specific tasks, especially the tasks that are inevitable in a particular domain of practice (Sarfo and Elen, 2007). Such tasks are consistently repeated throughout the task classes, with the hope that they would become "proceduralized" as cognitive rules to the learners. Rule automation and strengthening of schemas are hence made possible as learners repeatedly carry out and complete part-task practices (Kirschner, 2002; Paas *et al*., 2003). Designing part-task practices can therefore be said to be a vital component of the 4C/ID model since it allows knowledge to be gained about a particular task/procedure until the performer is able to perform such task intuitively i.e. with minimal mental effort (Sweller, 1994). This is a desirable feature of expertise: automation frees up working memory capacity for other tasks and, by so doing, influences behaviour directly without the need to exert additional load on working memory (Hogarth, 2003).

7.7. POSSIBLE WAYS OF ASSESSING COGNITIVE PERFORMANCE IN NOVICES

Prior research has shown that if people are to learn from their mistakes and improve on their performance, then the validity and reliability of the competence assessment measures used by training facilitators or licensing bodies must be given a closer attention (see Epstein and Hundert, 2002 for detail).

Miller (1990) developed an assessment framework that has been widely used in the field of medicine (Fig. 7.2). The framework argues that whilst it can be important to test the intellectual knowledge of learners, such an assessment method is probably an incomplete tool for appraising expertise, particularly when one understands that there is more to the practice of medicine than knowing (Miller, 1990). Drawing insights from Miller's work, each task element on the competence assessment framework is proposed to be assessed against at least one of the following levels: the "knows" level, the "know-how" level, the "show-how" level and the "does" level (refer to the competence assessment framework in Table 7.1)

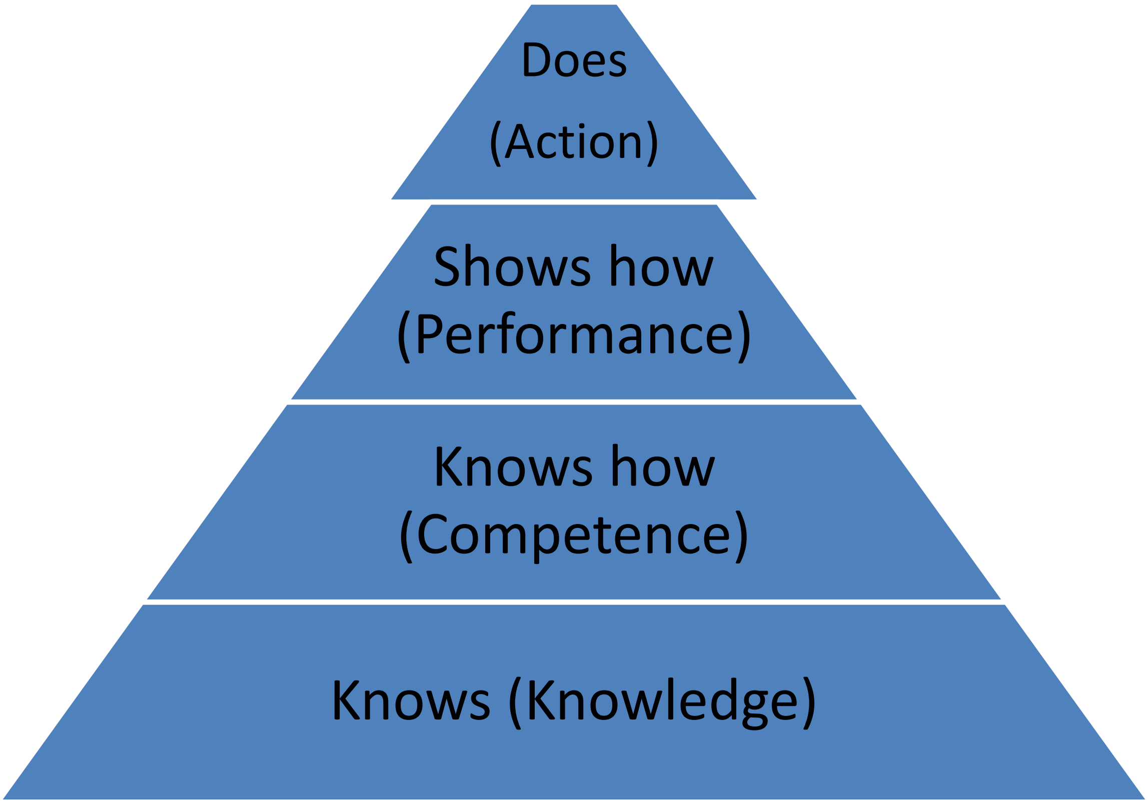

Figure 7.2 Miller's competence assessment framework (Miller, 1990, p.S63)

Knows level: Firefighters are made to recall facts, principles or theories e.g. providing information about fire, water or building properties.

Know-how level: Problem solving ability; the ability to describe procedures e.g. explaining how to evacuate trapped victims from a high rise building.

Show-how level: Demonstration of skills required for task performance e.g. showing instructors how to communicate with the fire control when requesting additional resources.

Does level: Performing real task practice with little or no support from instructors or peers e.g. using cold-cut cobra equipment to extinguish a severe fire in a tight space.

7.7.1. Performance based assessment versus mental load and mental effort

Performance: This assessment approach measures competence mainly through the outcome of an intellectual exercise e.g. test, oral or written examination etc. It is based on the assumption that learners become more liable to mistakes as tasks become more complex. For example, instructors can measure performance based on the number of answers a learner was able to get correctly or the number of errors committed.

Similar to other authors (Sweller, Van Merrienboer and Paas, 1998; Paas, Renkl and Sweller, 2004; Van Merrienboer and Sweller, 2005) the current study argues that the traditional assessment methods used in some domains of practice seem to be flawed as they often tend to limit competence to *performance* assessment only. Performance, although directly measurable, is not exactly a true test of competence since it is incapable of capturing the cognitive capacity of learners, which has been regarded as one of the most important assessment criteria for complex skill learning (Merrill, 2002; Pollock *et al*., 2002; Wulf and Shea, 2002). For example, testing the performances of learners through a theoretical examination in the fire service might produce misleading outcomes in terms of assessing level of competence. A fireman who has an exceptional ability to recollect written subjects but poor at performing practical hands-on tasks will most likely score a higher mark than another fireman who is adept at performing practical tasks but has a phobia for written exams. To therefore compensate for the shortcomings in the performance assessment measures, this study suggests using mental load and mental effort measures alongside performance measure.

Mental load: This is used to estimate the amount of cognitive load which a task exerts on learners, from the point of view of the learners. For example, Paas and Van Merrienboer (1994) developed a subjective mental load rating measure using a 7-point Likert scale. At the end of each training section instructors can ask their students to rate how difficult the tasks they were presented was, for example, on a scale of 1 (extremely easy) to 7 (extremely difficult)

Mental effort: This refers to the cognitive capacity that is actually available to accommodate the task demands imposed on learners while learning new skills. This assessment measure seems to be a more reliable way of estimating cognitive load than the other two methods as it provides more important cognitive information. For example, in the process of carrying out a task, two trainees may actually arrive at the same correct answer but with significantly different mental efforts. This assessment measure is therefore based on the existing assumption that expertise increases as people begin to think less analytically, which is evident from their ability to perform tasks with minimal mental effort (Chase and Simon, 1973; Baylor, 2001; Weiss and Shanteau, 2003; Gobet, 2005; Feldon, 2007)

For example, the mental effort of trainees can be assessed on the duration of time spent on a particular task, the level of support needed to perform a task, physical stress or fatigue and the amount of time learners seemed to be making reference to supporting materials etc.

CHAPTER 8
CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

With the emergence of expert systems and growing interest in naturalistic/real world decision making, researchers became more interested in the *content* knowledge of experts. The need to better understand how proficient individuals perform particular tasks in real life was therefore seen as one of the most efficient ways of improving the overall level of human performance in high reliability domains. Against this background, the current study set out to examine how best to capture expert knowledge (of firefighters in particular) and to address some of the misconceptions surrounding tacit knowledge elicitation. While some of the challenges of expert knowledge elicitation were acknowledged *a priori* (e.g. issues related to unconsciousness and automaticity), the motivation for this study was triggered by the need to preserve expert knowledge, to identify the tacit cues used by experts in solving complex tasks, to evaluate the decision making strategies used by experts on the fireground, to identify training needs for the design of training curricula, and to compare and contrast the cognitive and non-cognitive cultural differences between the UK and Nigerian fire services.

The study adopted the definition of knowledge as the interaction between intelligence (capacity to learn) and situation (opportunity to learn), suggesting that people will be unable to update their knowledge banks without the opportunity to learn and/or practice The current study was based on the notion that investigators ought to find a way of describing what experts do, and then teach this to novices. The principle behind this approach is that by carrying out a detailed study on the general knowledge, specific information, and reasoning processes used by experts, a “model” which exhibits some of the properties of experts can then be developed.

Since procedural knowledge and its associated cognitive skills cannot be learned by simply being told, but by doing, the study further provided an opportunity to advance research beyond the more obvious explicit or rule based what they have learnt. On this note, the study emphasized the provision of adequate learning opportunities as one of the most important conditions for developing the cognitive skills of novices. Eliciting expert knowledge is believed to be insufficient unless such knowledge is aimed to be utilized for training purposes.

In order to enhance ease of memory recall and to help experts more effectively share what they both know and do, the study utilized a credible knowledge elicitation tool known as the critical decision method (CDM). The CDM, being a retrospective technique, was deemed most appropriate in the context of this study as other techniques such as concurrent protocol analysis or think aloud methods could have posed more methodical and ethical challenges. For example, concurrent verbal protocol (i.e. asking participants to articulate their thoughts and considerations while performing their fighting tasks) could easily interfere with real-time activities and distract officers from effectively carrying out their duties. There is also only a remote possibility that the knowledge elicitor would be present during these major incidents to observe events as they unfold.

Below is a summary of the key findings from the current study, outlined to specify how the research questions set out in section 1.2.1 have been answered:

<u>Research Question 1: How do experts utilize their skills in managing complex non-routine incidents?</u>

1) By utilizing the critical decision method as knowledge elicitation tool, this study revealed some of the skills, knowledge and competencies inherent in the expert firefighters that were interviewed. The relevance of the study is further underscored by the decreasing rate of major fire incidents in both countries, resulting in novices not having as much of a window of opportunity to gain real-life experiences as before. For this reason, the outputs developed in this study — the competence assessment framework, information filtering and intuitive decision making model, critical cue inventory — all appear to be perfectly timed, especially from the point of view of the Nigerian fire services. These products are expected to play significant roles in enhancing complex skills learning through the design of well-informed training and learning tasks. For instance, trainers and facilitators will be able to develop a wide range of learning tasks from the elicited expert knowledge (as discussed in chapter 7). These knowledge outputs are ultimately aimed at providing novice firefighters with opportunities to update their knowledge banks particularly with scenarios that address real-life events.

2) Although intuition and analysis were found to be complementary rather than competitive, experts tended to use intuition as their default strategy. Findings from the study showed that the analytical strategy is only invoked when the intuitive system cannot solve a current problem or when there is need to make a conscious decision, such as evacuating people to a safe shelter. In contrast to other studies that failed to clarify how intuition was being utilized, an intuitive decision for the purpose of this study was defined along three dimensions: decision time (decisions that took less than a minute), tacit knowledge (decisions that emerged from tacitly held knowledge that is difficult to verbalize) and unconscious processing of information (mainly prototypical decisions that required minimal mental energy).

3) Another important finding from this study relates to the role of intuition in analytical thinking. Studies have shown that deliberation is contextually different from intuition i.e. whilst the former operates in the conscious realm, the latter operates in the unconscious mode. The model developed in the study revealed that experts often use their intuition to decide whether or not to initiate a deliberative process. In other words, experts understand when to deliberate on a particular action plan and when to intuitively act on their first impression. It therefore appears that experts mostly use their intuition to direct analytical thinking, rather than the other way round. By so doing, experts also seemed to know when their intuition is likely to betray them.

4) The study provided additional insights regarding the role of intuition in creative decision making. Notwithstanding the remarkable progress that has been experienced in recent years on the subject of intuition, some scholars have criticized the extent to which researchers on intuition have emphasized its role in judgment making to the detriment of its role in creative thinking. The current study analyzed 134 decision points and found evidence to support the notion that intuitive insight and intuitive judgment represent two different but related routes to intuitive decision making (14.5% and 9.2% of all decisions made respectively by the UK and Nigerian experts were creative). While the former relates to decisions made during unusual circumstances that require improvisation (creative decisions), the latter, intuitive judgment, relates to decisions made through pattern recognition — in which case a decision maker assesses an ongoing situation and then matches the cues, goals and actions against the repertoire of patterns stored in the memory. Hence, although the creative use of intuition was found to be less prominent than its use in judgment making, this study demonstrates that problem solving on the fireground involves both intuitive insight and intuitive judgment.

5) Analysis of the interview transcripts revealed the role of experiential knowledge in coping with the task constraints associated with firefighting. All the experts (both in the UK and Nigeria) reported that their ability to put up effective performance amidst task difficulties was largely due to their level of experience as well as the quality of training they had received in the course of their firefighting career. This justifies why they are able to look at a burning building, envision the stairways and then intuitively predict what was happening inside, making sense of the implications of such for task performance. Experience (rooted in deep domain knowledge) was therefore found to be vital in making critical fireground decisions.

6) The study showed that experts usually rely on their experience to generate a workable option, which is usually the first and possibly the only option they would have to consider. Using the term pattern recognition (a widely utilized concept in the field of cognitive psychology) this study posits that experts are able to utilize previous knowledge in solving current tasks by carrying out a quick mental scan across the large repertoire of patterns they had stored in their memory. This then allows them to select the most appropriate 'action scripts' that best suit a current situation. Simply put, experienced firefighters often strive to draw from their rich mental model through which they are able to describe, explain and predict events.

Research Question 2: How can the elicited expert knowledge be transformed into useful knowledge outputs that will facilitate learning for potential incident commanders?

7) The model developed in this study (the information filtering and intuitive decision model) attempts to describe how the thirty experienced firefighters (both in the UK and Nigeria) were able to effectively manage various task constraints on the fireground, including coping with incomplete and conflicting information. The model revealed that the incident commanders were often faced with important tasks of collecting, filtering and processing multiple informational cues from various sources within a limited timeframe. This is because most of the cues on the fireground rarely appear in clearly defined forms, particularly at the initial phase of an incident. Hence, regardless of the commanders' ability to recognize previous incidents, they were also able to identify the most important informational cues and to discriminate between relevant and irrelevant cues.

8) The model also revealed that experienced officers often initiate response plans using the information they have as a starting point (no matter how little), and then subsequently rely on additional information to refine and clarify their understanding of the problem as events proceed. Nine principal cues were identified in the study from which the commanders reportedly drew insights to develop their action plans: the class of fire involved (Class A - F), including the colour of smoke each class generates; the type of materials present within and without a building (e.g. acetylene, carbonaceous substances, electronics); the intensity of the fire; the work the building is used for (e.g. garage or mechanic workshop); the cause of the fire (Arson, electric spark, lightening); the psychological and emotional states of victims; cracks spotted on the building wall; the layout of the building; presence or absence of individuals in the burning building (e.g. trapped victims, disabled individuals, elderly persons)

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9) The ability to differentiate between cues that trigger actions and those that are not very relevant (in the form of noise and distraction) was seen as an important aspect of expertise. The study therefore emphasized that *whilst having too little information about an incident could be quite risky, having too much information could even prove more dangerous*. This implies that a point is reached when acquiring and computing more information becomes detrimental to the outcome of a decision.

Research Question 3: What cognitive and contextual (cultural) differences exist between the UK and Nigerian firefighters, and what/how can the two groups possibly learn from each other?

10) In all of the enlisted dimensions through which intuition was measured, intuitive decisions appeared to be higher than the analytical strategy (option deliberation) in both countries. Specifically 88.4% and 84.6% of the total decision points reported by the UK and the Nigerian firefighters respectively were found to be made through existing prototypes in the memory, which is based on accumulated experiences of having managed numerous fires. The study also revealed that 80% and 72% of the total decisions made by the Nigerian and UK officers respectively were made within 1 min.

11) It is important to emphasize that the UK and the Nigerian firefighters approached their firefighting duties uniquely as the two groups differed in their organizational and operational setup, thereby making it difficult to directly compare the level of effectiveness of the two groups. The notable differences that were found to exist between the two groups related more to non-cognitive factors such as (equipment, training, staff welfare, crowd control etc.) as opposed to cognitive factors. Comparing the decision making and problem solving strategies of the two groups, findings showed that a considerable amount of similarities exist. For instance, analysis of the decision points showed the following estimates between the UK and the Nigerian firefighters respectively: 7.2% and 7.7% of the entire decision points were found to be made deliberatively; 88.4% and 84.6% were prototypical decisions; 4.3% and 7.7% were based on analogues; 23.2% and 26.2% fell under the standard category, and 62.3% and 64.6% of the decisions were adaptive.

12) The Nigerian firefighters reported facing numerous challenges compared to their UK counterparts. In contrast to the UK firefighters who struggled to think of any aspect of training that had not already been covered either in the incident command and control training or as part of the day-to-day training routine at their respective stations, the Nigerian firefighters emphasized the need for additional training on specific fireground tasks as shown in section 6.2. Furthermore, the Nigerian officers all admitted there is a need to restructure the fire service in three important areas: (i) improved government support, which includes making significant improvements to staff welfare (ii) provision of advanced firefighting equipment that will allow for effective firefighting operations (iii) provision of optimum support and funding for both in-house and overseas training.

13) The expert knowledge and tacit skills elicited from the study (across both groups) were indexed into a competence assessment framework and the four component instructional design (4C/ID) model was recommended as an efficient learning framework for training instructors. The main assumption of the 4C/ID model is that the environments where complex skills are learnt are described in terms of four interlinked components (4C): Learning tasks, supportive information, just-in-time information, and part-task practice. The implications for transferring expert knowledge to novice firefighters were also discussed.

8.2. Recommendations

Based on the findings from the study and the gaps identified between theory, policy and practice, the following recommendations are made to the various stakeholders as shown below:

8.2.1. Recommendations for policy and practice

1) Since the ability to effectively conduct dynamic risk assessments on the fireground lies in utilizing existing knowledge, which is largely rooted in experience and deliberate practice, this study recommends that developing training programmes should be done such that novices are taught to use the standard operational procedures of the fire service as a tool for informing rather than one for dictating. The less experienced officers should be made to engage their "thinking hats" by exploring a wider range of options beyond what the fire books would normally stipulate. For instance, facilitators could design learning tasks for which novices are only required to apply basic firefighting rules and those where applying such rules could appear counter-productive. A training procedure that is heavily focused on making rule-based decisions is therefore believed to risk jeopardizing the creative power of learners therefore slowing down their learning curve.

2) Attention has been drawn to the fact that when officers who regularly perform operational hands-on tasks are also involved in the training process, they tend to unintentionally omit some useful cognitive strategies when communicating and teaching complex skills to their students. Specifically it was shown that when health experts teach surgical operations to students, they often leave out approximately 70**%** of the vital information that should have facilitated students' understanding (Clark, 2014). To make matters worse, these experts are usually unaware of these lapses, which can be attributed to the fact that the knowledge they are trying to transfer to novices is largely tacit, automated and unconscious. Care should therefore be taken when using experts that are heavily involved in operational firefighting tasks to train novices. These experts may find it difficult to breakdown what they do and know in ways that are easily understandable to novices, and continue to teach them "shortcuts" to performing tasks instead.

8.2.2. Recommendations to the Nigerian fire service

1) It is surprising, yet true that many Nigerian citizens do not know the emergency numbers to call following a fire breakout. This was believed to be a serious issue from the point of view of the interviewed Nigerian firefighters for a number of reasons: first, the Nigerian officers believe the fire service is being denied its mandate to protect the lives and properties of the Nigerian masses each time fire incidents occur without the awareness of the fire service. Second, the officers saw it as a waste of resources if millions of Naira (Nigerian currency) are continuously lost to fire incidents that could have easily been managed, simply because members of the public are ignorant of how to reach the fire service. This issue of poor accessibility is one that therefore needs to be addressed urgently. This study recommends the need to utilize all available media sources such as national and local newspapers, TV and radio adverts, as well as organizing local community awareness programmes in order to enlighten the public members on why/how best they can reach the closest fire service in case of emergencies. The Lagos state fire service (one of the study areas in Nigeria) has currently started a massive public awareness campaign in this regard by providing the public members with all the contact numbers and details of all the available fire stations within the state. Other states in the country are encouraged to emulate this positive step.

2) One of the most appropriate goals for crisis management is learning to prepare for as many crises as possible through effective training. Training teaches an organization how to cope when a crisis eventually occurs, thereby increasing their chance of success. It has been hypothesized that the less vulnerable an organization thinks it is, the fewer crises it prepares for, and the more vulnerable it eventually becomes when a crisis occurs. The Nigerian fire service must therefore improve their attitude towards, and approach to training if any meaningful progress is to be made. They must stop seeing training as merely a way of fulfilling their daily work routines and start seeing it as an opportunity to ask important questions, such as what if a set of crises hit us simultaneously what are we prepared to do? What part of the firefighting tasks do we often struggle to cope with? Top managers and policy makers (strategic commanders) in the Nigerian fire service therefore have a huge part to play in pushing for this cultural change. The good news, however, as revealed from the current study is that the Nigerian officers seemed to be willing to learn new skills and work with more advanced firefighting equipment; they are just waiting for when this would happen.

3) Drawing insights from the UK fire service, this study recommends incorporating a station to station type of training for novice firefighters in Nigeria who may benefit from gaining additional skills which may perhaps be impossible with serving in only one station. Fire stations are often located strategically, depending on the prevalent problem case that is peculiar to an environment. Officers in the UK and a few of the Nigerian ones who have served in more than one station admitted that working across different stations is an essential part of gaining expertise. Different stations, they say, present different challenges. While this inter-station work experience is common in the UK, it is perceived as a big challenge in Nigeria because of the very limited number of fire stations that exist in major states of the country (see section 6.4). The starting point is to motivate the Government to establish more fire stations and equip them with up-to-date resources. This will also help to reduce the huge loss often incurred during fire incidents due to insufficient resources.

8.2.3. Recommendation to the UK fire service

1) Three of the UK senior officers interviewed in the study claimed that the UK fire service must go back to the previous mode of promoting officers, which is mainly by examination. Until July 2006, the Fire Services Examinations Board were responsible for setting and administering national written exams for promotion to the ranks of crew commander and watch commander. But now, the service currently uses a new method known as "integrated personal development system" (IPDS) whereby officers seeking promotion are made to demonstrate their competencies based on workplace assessment guidelines. These officers are tested against the particular skill sets they desire to develop (practical assessment), from which a decision is then made whether or not they merit being promoted. The problem with this new method as noted by the interviewed officers is that the crucial aspect of gaining technical knowledge is lost. These officers argued that the newly introduced IPDS approach does not accord “potential experts” the opportunity for self-study, which is believed to be the basis for gaining technical knowledge (this contrasts the previous approach that entailed writing statutory exams). It is therefore recommended to the UK fire service to consider incorporating into the promotion procedures the writing of statutory examinations or to include a similar method that will encourage rigorous self-reading as part of the requirements for promotion.

8.3. Limitations of study

Just like every other research, the current study has its own limitations:

1) The critical decision method that was utilized as knowledge elicitation tool in this study is generally seen as a complex method of inquiry as discussed in section 4.3. It involves initiating and maintaining good rapport with participants, listening to fire-stories, applying cognitive probes, questioning expert judgement where necessary, taking field notes and carrying out external observations. As a result, CDM experts have suggested involving two or more persons when conducting CDM studies so as to reduce the risk of missing out vital evidence. Whilst this appears as a possible limitation, conscious efforts were made in this study to manage any potential impacts of using one investigator. For instance, an MP3 tape recorder was used during each interview session, which made it possible for the author to still take notes and observe around.

2) Another possible limitation of the study was the fact that only one knowledge elicitation method was employed throughout the data collection process. The critical decision method would have perhaps been used along with at least one other knowledge elicitation tool such as cognitive interview (CI) or concurrent verbal protocol. But as stated in section 4.2.2 it would have almost been impossible to follow firefighters to the scene of incidents for ethical and safety reasons, hence the

rationale for choosing the critical decision method which uses retrospective reports. Moreover it is not entirely certain that utilizing more than one knowledge elicitation tool would yield richer outputs

3) Finally, the CDM was found somewhat wanting in attempts to identify and analyse the cultural differences between the UK and Nigeria fire fighters. Since analyses of cultural differences was part of the objectives of the study, it was eventually carried out through “selective coding”. Although the method generated a considerable amount of insights in terms of the differences that exist between the two cultural contexts, it was perceived that using a framework specifically designed for cultural analysis would have yielded more results. This is a challenge that must therefore be embraced by knowledge elicitation researchers particularly those within the field of naturalistic decision making.

8. 4. Areas for further research

1) One of the greatest criticisms of using retrospective verbalization methods (such as the critical decision method) in expert knowledge elicitation has been attributed to the problem of memory limitations. This is because the required information from experts may not have been encoded in the form that makes them easily accessible as verbalizable recollections. For the purpose of future research and as one of the solutions to the problems of memory limitations, this study recommends the use of stimulated recall procedures. One of the most promising approaches in this regard is the use of video-assisted stimulant where participants are actually observing themselves undertaking the task for which they are being interviewed. This approach will likely help reduce any form of retrospective bias, thus allowing a more reliable representation of the recalled incident.

2) Although prior research has suggested that the completeness and accuracy of elicited knowledge is largely influenced by the particular knowledge elicitation tool used by investigators, only a few studies have thoroughly evaluated or compared the effectiveness of existing knowledge elicitation techniques. A Meta-analysis centred on comparing the strengths and weaknesses of various knowledge elicitation methods is perceived to be important in order to enhance the educational value of the instructional contents generated from experts.

3) While the current research utilized a qualitative approach to examine how expert firefighters utilized their intuition in solving complex non-routine tasks, previous studies have also utilized a more quantitative approach such as Agor's Intuitive Management survey (Agor, 1989); the International Survey on Intuition instrument (Parikh *et al*., 1994); the Rational Experiential Inventory (Epstein, 1998). Although scholars leaning towards the qualitative approach have criticized the use of surveys in studying how people make intuitive decisions, this study recommends a hybrid method that will utilize both qualitative and quantitative approaches within a single study. Due to the multi-faceted nature of intuition as a subject, it is logical to infer that the reliability of findings on intuition might be better enhanced using more than one single methodology

4) More studies are needed to focus on how firefighters develop expertise within a community of practice. This involves researching around the social dimensions of learning as opposed to the conventional (cognitive/individualistic) approach to studying expertise. NDM researchers can therefore advance research around knowledge elicitation to include ethnographic studies on team decision making, shared cognition and group tacit knowledge, all within the scope of collaborative learning.

8.5. Plans for dissemination

Research findings from this study are hoped to be effectively disseminated, thereby informing decision making and ultimately improving training outcomes in the firefighting domain. To this effect, the plans for dissemination are outlined below:

- The outputs and findings from the study are expected to benefit from peer reviewed publications so as to serve a wider audience. Three papers have already been published from the study, with more publications targeted in the nearest future.

- Findings from the study are also aimed to be presented at conferences that cover related themes. Some of the findings from the study have already been presented at two separate conferences in the course of the study: The naturalistic decision making conference, Marseille France 2013 and the society for risk analysis conference, Istanbul, Turkey, 2014. More conferences in the area of cognitive science, knowledge management and cultural studies are all potential spots for further dissemination

- Finally, findings from the study are hoped to be published as a complete book which will be targeted at the Nigerian fire service. The book will aim to synthesise all the knowledge elicitation outputs from the study, with particular emphasis on the key lessons that emerged from the cultural comparison between the UK and the Nigerian fire service.

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APPENDICES

Appendix A: The decision points reported by the UK firefighters

Appendix B: The decision points reported by the Nigerian firefighters

Appendix C: The critical decision method interview protocol utilized in the study

Appendix D: Ethical approval letter

Appendix E: Letter of approval for access to the Nigerian fire stations

Appendix F: Examples of worked thematic analysis based on the emergent themes approach

Appendix A: Decision points: UK Firefighters

1	I checked the situation and decided to call for extra assistance- fire engines and personnel
2	Decision to evacuate people out through the window which is against our SOPs
3	Decision to split crew and manage resources from other stations
4	Monitor the woman to prevent her from harming herself
5	My insistence in keeping the appliances on a welfare issue for a long time
6	Call for 15 additional pumps
7	Exterior attack, too dangerous to commit crews
8	Decision to climb up to see the sit of the fire as water attack was not getting effective.
9	Decision to call for specialist appliance- foam attack
10	Decision on how to get access to the scene of the fire (the building)
11	Decision on firefighting strategy to employ (firefighting medium)
12	Decision to request more appliances from 2 to 5 then to 7
13	Decisions on how to effectively delegate tasks to other personnel
14	Decision to consider evacuation (defensive attack)
15	Decision on stabilizing the patient first while at the same time fighting the fire
16	Decision to ask for assistance; call the police and a senior firefighter
17	Decision to ask the police to take the family of the victim away from the scene of the incident to a safe place
18	Refusal of Fire Chief's order and offering an alternative order
19	Calling the incident DM team together
20	Over-ruled shelter location and messages going on at the time
21	Briefed crew to put on BA on our way
22	Changed plan to use hosereel and smothering on getting to the scene of the incident
23	Ensuring the safety of crew by being more defensive and ensuring the machine was moved with care

24	Made up for 2 additional appliance
25	Decision to use smoldering/hose reel in order to preserve water
26	Getting enough water
27	Dividing the sector further into two because of the scale of activities going on
28	Putting water inside the building – that is not yet on fire. (Putting a fire break)
29	Get water to the hydraulic platforms
30	To request additional hydraulic platform as the one there was not serving enough
31	Crew safety by ensuring there are exit plans in case the fire comes through to the building.
32	Put ladders up to the front of the house to reassure people
33	Send firefighters up to be sure those trapped in the building were OK
34	Decision to keep the house owners in the bedroom at first
35	Decision to send 2 firefighters with BA sets
36	Decision to evacuate people through the ladder
37	Deploy BA teams
38	To start resuscitation of the children
39	Resource the incident gap (Ambulance, fire engines and fire investigation)
40	Looking at the stability of the house if anything is going to collapse
41	Fire investigation; trying to determine what caused the fire.
42	I asked the guys to put the BA on and start breathing, while we were still on the way
43	Decision to break the windows to let the gases out.
44	I had to commit 2 firefighters into the incident with BA, but also to let them make their own decision once they got inside.
45	I asked the fire appliances that are coming on to the incident to have, the first to have breathing air like I did my guys, and the second one to have breathing apparatus on them.
46	Next we got the other services involved, Ambulance, Police, FRIT and

	SOCO
47	We used a hose reel and not a main jet
48	I asked for assistant message once I knew we were under-resourced
49	Informed crew to get ladders and start carrying out rescue operation
50	We involved the Police
51	Decision to rescue those directly above the flat first
52	Splitting our resources immediately we arrived at the scene of the incident (front and back)
53	Deploying medical personnel to treat the casualties
54	Deploy firefighters using a ladder in through the windows
55	Using two firefighters instead of more because it's a small apartment (space-wise)
56	Using main jets instead of hose reels.
57	Decision as to when to take over from the watch commander
58	Decision to leave the crews inside the building after finding out other fire sources
59	Resolving water challenges and sourcing water
60	Requesting aerial appliance
61	Requesting extra 10 pumps, and then eventually to 12
62	Withdrawing the crews because the fire became fierce and unsafe
63	Change the existing tactics upon my arrival by changing the firefighting position of the crews (i.e. directing the jets from the front door)
64	Taking charge of the incident without any formal handover
65	Increasing the number of resources from 6pumps to 10
66	Continued to attack the fire by directing a jet against the corridor ground floor and breaking the window to jet the cylinders first floor
67	Decision not to evacuate the crews 200m despite acetylene cylinder being involved
68	Preventing the fire from spreading by confining the fire from either side of the building

	(cold cut cobra strategy was used)
69	Got the fire surrounded at the back of the garden

Appendix B: Decision points: Nigerian Firefighters

1	Looked for the nearest route to the incident
2	Apportioned task while still in the vehicle, on the way to the incident
3	look at what to do to make the work easier- sizing- in this case identifying what class of fire it is
4	Using fireman Axe to break the vehicle in order to get the people out
5	Decision to call the Road Safety
6	Go round the building and see where I can begin to fight the fire from
7	Break into the door to enter the scene
8	Layout the hose in advance
9	Find a means of entering the building
10	Blocking the other side of the building to prevent fire from affecting the next building
11	Sizing, checking around the building
12	Finding alternative means of entering the building(breaking wall)
13	Decision to use our Breathing Apparatus (BA)
14	Failure to allow Julius Berger fire service to work with us
15	Looking for the source of electricity and switching it off from the switch board
16	Blocking the fire from the last office and not fighting it directly; to prevent it from damaging the unaffected offices
17	Breaking the door of the office where the fire started to look for the seat of the fire
18	Fighting the fire from the back of the office where it started and not directly on the seat of fire; to avoid the walls falling on us.
19	Noticing that some areas have not been affected, I withdrew the men

	to start fighting the fire from areas that have not been affected.
20	Cut off the spread by fighting from areas affected to prevent areas unaffected
21	Use of spray instead of jet.
22	We firstly laid down the hose and take the end to upstairs
23	Broke the glass in order to get access to the seat of the fire.
24	We used jet to fight the fire that day
25	Sizing, putting things in view
26	We broke the door to pave way for the passengers to come out
27	Immediately we applied water with a chemical (i.e. foam) to extinguish the fire
28	Splitted the crew into two, one are fighting the fire, while the other were paving way for the passengers to come out
29	Tried attacking face to face with water as instructed by the officer in charge, but discovered it was not working, so told him we need to change strategy
30	Approach the scene from the back and not through the entrance because the fire was facing us directly
31	We used cooling rather than fighting the fire directly.
32	Cooling the cylinder around the plant to avoid it from exploding
33	Called for more assistance, assistant message.
34	Sizing up where I found out it was an electrical spark
35	Informed NEPA to cut off the light from that area
36	Found out the need for more water and continuous replenishing
37	We decided to back the wind to avoid it blowing towards us
38	Preventing the fire from spreading by fighting those affected
39	Dividing the line into two
40	Calling for additional appliances
41	Looking for the seat of fire; climbing the roof to see the seat, but almost fell into the fire because of broken beams
42	Decided to break the wall to enter as it is not possible through the

	roof
43	Water was showered directly on us by other crew members while we were inside the smoke-logged room to supply fresh air
44	Decision to take risk to stand risk and withstand the smoke pressure, ceasing breath
45	Decision to approach the fire from 2 sources
46	Taking the fastest route to the scene of the incident (Topography)
47	We lied down and crawled in to fight the fire
48	We laid two lines of hose
49	We cooled the whole tank before leaving the area
50	We used foam compact to extinguish the fire
51	Entered the building by crawling, using the back of my hand to feel
52	Went into the building with hose fully charged, using oxygen from the water to sustain myself
53	We jet the ceiling to drive away toxic gases
54	We divided a line of hose into two
55	When we received the call, we informed the operational men, while on the way we informed the police of the fire accident, we also informed the head office that a call was made to our station.
56	Getting to the scene, we observed and thought about how best to control the fire safely, we asked questions from the members of the public.
57	We called for assistant message
	58. We thought of how best to get to the scene of the incident; we climbed through the roof to the seat of the fire.
59	We had to use full jet in putting out the fire
60	Taking the easiest and closest route to the incident

61	Making 2 streams of hose i.e. 2 lines
62	We capped the licking and flowing fuel with chemical foam (foam compact)
63	We used spray for cooling the burning fire on the summersaulted tanker
64	Informed the public members not to use their mobile phones when the fuel was licking
65	We waited for them to remove the remaining fuel from the tanker before we left.

Appendix C: The full critical decision method interview protocol utilized in the study

INTERVIEW GUIDE

Title: Decision making strategies used by Firefighters and the potential for training intuitive skills

Interview Date/Time ______________________ Location _______________

Duration of Interview ______________________

1. **GENERAL DATA**

    a. Gender ______________________

    b. Position/Rank: ____

    c. Year of Experience: ____

    d. Year of Experience as an Incident Commander: ____

    e. What is your highest level of educational? ____

    f. Mention the fire service qualifications/certifications you acquired in the course of your profession till date (if applicable)

    ____

    g. Briefly describe the various fire stations you have worked in, and what you did/doing in each

    ____

    ____

2. INCIDENT ACCOUNT

a. Please narrate a particular incident where you were personally involved in decision making; from the time the alarm was received till the time the fire was brought under control.

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b. Why did you choose to narrate this particular incident?

____

3. TIMELINE CONSTRUCTION AND DECISION POINTS IDENTIFICATION

(a) On the basis of the above Incident, please construct a timeline showing how various events happened from the time your team arrived the scene to the time the fire was brought under control.

(b) On the timeline, identify the points where critical decisions were made

Sketch of the timeline

4. COGNITIVE PROBES AND PROGRESSIVE DEEPENING

A. Cues

i) What features were you looking at when you formulated your decision?

ii) How did you know when to make the decision?

B. <u>Knowledge</u>

i) Was there any information you used in making this decision? Please Explain

ii) How was it obtained?

C. <u>Analogues/Prototypes</u>

(i) Were you reminded of any particular previous experience in which a similar decision was made?

D. <u>Standard Or Typical Scenario</u>

i) Does it fit a scenario you were trained to deal with?

iii) Were you following any rule? Please elaborate on the rules you were following

E. Goals

i) Were you pursuing any specific goals and objectives at the various decision points? Please elaborate on these goals

F. Options

i) Were there other alternatives available to you other than the ones you chose? Please explain

ii) Why were these alternatives considered inappropriate?

G. Experience

i) What specific training or experience was necessary or helpful in making this decision?

ii) What training, knowledge, or information might have helped make the decision better?

H. Situation Awareness

i) If you were asked to describe the situation to a relief officer at this point, how would you summarize the situation?

ii) What was the most important piece of information that you used to formulate the decision?

I. Decision Making/Time pressure

i) How long did it actually take to make this decision?

ii) Were you under any time pressure? If yes, why?

J. <u>Errors</u>

i) What mistakes are likely at this point?

ii) How might a less experienced fire fighter have behaved differently?

5. HYPOTHETICAL SCENARIO (WHAT IF'S)

a) Briefly explain what you would do if you get to the scene of a serious fire as an incident commander, and find out you have very little information about what is happening, and yet you have to make decisions as to whether to be offensive or defensive in your attack?

Appendix F: Examples of worked thematic analysis based on the emergent themes approach

FULL NARRATIVES NARRATIVES FROM TRANSCRIPT (CONDENSED MEANING UNIT HIGHLIGHTED)	CODES AND CONDENSED MEANING	CATEGORIES
CUES: Were you seeing any cues/features that helped you formulate your decisions?		
A: At those point im looking at it, I know, ive got a measure that if ive got a house on fire, just a normal standard house with nobody in it, I can do that with 2 trucks, 9 people, 2 fire engines, no doubt, that is a box standard measure, I know that. If I've got a car on fire I can deal with it with one fire engine. So there are basic measures[1]. So when I come to that incident I look at it and think, well, that's 10,000 bigger than a house, I know I haven't got enough to deal with this. So I need to make more appliances[2], so I chose 5 partly based on how many I know are in Coventry, partly based on how many of the officers I would like to have to help me control what ive got[3]. Im looking at the physical size of the fire, the intensity of the fire, how close it was to the houses[4-6]. If it was not surrounded by houses, probably 5 would have been enough, but because it was situated right in the middle of all these houses, I got the houses to worry about, the people in the houses. So we needed more people with me if needed people to evacuate.	1. Box standard measures 2. Making sense of cues 3. How many appliances in town 4.Physical size of fire 5. Intensity of fire 6. How close it was to the houses 7. Task constraints	1. Prerequisite knowledge 2. Predictive cues 3. Prerequisite knowledge 4-6 Visible cues 7. Task constraints
TACIT KNOWLEDGE ON CUE: What do you mean by intensity of the fire.		

A: Say for example, I go to a house, and the smoke is creeping out the window, the smoke coming out of the door, I'm thinking there is a fire somewhere burning in the room. Not particularly massive, but its something you don't want in the house[1]. If I turn up to a house, and the window is completely fallen out and there is flames leaking out there, that's an intense fire[2]. If its that bad that has got a real hold on it, and opening of door and doing different things will affect how the whole building reacts[3]. That is how I look at the intensity of the fire. Its visual; if you can actually see flames, especially in the building fire, well that's fairly severe[2]. Normally fires maybe inside the building, you will see smoke, you wont necessarily see flames. But if you could see flames, then it is serious[2]. You can even make that decision on the way. While on the way to that incident, you can see the glow in the sky, you can see the flame coming up- you are already formulating plans in your head what you are going to do. So if I cant see anything, I cant make any decisions because im thinking this might not be anything or might be a small fire, but if I can on my way see something, that means its quite an intense fire because there is a lot going on[4].	1. Smoke creeping out of window and door (dangerous but not massive) 2. Windows fallen out and flames leaking out (intense and massive) 3. How building reacts to smoke 4. Planning ahead while on the way	1&2. Cue discrimination (Tacit knowledge) 3. Domain knowledge(Tacit knowledge) 4. Pre-planning (tacit knowledge)
TACIT KNOWLEDGE: What is the difference between smoke and flame?		

A: Smoke can clearly kill people, people can die from a smoke fire through inhalation. It is more smoke that kill people than fire can kill people[1]. If you are in a modern building with double glazed windows sealed against cold weather - that is a sealed unit, a compartment. And when fire develops in a compartment- you can imagine this room, the door closed and the fire starts over there, there will be flames it will build up, it will build up until smokes gather on the ceiling. It will slowly lower down until it reaches a point where there is no oxygen left in this room. That fire would die down but this room is full of flammable gases. Immediately you open that door, air will tract in, because the fire needs air- because its sucked all the air up. Immediately you open the door, air will rush in, the fire will reignite, and it will reignite all the gases and the whole room will set on fire again[2]. So, that is smoke from bump fire- nothing but smoke in a compartment- so if it's not what we call vented. So if we came and that window is mashed through, or the window was opened and smoke was pouring out and there was a door there opened and smoke was pouring out- that would be reasonably safe for us to enter. But if we could see it was thick-black smoke, the door was shot and we could see little bit of smoke creeping out or pushing out under pressure, we know it is dangerous in here because if we open that door the fire will ignite[3]. So then we have to use special techniques to cool the gases. So that's when the hosereels	1. Smoke kills faster 2. chemistry of combustion 3. smoke behaviour 4. Fire control using hosereel 5. Flashover/missing cues 6. Thickness, colour and reaction of smoke 7. Understanding smoke behaviour 8. Colour of smoke 9. Flashover and backdraft	1-2. Pre requisite knowledge 3. Cue discrimination (Tacit knowledge) 4. Domain knowledge (Tacit Knowledge) 5. Predictive cues 6. Visible cues 7. Safety Culture 8. Cue discrimination (Tacit knowledge) 9. Prerequisite knowledge

comes in handy, spraying a little bit gets it under control and so we open the door, and we straight away are fighting the fire. We drive the water in the air tract where the air is rushing in, and that water particle is get carried in to the fire. Its all about how we control the fire[4]. So in some cases when I turn up to a fire and the flames are flying out of the window, everybody thinks its really dangerous; but actually for us we can see what is dangerous; potentially everything is visible to us. But if we come to a place with black thick smoke where the smoke is not ripping out of the windows, that potentially could suddenly go while we were in there, whereas a fire that is already burning is burning before we got there we can deal with it because its going to get no worse[5]. You can tell how thick the smoke is, the colour of the smoke, how it reacts when you've got windows or anything[6]. If we open the door and the smoke was coming out and then suddenly starts to suck in- then we know the fire is waiting to get oxygen so we pull the door shot. You see what I mean- it's a visual signs of what is happening in that building. And you get like pulsing- sometimes it sucks in and blow out, suck in and blow out- again that's another dangerous sign[7]. The colour of the smoke; if its like a thick yellowish-grey that's a fire that hasn't got enough oxygen- so immediately you open the door it will suck oxygen in- its got a potential to what we call a 'flashover'[8]. There is flashover and backdraft. Flashover is when something		

burns and creates combustible gases and it reaches a point where there is enough temperature in the room for the gas to ignite. A backdraft is when a fire is died down and is just waiting for oxygen to come in. so when you open the door, the backdraft of air rushes in and the fire goes again and the fire rushes out[9]. That's a couple of terms.		
INFORMATION USED: What information were you using to make these decisions?		
A: Initially it is training; what I have been taught and told[1]. Q: Does that mean you carry your training manual with you? A: No, it is in your head. We do have a folder in the truck called the fire facts- just got basic facts about certain things- information that may be useful if I need access to it. Generally, everything is dynamic- im using dynamic risk assessment continually[2]. Alongside training is experience- you can be the best trained person in the world but if you've never seen it, that is a little bit more difficult for you, isn't it[3]. And then obviously, im gathering	1. Training 2. Dynamic Risk Assessment 3. Experience 4. Information gathering by self by looking 5. Information gathering by speaking to people	1. Training 2. DRA 3. Limits of training 4&5. information search (IFID)

information myself, im looking, I'm speaking to people; im looking at what I can see. Information is important as an officer in making decisions; you can make a terrible decision without the right information[4&5].		
RECOGNITION: Did this particular incident remind you of previous incidents you have managed in the past?		
A: Yes, yes, that is generally the case- I mean- it may have come from the days of being a fireman before I was an officer[1]. I have attended incidents like that; I have seen other officers dealing with them- so that kind of thing will remind me, I will remember those things- they did that it worked, they did that it didn't work- so im not going to do that[2]. Q: Did this incident remind you of anyone in particular? A: Errrm, I have been to so many fires like that, probably, but I couldn't tell you of anyone in particular. I have been to a lot of various kinds of fires, maybe in different situations[3].	1. Fireman to officer 2. What is remembered 3. Many incidents	1. Memory space (principles of rec) 2. Principles of recognition 3. Prototype
LEVEL OF NEOVELTY: Does this incident fit a scenario you were trained to deal with?		
A: Erm, yes it does, not in the difficulties as in the access behind the houses and things[1]. But we have done training for small industrial unit, things like that how to deal with them, what to expect to find in them; so we have done training to suit that[2], but as every incident is different- training is like a generic training that gives you a basic knowledge to then adapt to suit what you are doing, which is basic for fire services- You	1. Difficulty in access to the building 2. Every incident is different so training is generic 3.Training gives	1. Task constraints 2. limits of training 3. Limits of training 4. Adaptive decisions

are given training, then you adapt to suit[3]. Q:Are you also trained to know how many resources to request? A: No, you are not trained for that- nobody sits you down and say when you have this incident you need this, when you have this incident you need that. That is an experience, and you make decisions based on what you think you need for the incident[4].	you basic knowledge to then adapt to suit what you are doing. 4. Make up of resources	

FULL NARRATIVES NARRATIVES FROM TRANSCRIPT (CONDENSED MEANING UNIT HIGHLIGHTED)	CODES AND CONDENSED MEANING	CATEGORIES	NOTES (RATIONALE FOR SELECTING CATEGORIES
CUES: What were you seeing, hearing or smelling (cues) that made you make those decisions?			
A: Immediately I heard the information that that fire was caused by spark or upsurge of fire current from the NEPA pole, I know that, for safety of lives I need to inform the NEPA to take off the light[1]. Already it is a well alight fire[2] that the flame is visible (flame is a mass of gas undergoing oxidation). The flame has mixed up with oxygen in the surrounding[3]. The colour of the flame is red[4].What made me know I had to back the wind is that I watched the direction of the wind, the direction it is blowing, so I made the decision to back the wind[5].	1. Immediately I heard the fire was caused by spark or upsurge of current (Class of fire) 2. Well alight fire 3. Visible flames 4. Flame colour is red 5. Direction the wind was blowing	1. Visible cue 1. Safety Awareness (Tacit Knowledge) 2. Visible cue 3. Visible cue 4. Visible cue 5. Environmental cue	
SOURCES OF KNOWLEDGE: How did you obtain the knowledge you used in making these decisions?			
A: The knowledge I made use, one of it is my experience, my experience in firefighting[1]. I also got information from people, onlookers and those living around there, the information I got from them helps[2]. The experience and the knowledge I have got also, in the course of my training[3], because we were taught many other subjects apart from fighting fire, we were taught chemistry of combustion, building construction and how the materials used in building behaves when they are affected by fire[4].	1. Experience 2. Information from crowd 3. Training 4. Subjects covered in training	1-3. Sources of Information (IFID) 4. Nature of training	
RECOGNITION: Did this incident remind you of previous incidents you have managed?			

A: Yes it does, and it helps. There was one like that we attended at ICI paint Ikeja, it was during Harmattan also, that was the point when I just joined the service and we were there[1]. So I saw how Harmattan wind is controlling that fire then, and I see the decision some of our officers took in fighting the fire as at that time, it contributed to my own experience[2].	1. There was one we attended at ICI 2. Things remembered (Harmattan fire) 3. Saw what officers were doing then	1. Analog 2. What is remembered? 3. Commitment to memory (PoR)	In most cases, experts have a wide range of incidents they have attended and this is one of the hallmark of expertise. However, evidence shows that they only bring to closer view (and remembrance) incidents that are most closest to the ones they are currently managing.
LEVEL OF NOVELTY: Will you say that all the training you had was enough to handle that incident?			
A: You know training itself is a process of development, so there is need for continuous training no matter the one you have got before; locally, overseas and in many other things[1]. If I say I have experience of fighting fire, what of if I want to fight fire in a confined space?[2] What of fighting fire that involves other materials?[3] That is why there is a need for continuous training as a source of development. For this particular incident, what I have got as at that time was enough for me, yes, but at the same time that does not stop me from having other training[4].	1.Training itself is a process of development 2.Fighting fire in a confined space 3. Fire involving other materials 4.What I had was enough for me on this incident but more needed	1. Definition of Training 2-3. Training needed 4. More training needed	This expert admits that the training he had was sufficient for this incident. However more training would be welcomed - he cited examples of incidents where training would have fallen short
RULES, SOPs & CREATIVITY: Were you following any rule, or were you being creative?			

A: Some are creative, but most of it are following the rules. Like when there is a fire in a room now, we were told that the hot air normally rise up, so in a room that is well alight with fire, by the time you started applying your water and you want to come inside the room, in order to be conducive for you, you need to go down, because the hot air there has rise up. By the time you go down you will be able to penetrate to come in and fight the rest of the fire[1]. Actually it is in our rule that you need to replenish when there is no more water[2], but at the same time I envisaged that we need a lot of water in order to cope with the situation at that time, so I quickly went into action to take that decision of seeking for water in good time, that is why we were able to put out the fire in quickly[3].	1. Hot air rising up when entering a room on fire (ingress) 2. It is in our rule to replenish water 3. I envisaged that we will need a lot of water	1. Cognitive rule (Ingress) 2. Rule (replenishment) (UK Vs Nig) 3. Preplanning (UK Vs Nig)