The Emergency Department response to Chemical, Biological, Radiological, and Nuclear events: A Human Factors and Ergonomics Approach

by

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Volume 1 of 2

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Abstract

Since the September 11, 2001 terrorist attacks in the USA, government agencies and professional societies have focused greater attention towards the hospital response, particularly Emergency Departments (EDs), for emergency preparedness and response. In the UK, the Civil Contingencies Act lays out responsibilities on NHS organisations to uphold civil protection.

The ED is a complex, hectic, and high-pressured environment. Chemical, Biological, Radiological, and Nuclear (CBRN) events are multi-faceted emergencies and present numerous challenges to ED staff (first receivers).

This thesis used Hierarchical Task Analysis (HTA) to explore whether there were differences between operational procedures and practice using the Human Factors/Ergonomics (HF/E) approach for Work as Imagined (WAI; procedures) and Work as Done (WAD; practice). The aims were to 1) Explore whether HTA could be used to map complex socio-technical systems and 2) Make recommendations to improve the ED response to CBRN events.

Study 1 (WAI) took a top down approach for document analysis of standard operating procedures (emergency plans) at two Type 1 NHS Trust EDs. The plans were analysed thematically to create colour coded HTA representations of the CBRN plans. Differences in General Organisational Responsibilities (GORs) were found between the two Trusts; Trust A had 13 GOR themes and Trust B had 20 GOR themes, of which 13 overlapped. The emergency plans include role-specific action cards used to support individual tasks; each card (n=30) was analysed and represented as HTAs. An Ergonomics review of the HTAs as part of the coding process produced higher level (standardised) themes at both Trusts as:

1. Prepare to respond to CBRN incident (Trust A and B).
2. Respond to CBRN incident (Trust A and B).
3. Initiate recovery from CBRN incident (Trust A).
4. Document CBRN incident (Trust A).

Study 2 (WAD) collected data with semi-structured interviews from 57 first receivers. Scenario cards were used as prompts to explore clinical and operational practice. The field notes were converted to HTAs and thematically analysed. The synthesis of these themes provided a bottom up perspective to consider standardisation based on WAD (how first receivers respond to CBRN events). Similarities between the Trusts were evident in the importance placed on actions for isolate and contain, liaise and communicate, and escalate. Differences were found in the importance placed on Personal Protective Equipment (PPE), decontamination, treatment, and investigation of the presentation. The results for WAI and WAD were compared. WAI focused on actions such as documentation, checking, and timing; WAD prioritised patient needs through assessment, treatment, and diagnosis. Finally, the findings were synthesised into standardised recommendations as:

- A CBRN planning checklist.
- Action card template.
- Example of a meso-system.
- CBRN response framework.

The WAI vs WAD framework provided a robust theoretical framework to identify gaps and improvement opportunities in the ED CBRN response. This research shows that HTA can be used to unpack a multifaceted event in a complex environment.

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List of Abbreviations

ACP	Acute Care Practitioner
AEO	Accountable Emergency Officer
ARS	Acute Radiation Syndrome
ANP	Acute Nurse Practitioner
C&C	Command and Control
CCA	Civil Contingencies Act
CCF	Civil Contingencies Framework
CIEHF	Chartered institute of Ergonomics and Human Factors
ConsOps	Concept of Operations
CPAP	Continuous Positive Airway Pressure
CPPE	Chemical Personal Protective Equipment
CQC	Care Quality Commission
CSS	Complex Socio-technical Systems
DIC	Doctor in Charge
DIM	Detection, Identification, and Monitering
DoH	Department of Health
ECP	Emergency Care Practitioner
EDA	Emergency Department Assistant
EDP	Emergency Department Practitioner
EMS	Emergency Medical Services
ENP	Emergency Nurse Practitioner
EPRR	Emergency Preparedness Resilience and Response
ERO	Emergency Response Officer
ERU	Elderly Receiving Unit
EVD	Ebola Virus Disease
FESS	Functional Endoscopic Sinus Surgery

FRAM	Functional Resonance Analysis Method
GP	General Practitioner
GOR	General Organisational Responsibilities
GST	General Systems Theory
HART	Hazardous Area Response Team
Hb	Haemoglobin
HEFT	Heart of England Foundation Trust
HDU	High Dependency Unit
HF/E	Human Factors and Ergonomics
HFRM	Human Factors Risk Manager
HPA	Health Protection Agency
HRA	Health Research Authority
HTA	Hierarchical Task Analysis
ICU	Intensive Care Unit
IEA	International Ergonomics Association
IOM	Institute of Medicine
IOR	Initial Operational Response
IV	Intra Venous
MAJAX	Major Incident
MDU	Mobile Decontamination Unit
MCI	Mass Casualty Incident
MTC	Major Trauma Centre
MMAT	Mixed Methods Appraisal Tool
NAIR	National Arrangements for Incidents involving Radioactivity
NARU	National Ambulance Resilience Unit
NHS	National Health Service
NIC	Nurse in Charge

NIHR	National Institute of Health Research
NOF	Nominated Officer for Fire
ORCHIDS	Optimisation through Research of Chemical Incident Decontamination Systems
PHE	Public Health England
PICU	Paediatric Intensive Care Unit
PRPS	Powered Respirator Protective Suit (PRPS)
RE	Resilience Engineering
R & D	Research & Development
RGF	Research Governance Framework
SARS	Severe Acute Respiratory Syndrome
SHERPA	Systemic Human Error Reduction and Prediction Approach
SOP	Standardised Operating Procedures
TTX	Tabletop Exercise
UHL	University Hospitals of Leicester
UNDRR	United Nations Office for Disaster Risk Reduction
VPA	Verbal Protocol Analysis
VR	Virtual Reality
WAD	Work as Done
WAI	Work as Imagined
WAP	Work as Prescribed
WHO	World Health Organisation

Chapter 1. Introduction and overview

"Complex systems cannot be understood by studying parts in isolation. The very essence of the system lies in the interaction between parts and the overall behaviour that emerges from the interactions"

(Ottino, 2003)

1.1 Introduction

The researcher has a clinical background within the NHS and is employed as an Emergency Department Practitioner (EDP), this experience provides a first-hand insight into the functioning of an Emergency Department (ED), which informed the topic of this research. The researcher has questioned the ED Chemical, Biological, Radiological, and Nuclear (CBRN) response because key factors are often associated with ambiguity and uncertainty (Kotora, 2015; Larson et al., 2016; Mitchell, Kernohan, & Higginson, 2012).

Since the September 11, 2001 (9-11) terrorist attacks, government agencies and professional societies have focused greater attention towards the hospital response, particularly EDs, for emergency preparedness and response (Becker & Middleton, 2008), because EDs are at the forefront of the CBRN response and serve as the gateway to the most appropriate care of patients (Whetzel, Walker-Cillo, Chan, & Trivett, 2013).

Employees within the ED are often considered a subset of first responders in CBRN incidents (Leiba et al., 2006; Mitchell et al., 2012). However, the role and definition of ED employees in response to CBRN events is vague (Koenig, 2003; Whetzel et al., 2013). Being referred to as front line staff in the UK, is misleading as it usually refers to police, fire, and ambulance crews as a general term to manage a multi-faceted event (Hayward, 2003). The term clinician is interchangeably used in this thesis to refer to healthcare professionals who have direct contact with and provide care to patients. However, the ED CBRN response consists of a diverse set of individuals, the term *"first receivers"* coined by Koenig, (2003) is suitable for ED staff, which consists of clinicians such as doctors, nurses, allied healthcare professionals, health care assistants, and other professionals such as porters, medical physicists, and security officers.

A CBRN event is *"The exposure (or risk of exposure) of a large number of individuals to hazardous Chemical, Biological, Radiological, and Nuclear materials which may occur through a variety of means including natural, accidental, and deliberate acts"* (Chilcott & Wyke, 2016, p. 179).

Examples of CBRN events include the chemical sarin attacks in Tokyo in 1995 (Okumura et al., 1998), the 2001 biological anthrax letters in the USA (Koenig, 2013), the use of radioactive Polonium-210 in London in 2006 (Day, 2006), the Birling Gap incident in East Sussex (Greenfield, 2017), and the Salisbury novichok incident (Vale, Marrs, & Maynard, 2018).

CBRN events are becoming more frequent for example, the National Health Service (NHS) was exposed to a CBRN event through the novichok incident on March 4th, 2018 (Hulse, Haslam, Emmett, & Woolley, 2019; Vale et al., 2018). The novichok incident is described as the longest-running major incident in the NHS, lasting 72 days (Rimmer, 2019). During which 46 people attended the hospital with concerns of exposure, and a potential 131 individuals who may have had contact with the substance were identified. The novichok incident resulted in the death of one individual. It is reported that effectively responding to nerve agents is a gap in knowledge amongst clinicians (Hulse et al., 2019). This thesis is aiming to understand response as a means of closing this gap in knowledge.

In England, the Civil Contingencies Act (CCA) (red arrows) (Cabinet Office & The Civil Contingencies Act, 2004) lays out responsibilities on NHS organisations to uphold civil protection and act as the foundation to emergency preparedness, response, resilience, and recovery (black arrows) as shown in Figure 1 (p. 3).

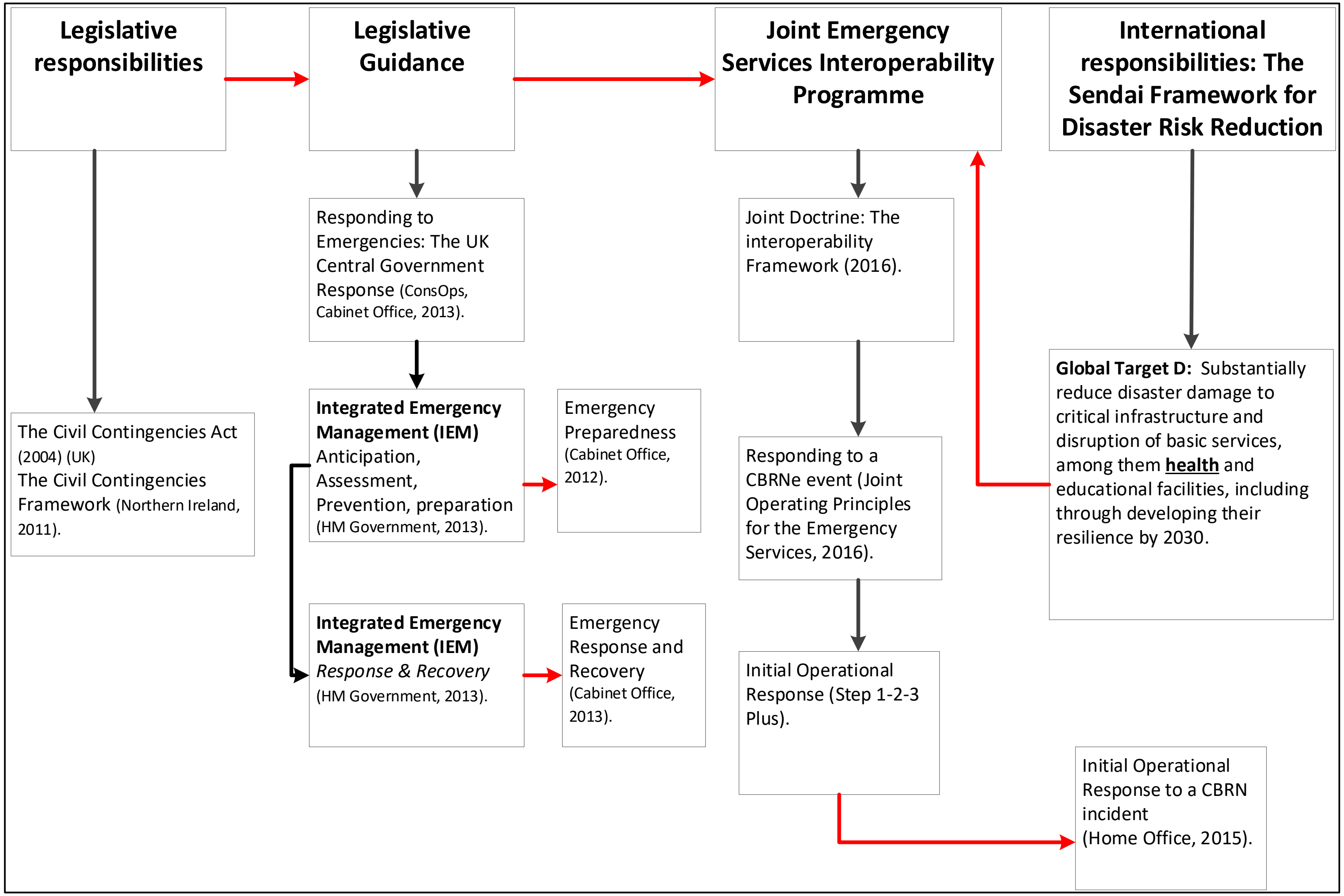

Figure 1: National legislative responsibilities and international guidance frameworks for civil protection during an emergency

The CCA outlines responsibilities such as implementing emergency plans for category 1 organisations which include EDs (Cabinet Office & The Civil Contingencies Act, 2004). Additionally, guidance for the NHS on Emergency Preparedness Resilience and Response (EPRR) (Cabinet Office, 2012) is governed by NHS England and provides a strategic national framework consisting of core principles which NHS organisations must meet (Sellwood & Wapling, 2016).

Although there is governmental guidance on how to respond to CBRN events (Gov UK, 2008). On a local level, this means that Trusts must plan, clinically recognise, respond to, treat, and recover from CBRN exposure - the implementation of this guidance can be considered unrealistic because EDs are already highly pressured, complex, and volatile work environments.

Once Trusts have implemented frameworks and key legislative responsibilities through employing Accountable Emergency Officers (AEO) (Legislation UK, 2012), a critique arises in whether CBRN response concepts would be carried out on the front line, based on the variability in the care provided by first receivers when faced with an unfamiliar CBRN emergency. Therefore, mapping out the ED CBRN response is crucial to enhance understanding and ultimately practice which is embedded in legislation, local top down perspectives (AEOs/CBRN plans/planners), and local bottom up insights (first receivers). Through understanding CBRN response practice, recommendations to enhance the care delivered to patients during such emergencies can be proposed.

On an international scale, the Sendai Framework for Disaster Risk Reduction 2015-30 (Aitsi-Selmi, Egawa, Sasaki, Wannous, & Murray, (2015); UNISDR, 2015), has emphasised health impact and the importance of health system resilience, through focusing on infrastructure, health innovation, and technology; in order to reduce disaster risk, losses in lives, livelihoods, and health. Therefore, unpacking the ED CBRN response is also crucial because EDs are central to all health systems and are thus key in reducing the number of lives lost – locally, nationally, and internationally.

1.2 Problem statement

The Emergency Department is a Complex Socio-technical System (CSS) (Braithwaite, Wears, & Hollnagel, 2017), in which groups of people such as patients, relatives, and clinicians interact with different technologies in various physical and organisational environments (Carayon, 2006; Effken, 2002). CSSs have been associated with unexpected variability in performance in which patient safety can be compromised (Saurin & Werle, 2017).

The ED is the highest risk area for patients in healthcare (Bleetman, Sanusi, Dale, & Bruce, 2012). CBRN events present multi-layered demands on the ED (Koenig, 2003; Luther, Lenson & Reed, 2006) which is already a complex, hectic, high-pressured, and often short-staffed environment (Chartier, Cheng, Stang, & Vaillancourt; Basu, Qayyum, & Mason, 2016). CBRN events are rare (Boyd et al., 2014) resulting in first receivers being unfamiliar with the clinical assessment, containment, and treatment unique to patients who have been exposed to CBRN materials.

Patients arrive at the ED by ambulance or self-presentation. If they have been brought in by an ambulance, they receive a medical assessment and care by paramedics whilst waiting to be allocated an ED cubicle. Patients who self-present are not provided with this assessment or care (Smith, Bouchoucha, & Watt, 2016). This introduces challenges in the ED CBRN response, particularly in terms of detection, for example detecting a contaminant on a self-presenting patient at the ED triage or waiting area (Koenig, 2003).

Another associated challenge related to self-presenters and the ED CBRN response is decontamination, defined as *"The reduction or removal of harmful substances from the body"* (Levitin et al., 2003, p. 201); this is an area of ambiguity in the ED and is negatively associated with the donning of Personal Protective Equipment (PPE) (Larson et al., 2016).

Finally, the diagnosis of CBRN related symptoms is difficult due to the rarity of CBRN events and similarity with other diseases making CBRN exposure difficult to diagnose (Mcfee & Leiken, 2009).

Under preparedness relating to CBRN events is suggested to be a consequence of unclear guidance and lack of consistency across the UK, inadequate and insufficient equipment, under-resourcing, and unsatisfactory training (Hayward, 2003; Williams, Walter, & Challen, 2007). A means of enhancing preparedness is by health organisations exercising the required procedures and skills for CBRN events (Skryabina, Reedy, Amlôt, Jaye, & Riley, 2016). Emergency exercises are considered an integral component of emergency preparedness and are found to be effective at enhancing knowledge of emerging activities, policies, and procedures as well as improving overall competence. However, exercise associated improvements tend to persist over time, and translation into improved emergency response is unclear (Boyd et al., 2014; Skryabina et al., 2016). Another way of enhancing ED staff CBRN preparedness, is through training staff to respond to CBRN events (Boyd et al., 2014; Mitchell et al., 2012). Numerous studies have focused on identifying competencies and skills which need to be integrated into CBRN training (Djalali et al., 2016; Linney, Kernohan, & Higginson, 2011; Mitchell et al., 2012).

Although evidence suggests that training will enhance preparedness to effectively respond to a CBRN event (Kotora, 2015; Mitchell et al., 2012), this is not as straightforward in practice. Firstly, training feasibility can be challenging in the fast-paced ED environment owing to unpredictable factors such as staff turnover, short staffing, and increased clinical workload (Koenig, 2003). Barriers to training are identified as - lack of time and space in current training programmes, multiple competing courses or training options outside of disaster medicine, lack of funding, and a sense of complacency about the current level of training options (Schultz, Koenig, Whiteside, & Murray, 2012).

Emergency exercises and training are encouraged by the EPRR framework (NHS England, 2015a) to improve preparedness. Primarily because training and exercises familiarise staff with their roles, plans, and procedures relevant to a CBRN emergency. However, exercise and training do not guarantee an effective CBRN response or actually acknowledge how prepared first receivers are to respond to a CBRN event. First receivers are familiar with unexpected and unpredictable occurrences being a part of their daily practice and can adapt their actions accordingly.

A lack of consistency in clinical practice and processes – variability in practice between healthcare organisations, departments, and even amongst clinicians pose challenges to responding to rare CBRN events. In the context of this thesis, safe and effective patient care exceeds knowledge, skills, and the behaviours of clinicians. This is based on the diverse skill set in the ED, the presence of agency/locum staff, and constant staff turnaround.

Standardisation is *"The process of developing, agreeing upon and implementing uniform technical specifications, criteria, methods, processes, designs or practices that can increase compatibility, interoperability, safety, repeatability, and quality*" (Leotsakos et al., 2014, p. 111).

Standardisation overcomes variability by *"Setting formal rules to guide employees' activities, which are operationalised in organisations by means of work instructions, guidelines, manuals, and work procedures"* (Nissinboim & Naveh, 2018, p. 44). Standardisation aims to embed best professional practice whilst minimising the risks of variation, consequently maximising consistency of actions across teams, organisations, and the health system (NHS England, 2014).

There are numerous factors which have contributed to the limited traction of process standardisation (Leotsakos et al., 2014) in healthcare environments. An understanding of these factors is crucial to catalyse the acceptance of standardisation in healthcare. For example, standardisation is considered *"Outmoded"* (Berwick, 2003), and an extension of Taylorism promoting the scientific management movement (1911, see Chapter 3) by taking away employee autonomy to promote productivity. Standardisation in healthcare is suggested to be unsuitable for complex and unpredictable work environments (Braithwaite, Clay-Williams, Nugus, & Plumb, 2013, Wears, 2014; Wise, Duffield, Fry, & Roche, 2017). However, this thesis promotes "*The choice approach"* (Nissinboim & Naveh, 2018) to standardisation, which provides first receivers with clinical autonomy when responding to CBRN events in the ED.

The focus of this thesis are procedural standards which specify how processes are to be performed and describe the steps involved (Timmermans & Berg, 2003; Mannion & Exworthy, 2017), as represented by CBRN plans (Chapter 4). The type of standardisation to be achieved through this research is process standardisation which is "*The specification and communication of a process at a level of detail sufficient to permit consistent and verifiable implementation by different users at different times and in different settings"* (Leotsakos et al., 2014, p. 111).

Process standardisation is the most apt because of agency workers. Agency workers are described as *"Travellers"* amongst permanent ED staff (Abellanoza, Provenzano-Hass, & Gatchel, 2018) and are employed on a shift by shift basis to cover short staffing in the ED. Bajorek and Guest (2019) found that there was a preference for temporary staff with familiarity with the context, whereas unfamiliar staff were considered to be a distraction to permanent staff due to having to manage them in various ways. Although ED environments might be different to agency workers procedural standardisation and process standardisation for the ED response to CBRN events, can result in familiarity with core CBRN actions, in turn allowing both permanent and temporary staff to respond to the event in an efficient manner.

1.3 Human Factors and Ergonomics principles in the Emergency Department response to Chemical, Biological, Radiological, and Nuclear events

HF/E *"Is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance"* (IEA, 2017).

The scientific discipline of HF/E uses understanding of human physical, psychological, and social abilities and limitations to develop systems with safe, effective, and productive interactions as (re)designed tasks, environments, and tools. HF/E is widely adopted in other safety critical industries (e.g. aviation and defence) and its use is increasingly advocated as a means of improving healthcare quality and safety. HF/E aims to improve the systems of people, processes, products, and policies (Blandford, Furniss, & Vincent, 2014).

Two core HF/E principles formed the foundation of this research:

1. **Theory:** Work as Imagined vs Work as Done (WAI vs WAD).
2. **Method:** Hierarchical Task Analysis (HTA).

1.3.1 Work as Imagined vs Work as Done

It is suggested that HF/E can be applied to redesign healthcare work systems and processes to improve the safety and quality of care (Xie & Carayon, 2015). A way of improving clinical work is to comply with guidelines and policies because they represent Work as Imagined (WAI) - which is what designers, managers, regulators, and authorities believe happen, or should happen (Chuang & Hollnagel, 2017; Saurin, Rosso, & Colligan, 2017). Compliance to policies and guidelines suggests that Work as Done (WAD) which is what actually happens in the work place, are similar or identical (Chuang & Hollnagel, 2017). The concept of WAI and WAD in healthcare environments has been considered in infection prevention practice in the anaesthetic work environment (Franklin & Stein, 2017). More closer to this research, WAI and WAD has been explored in the ED in terms of escalation policies (Back et al., 2017).

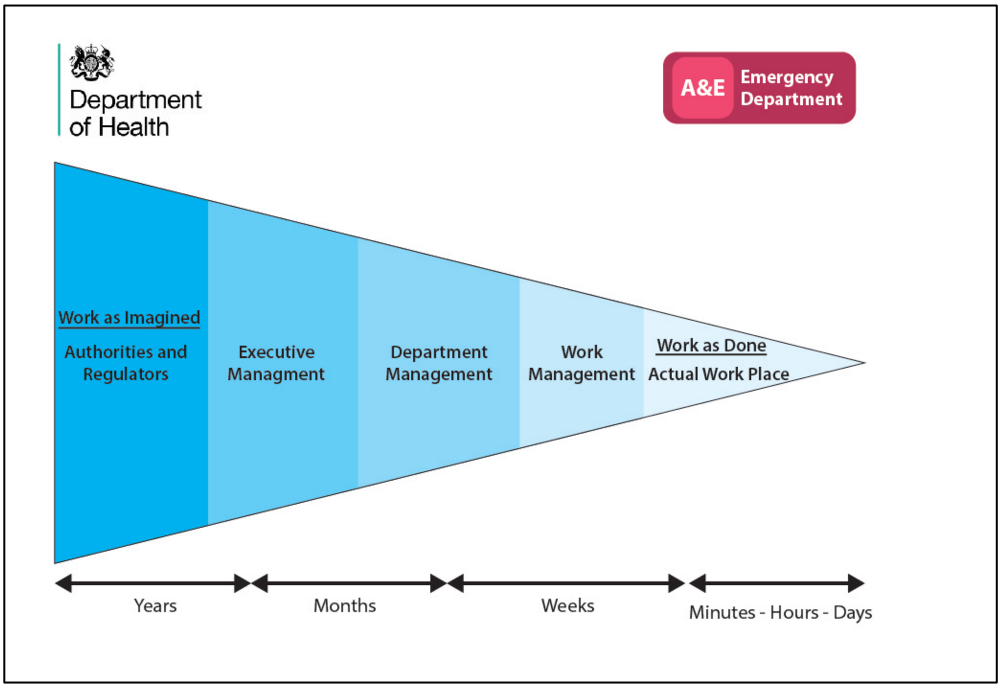

Figure 2: The sharp end and blunt end paradigm adapted from (adapted from: Hollnagel, 2015, image courtesy of Victor Jaganathan)

The dichotomy of WAI and WAD in the workplace dates back to the 1950s when the difference between prescribed work (the task) and the real work (the activity) was described (Leplat & Hoc, 1983; Ombredane & Faverage, 1955; Daniellou, 2005; Wisner, 1995). A key component of the WAI and WAD concept is that of *"The sharp end and the blunt end"* (Figure 2). By the 1980s it was becoming clear that most failures made at the sharp end were a result of working conditions and the nature of the task rather than *"Human error"*, and there was a need to describe how these failures came about. Accordingly, the sharp end-blunt end model was introduced to describe the events leading to failures and accidents (Hollnagel, 2015;

Hollnagel, 2004). People working at the sharp end are working at the time and place where the work is done; they actively carry out the daily work and experience it directly.

When people at the sharp end are working, feedback or response arrives instantly and their understanding of what occurs is detailed and precise. On the other hand, the blunt end of the spectrum is separated from the sharp end by time and space. The blunt end represents people who influence how work is done, in terms of safety, how work should be organised and planned, and how resources should be allocated. People at the blunt end do not actively take part in the daily work and therefore experience it indirectly. The response or feedback when they try to experience work at the sharp end is delayed. Individuals at the blunt end rely on information which is filtered. Their priority may still consist of managing the work, but this happens at a distance (Hollnagel, 2015).

In the context of this thesis, the sharp end and blunt end is not being implemented to highlight failures and accidents. Rather, the sharp end – blunt end analogy is being used because factors at the blunt end influence and drive care delivered at the sharp end (Marshall, 2016; Wears & Leape, 1999). The sharp end and blunt end in this case, graphically illustrates the differences between WAI and WAD and thus can be used as a means of highlighting misalignments, in terms of compliance to guidelines in the form of CBRN plans. Chuang & Hollnagel (2017) however suggest that absolute compliance to guidelines is unrealistic. This is because, frontline staff - people at the sharp end - improvise and adjust their work to the situation. These improvisations are not non-compliance, rather they are needed for work to be carried out under varying and unpredictable circumstances (see Section 1.3.4, p. 19).

The unpredictability of the ED environment can be an obstruction in usual clinical practice entirely based on clinical recommendations, which are instilled by Trust policies (documents that describe a series of actions or activities to achieve the end result) (Clay-Williams, Hounsgaard, & Hollnagel, 2015). This means that WAD on the front line of patient care is not synonymous with WAI by those who create policies and guidelines (Hollnagel, 2011).

1.3.2 Hierarchical Task Analysis

Hierarchical Task Analysis (HTA) is a central method of analysis in HF/E. HTA describes a task as a higher-level goal with a hierarchy of superordinate and subordinate tasks. At each level of the subtasks, a plan directs the sequence and possible variance of task steps (Shepherd, 2001). HTA has been suggested to be an effective way of stating how work should be organised to meet a system's goals (Kirwan & Ainsworth, 1992).

HTA is increasingly used in safety critical environments such as aviation (Morowsky & Funk, 2016), transport (Wang & Fang, 2014), medicine management (Allitt, Kirby, & Hignett, 2017), and surgery (Demirel et al., 2016; Sarker, Chang, Albrani, & Vincent, 2008).

One novel contribution of this thesis is the use of HTA as the main method to form a better understanding of how:

1. The ED as a complex system responds to CBRN events.

2. First receivers are expected to respond to CBRN events.

3. First receivers actually respond to CBRN events.

An in-depth explanation of the development and critique of HTA is provided in Chapter 3.

1.3.3 The systems approach

In order to unpack the ED response to CBRN response, it is important to understand the systems theory, and how it is embedded in this thesis. The systems theory is rooted in the 1920s when Bertalanffy carried out studies in theoretical biology and recognised organisms as systems, made up of the organisation of parts and processes (Drack, 2015). Bertalanffy suggested that the systems approach goes back into Aristotle's Metaphysics (Bertalanffy, 1972; Bertalanffy, 1950).

In the 1950s Bertalanffy, criticised the traditional positivist-reductionist view of science which consisted of isolated elements as failing to represent the behaviour of the whole system. In his new transdisciplinary approach, Bertalanffy proposed a mechanistic view in which living things were divided into individual parts and life processes were considered in line with their subprocesses. In line with individuals in the field of Cybernetics, Bertalanffy, (1950) pushed for a "*Unification of science*", and a need for *"General superstructure of science"* which was called the General Systems Theory (GST), and was based on logico-mathematical foundations.

The GST describes the behaviour of systems, independent of the nature of their components. GST has been described as *"A level of theoretical model-building which lies somewhere between highly generalised constructions of pure mathematics and the specialised disciplines"* (Boulding, 1956, p.197). Bertalanffy, 1972 defined a system as *"A set of elements standing in interrelation among themselves and with the environment"* (p.417). GST consists of the scientific exploration of the wholeness, through novel concepts, methods, and mathematical reasoning; combined with the interdisciplinary notion of concepts, models, and principles contributing to the unification if science (Bertalanffy, 1972).

Mathematically based systems theories were developed and applied to disciplines such as engineering, operations research, and ecology. Non-mathematical systems theories were also developed and were more applicable to disciplines such as economics, sociology, political sciences, and psychology (Schwaninger, 2006).

The Socio-technical System was developed by members of the Tavistock Institute of Human Relations (e.g. Emery, 1959; Trist, 1959). The STS approach resulted from insight into successful coal mining practice (Trist, 1981; Trist, Higgin, Murray, & Pollock, 1963) through which Trist visualised a new paradigm of work as *"One that would effectively blend the requirements of both the technical and social systems"* (Fox, 1995, p.92), in which there are complex systems of interrelated human and technological components.

Research from an STS perspective was encouraged on three interrelated micro to macro system levels, consisting of *primary work systems* which consist of the work activities in the bounded subsystem of the whole organisation. *Whole organisation systems* which consist of the workplace organisation that maintains a steady state of their environment; and the *macrosocial system* which includes communities and institutions operating at the overall level of a society (Trist, 1981).

1.3.3.1 System approach components

Despite the vast literature on the systems theory, Waterson (2009) highlighted that defining the core components of the systems approach is a difficult task based on the lack of agreement amongst researchers. However, system structure, component relationships, and behaviour are core concepts within the literature (Underwood, 2013) as shown in Figure 3 (p. 14).

1.3.3.1.1 System structure

A system is a complex of interacting elements (Bertalanffy, 1950). A reason behind using the systems approach in this thesis is because systems represent a hierarchy of subsystems that are formed to perform specific functions (Skyttner, 2005). When examining work systems, Vicente (1999) highlighted the importance of understanding the connections between the levels as a means to understand the whole system – by moving up the hierarchies a deeper understanding of the systems goals and purpose is achieved. By moving down the hierarchy a more detailed explanation of the systems functioning to reach the goals and purposes is achieved.

1.3.3.1.2 System component relationships

Leveson (2011) described complex systems as a hierarchy of levels of organisation in which levels are characterised by having emergent properties such as safety. In order to understand the whole system, individual parts must be studied (Gibson, 1979). The whole is more than the sum of the parts and the combination of these parts is dynamic, at times unpredictable and or chaotic (holism) (Sinclair, 2007; Waterson, 2009). Although system elements are independent elements, they cannot be considered in isolation.

1.3.3.1.3 System behaviour

Skyttner (2005) suggested that to achieve a systems goals, inputs are converted to outputs through transformation processes. Systems components are controlled through feedback mechanisms when deviations occur. Dynamic system behaviour suggests the principle of equifinality in which the same outcome can be achieved from a variety of starting conditions, along with the principle of multifinality in which there is a potential of a number of outputs from the initial staring point. Having dynamic characteristics also means that systems can adapt to changing conditions.

Adaptability can be considered beneficial from a safety-II (Section 1.3.4, p. 19) perspective in which adaptive performance outside procedures at the sharp end in Complex Socio-technical Systems (CSS) is vital to cope with variation and unexpected events (Rankin, 2017). However, the adaptations can potentially expose new vulnerabilities within the system and can result in failures (Dekker, 2011).

System elements do not operate in isolation and their actions must be placed within the context (Underwood & Waterson, 2014). The characteristics of living organisms is that they are on open system based on the inflow and outflow of material (Bertalanffy, 1950). Socio-technical systems are considered open systems which interact with the environment, and their level of entropy (the amount of order within a system) can vary.

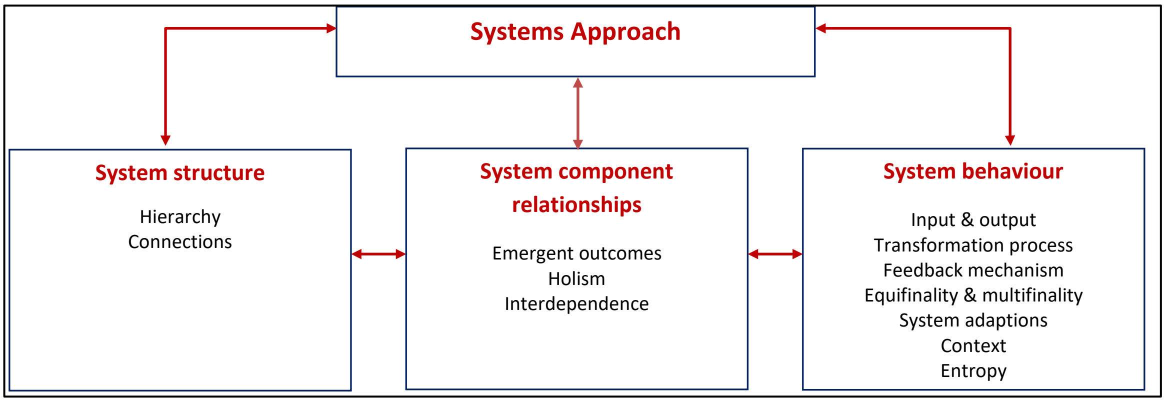

Figure 3: Core components of a systems approach (adapted from (Underwood & Waterson, 2014)

Over the years, core components of the systems theory have been developed, extended, adapted, and been applied to healthcare because delivering safe care to patients in complex, pressurised, and fast-paced environments is challenging (WHO, 2017a).

Leveson, Dulac, Marais, and caroll (2009) combined the system engineering and HF/E contributions of Dekker 2005, Hollnagel 2004, and Rasmussen 1997 to technical and organisational safety in which the characteristics of a systems approach consists of:

- Top down systems thinking which recognises safety as an emergent system property rather than a bottom up summation of reliable components and actions.
- Focused on the integrated socio-technical system as a whole and the relationships between the technical, organisational, and social aspects.
- Focused on providing ways to model, analyse, and design specific organisational safety structures rather than trying to specify general principles that apply to all organisations.

There are limitations with the characteristics proposed by Leveson et al. (2009). Although patient safety is an emergent systems property, the emphasis of a top down approach limits the potential in achieving a systems understanding of work done at the sharp end. This thesis uses principles of the systems approach to provide an understanding informed by first receivers from a bottom up perspective to change practice at the sharp end of clinical practice. The emphasis of only a top down approach jeopardising the applicability of a systems approach by healthcare professionals at the sharp end has further been raised by Cross (2018).

The integration of technical, social, and organisational relationships of the systems approach mirror the relationships in the ED as a complex socio-technical system, providing a strong foundation to meet the first aim of this thesis when combined with HTA. However, clarity in what accounts for the technical component of the approach is required. As suggested by Pasmore, Winby, Mohrman, & Vanasse (2019) the idea of joint optimisation between social and technical systems requires continuous change and adjustment, rather than designing a system around a fixed technology. In emergency response research, a key finding is that technical components consist of unique tasks such as decontamination, and traditional technological associated components (e.g. computer systems) are expected to fail. Therefore, consideration to the expansion and adaption of the definition of CSS components and relationships can be beneficial, moving forward.

The focus of the systems approach to design specific organisational safety structures is a concept which will result in patient safety in a variety of contexts. However, dismissing general principles limits the level of potential patient safety achievable through standardisation in the context of emergency response literature. CBRN events are rare, based on this, standardised actions based on data from top down and bottom up perspectives are proposed to be very important in achieving patient safety in a CBRN emergency.

The implementation of the systems approach in healthcare is advantageous (Clarkson, Dean, Ward, Komashie, & Bashford, 2018) because it compartmentalises as well as highlights interactions in work systems. However, this thesis suggests that the systems approach should be extended and place equal importance on top down and bottom up information, as well as reconsidering the definition, boundaries, and the relationship of the technical component of the approach in CSS and emergency response research.

Based on the importance of the system structure, relationships, and behaviour; combined with the limitations of the systems approach characteristics in the context of emergency response research, this thesis implements the suggestions by Vicente (1999) which contribute to work systems and are applicable to healthcare as suggested by Carayon (2006). Most importantly these factors are applicable to work system complexity factors in the ED response to CBRN events as shown in Table 1 (p. 17).

Table 1: Complexity of work systems (adapted form Carayon, 2006; Vicente, 1999)

Complexity dimension	Definition	Application to healthcare	Application to the ED response to CBRN events
Large problem spaces	Many different elements and forces.	Approximately 500,000 illnesses.	CBRN exposure spanning across international boundaries.
Social system	Consists of a large number of people who have to work together to make the overall system function.	Healthcare organisations, staff, patients, and families.	First receivers in the ED working together: Doctors, nurses, allied healthcare professionals, medical physicists, porters, and security officers.
Heterogenous perspectives	Workers with different backgrounds and disciplines.	Different disciplines and cultures i.e. hierarchical relationships.	Perspectives of ED first receivers, varying hospital specialities, ambulance first responders, fire, and police personnel.
Distributed systems	People located in different places.	Home health care such as community nurses.	Gold, Silver, and Bronze response being in different locations.
Dynamic system	Delay in effects of actions taken.	Preventative care.	Isolation of potential patients to contain spread.
Hazardous system	Potential catastrophic consequences (e.g. economic, social, and environmental).	Drug administration errors.	Cross-contamination of first receivers.
Coupling	Composed of many interacting sub-systems which are highly coupled.	Cancellation of elective surgery because allocated bed taken by an emergency surgical patient.	Delay or absence in carrying out physiological observations because decontamination is priority.
Automation	Highly automated with computer/algorithms controlling the system.	Using automated systems e.g. radiology.	Using automatic patient systems with the risk of the system being overwhelmed.
Uncertainty	Uncertainty in data available to workers.	Variation in patient characteristics.	Symptomology of CBRN exposure mimicking other ailments.
Mediated interaction	System is not observable by those who work in it.	Using medical technologies to carry out tasks such as endoscopic technologies.	Using Ram Gene monitors to measure radiological exposure.
Disturbances	Workers are responsible for dealing with unanticipated events.	Unexpected events such as drug errors.	Self-presenting CBRN exposed patients.

By adopting a systems approach in this thesis, an insight into how actions or occurrences at one level (e.g. first receivers) collectively interact with teams (e.g. decontamination team) and organisational (e.g. operational response) levels of analysis, which provides an in-depth insight into how patients can be optimally cared for during a CBRN emergency.

The association between systems thinking and task analysis is that systems have purposes and tasks have goals (Shepherd, 2001). In the context of this thesis HTA was used effectively to present a thorough examination of the ED as CSS through two means 1) By establishing how sub-systems relate to one another hierarchically and 2) In terms of information flow, control, and feedback through the sub-systems both from a top down and bottom up perspective.

The systems approach is often associated with accident analysis research (Salmon, Cornelissen, & Trotter, 2012; Underwood & Waterson, 2014), limiting the analytical potential of the systems approach. This thesis used the systems approach to understand organisational culture, processes, in line with the environment, technologies, and human behaviour as as suggested to be useful at the sharp end by Smith & Plunkett (2019).

This section has highlighted the development of the GST, and how principles have been combined and adapted to form core components of a systems approach. Healthcare is delivered in CSS, and the ED is a CSS. Limitations with systems approaches in the context of this thesis have been discussed and factors crucial to composing the complexity of work systems have been established as the foundations of this work.

Specifically, The Chartered Institute of Ergonomics and Human Factors (CIEHF, 2018) Human Factors for Health and Social Care White paper proposal of the systems approach has been adopted in this thesis. Systems are a set of activities or entities, such as hardware, software, buildings, spaces, communities, and people that have a common purpose. Systems can consist of individuals performing a single task using a tool (micro-system), or people working as a team (meso-system) or consisting of tools, people, spaces, hardware, and communities (macro-systems).

1.3.4 Safety in healthcare

The World Health Organisation (WHO) suggests that in order to provide a high quality of care to patients*, "Healthcare must be safe, effective, timely, efficient, equitable and people centred"* (WHO, 2017b). The optimisation of patient safety is the goal of healthcare and is a central activity for all healthcare professionals (Smith & Plunkett, 2019).

Historically, patient safety and quality of care moved to the forefront of British healthcare as a result of detrimental mishaps dating back to 1998 in which the Bristol Royal Infirmary was initiated to investigate the higher mortality rate (double in comparison for other centres in England) for open heart surgery on children under the age of 1 (Dyer, 1998; Kennedy, 2001; Spiegelhalter, Aylin, Best, Evans, & Murray, 2002).

During this time the US-based Institute of Medicine (IOM) published a report titled "*To err is Human: building a safer health system"* (IOM, 2000) calling for an international effort to make health care safer and improving the quality of care (Leape, Berwick, & Bates, 2002) by "S*ystematically designing safety into the process of care"* (IOM, 2000, p.ix). The publishing of this report resulted in patient safety becoming a focus for governmental and professional regulatory bodies, media, health care organisations, and concerned citizens as well as a means of stimulating research and discussion regarding patient safety issues (Leape & Berwick, 2005; Stelfox, 2006).

Despite awareness of the need to make healthcare safer, medical fatalities resulting from inconsistencies that ignore systemic issues in decision making processes still occur and attract a high-level of media attention. For example, the case of Dr Bawa Garba, which resulted in the death of a 6 year old boy (Samanta & Samanta, 2019). HF/E as a discipline aims to design safe systems of healthcare (Nolan, 2000) and many approach patient safety through different domains such as technology usability, the role of healthcare worker performance in patient safety, and HF/E approaches to patient safety (Carayon & Wood, 2010; Carayon et al., 2014).

A prominent HF/E approach to patient safety is the concept of safety-I and safety-II proposed by Braithwaite, Wears, & Hollnagel, (2015). Developed from the Euro control White Paper in 2013 (Hollnagel & Leonhardt, 2013) and Resilience Engineering (RE) which emphasises the notion of the world becoming more complex (Hollnagel, Woods, & Leveson, 2006). Safety-I proposes that work systems can be decomposed, and the systems components function in a bimodal way which either works correctly or incorrectly. Safety-I manages safety by ensuring *"As few things as possible go wrong"* and presents a reactive risk management principle. Humans in this approach are considered a liability in the system. Safety-I was a suitable approach in the 1960s in which the view of safety became widespread in safety critical industries such as aviation, in which systems were simpler. However, such stable system descriptions no longer fit current complex socio-technical health systems in which the environments cannot be decomposed effectively, and in which functions are not bimodal.

Hollnagel et al. (2015) proposed that complex clinical work requires some variability and flexibility. The proactive safety-II approach ensures *"As many possible things go right"* which highlights humans as a necessary resource in the system who provide flexible solutions to potential problems to succeed. The assumption underlying safety-II is that everyday performance variability provides the adaptions that are needed to respond to varying conditions and are the reason why things go right.

The safety-I and safety-II way of thinking are linked to how Work is Imagined and how Work is Done. Historically, WAI is associated with the scientific management movement (see Chapter 3) which through observing work demonstrated how the breakdown of tasks could be used to improve work efficiency. Scientific management provided a theoretical and practical foundation for the notion of WAI being necessary and a sufficient basis for WAD. Although safety was not the focus during the scientific management era, it provided foundations for investigating adverse events by looking at the work components to identify those that had failed through root cause analysis (Hollnagel, 2015); pushing the idea that safety could be improved by careful adherence to procedures – and that safety could be achieved by ensuring that WAD is identical to WAI. However, this view is challenged in current unpredictable work environments, in which WAD is different to WAI.

Further, safety-I proposes that when things go right, it is because the system is functioning as it should and people Work-as-Imagined, when things go wrong it is a result of something malfunctioning or failing. This way of functioning which places blame on people doing the work, which defeats the objective of HF/E designing safe systems of healthcare as people within the system will always present as a liability.

Hollnagel et al. (2015) propose that things go well in WAD because people adjust according to the demands of the situation (Safety-II). Which is a more applicable view in the realm of healthcare as there is variability in terms of patient presentations, healthcare worker skillset and experience, as well as organisational variability.

It is also suggested that what people do in everyday work is a combination of safety-I and safety-II and the balance depends on factors such as the nature of the work, experience, and patient pressures (Hollnagel, 2015). With characteristics of safety-I to simplify, automate, and standardise and Safety-II aiming to understand how people respond to risks at work and create safety (Vincent, 2010). A combined approach to achieving patient safety in the ED CBRN response is the basis of this thesis.

1.4 Research aims and objectives

Based on the complexity of the ED, the reported under preparedness of EDs responding to multifaceted CBRN events combined with the applicability of HF/E in both healthcare research and environments this PhD aims to:

1. Explore whether Hierarchical Task Analysis could be used to map complex socio-technical systems.

2. Make recommendations to improve the Emergency Department response to Chemical, Biological, Radiological, and Nuclear events.

The objectives of this research are:

1. To systematically review the ED response to CBRNe events relative to detection, decontamination, and diagnosis in terms of self-presenting patients.

2. To apply a pragmatic and generic qualitative approach to meet the aims of this research.

3. To use HTA to unpack the current ED CBRN response in terms of NHS CBRN plans (WAI).

4. To use HTA to understand current ED CBRN response practice (WAD).

5. Combine WAI and WAD to propose standardised CBRN response recommendations.

1.5 Research questions

The following research questions are derived from the aims and objectives of this research process:

1. What is known about the ED CBRNe response with respect to detection, decontamination, and diagnosis of self-presenting patients?

2. Which research methodology, methods, and design can be used to understand the ED response to CBRN events?

3. How are first receivers expected to respond to CBRN events according to CBRN plans?

4. How do first receivers anticipate responding to CBRN events?

5. What are the common and varying factors between WAI and WAD in the ED CBRN response?

1.6 Structure of the thesis

The thesis structure is illustrated in Figure 4 (p. 25). The thesis is comprised of eight chapters which are summarised below.

Chapter 1: This chapter provides an overview of the research. An outline of the legislative responsibilities, and the issues in implementing legislation in the ED are discussed. The research problem is introduced and core HF/E principles as a means of addressing the research problem are discussed. The research aims and objectives, research questions, and the structure of the thesis then follow.

Chapter 2: Presents a systematic review which focuses on the problems of detection, decontamination, and diagnosis of CBRNe presentations in the ED. This chapter sets clear boundaries and a definition of CBRN events which is used throughout the thesis.

Chapter 3: The third chapter presents the general methodology of the research.

Chapter 4: This chapter presents the first study of this research. Work as Imagined is combined with detailed document analyses (CBRN plans) to form HTA representations of the *"Blunt end"* of the ED response to CBRN events. Thematic analysis is implemented with colour coding HTA representations of CBRN General Organisational Responsibilities (GOR) and first receiver action cards.

Chapter 5: The fifth chapter is based on the second study of this research. The second study implements semi-structured interviews (n=57) and the use of expert verified CBRN scenario cards to represent Work as Done in the *"Sharp end"* of the ED response to CBRN events. The responses are converted to HTA representations and thematically analysed (colour coded) in line with the field notes.

Chapter 6: This chapter presents a synthesis of the findings from study 1 and 2 as a comparative review. A comparison between WAI and WAD within and between

Trusts is made as a means of formulating evidence based standardised recommendations to enhance the ED response to CBRN events.

Chapter 7: This chapter discusses the contributions of WAI vs WAD as a theoretical framework. The adaptability of HTA as a systems mapping tool in healthcare in terms of systems thinking and multiple level comparisons. The challenges of detection, decontamination, and diagnosis are met with the findings of the research. Four standardised recommendations to enhance the ED CBRN response are provided followed by the limitations of the research.

Chapter 8: The eighth chapter provides insights, implications, the impact of findings, contributions to knowledge, application to policy and practice, and opportunities for future work.

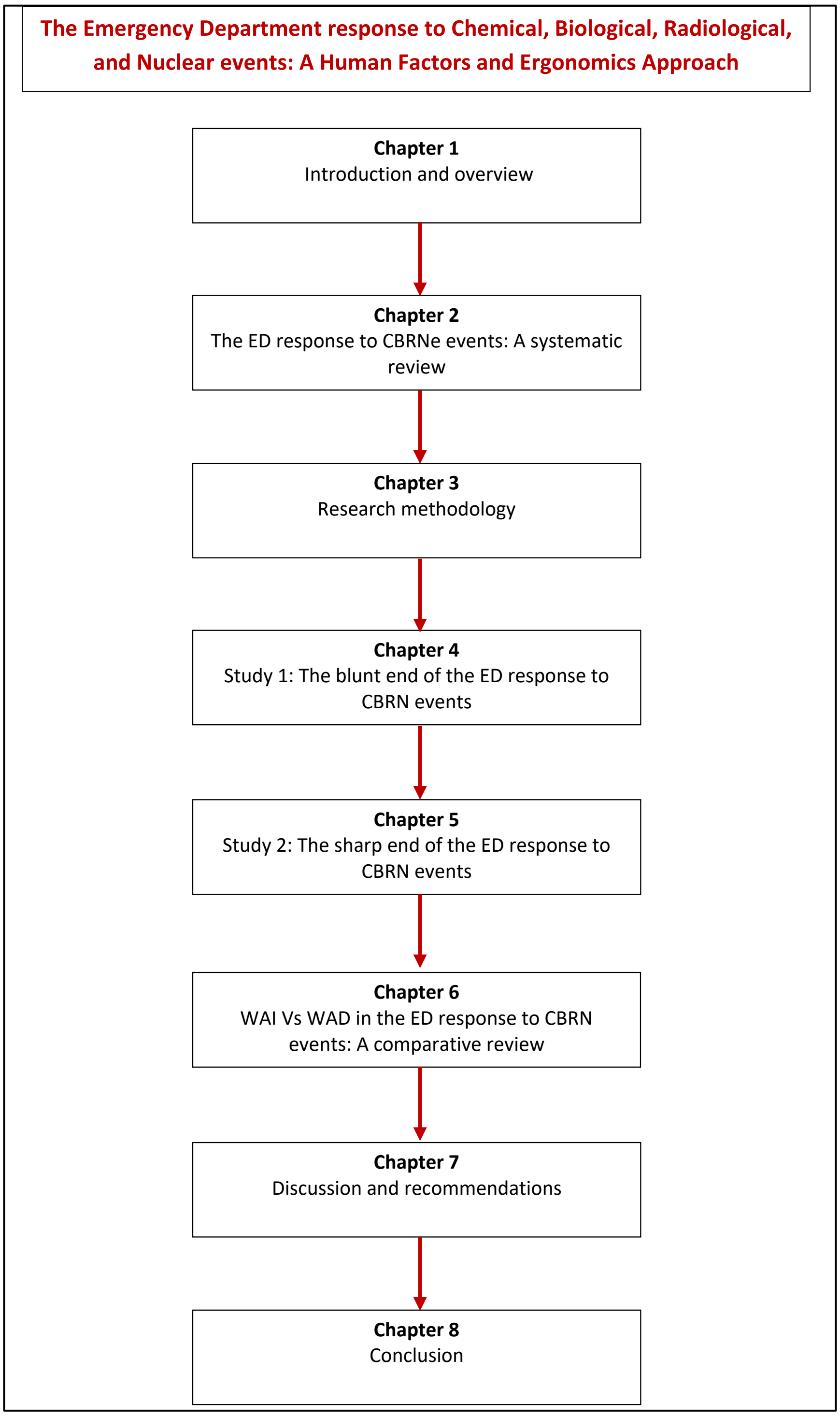

Figure 4: Outline of thesis

Chapter 2. The Emergency Department response to Chemical, Biological, Radiological, Nuclear and explosive events: A systematic review

"There are no health emergencies, all emergencies have health aspects"

(Sellwood & Wapling, 2016)

2.1 Introduction

A systematic review was carried out as a means of providing focus to set the scope to unpack the Emergency Department (ED) response to Chemical, Biological, Radiological, Nuclear, and explosive (CBRNe) events. CBRNe events occur through natural, accidental, and deliberate means (Chilcott & Wyke, 2016). These events present a threat to human welfare by causing, or having the potential to cause, injury, illness, or loss of life, and they can result in a large number of casualties. Emergency Departments (EDs) have statutory duties and responsibilities to prepare, plan, and respond to CBRNe events adequately (Cabinet Office & The Civil Contingencies Act, 2004).

The ED environment is unique, in both staff structure and the presentation of patients. This is further complicated by the multifaceted nature of CBRN events requiring a combined clinical and non-clinical response. The roles of first receivers differs from first responders, in recognising, detecting, decontaminating, diagnosing, and treating victims of CBRNe events and include doctors, nurses, allied healthcare professionals, and non-clinical staff for initial recognition (receptionists), cordon control (security), and general support (estates/porters) during the CBRNe response (Bland, 2006).

A point to note is that some of the sections are extracted from the published version of this systematic review: Razak, S., Hignett, S., & Barnes, J. (2018). Emergency

Department Response to Chemical, Biological, Radiological, Nuclear, and Explosive Events: A Systematic Review. *Prehospital and Disaster Medicine, 33*(5), 543-549.

This chapter aims to fulfil the following research objectives:

2.1.1 Research objective

1. To systematically review the ED response to CBRNe events relative to detection, decontamination, and diagnosis in terms of self-presenting patients.

2.1.2 Research question

The systematic review aims to answer the following research question:

What is known about the ED CBRNe response with respect to detection, decontamination, and diagnosis of self-presenting patients?

2.1.3 The problem

It is reported that after a CBRNe incident approximately 20% of the casualties remain at the incident site, with 80% moving to seek medical input or go home (Kenar & Ortatatli, 2013). For first receivers, the most challenging scenario is a contaminated patient self-presenting at the ED triage or waiting area (Dudley, 2003; Koenig, 2003; Subbarao, Bond, Johnson, Hsu, & Wasser, 2006).

Detection is a challenge in the ED CBRNe response, nurses find it difficult to recognise potentially lethal hazards such as anthrax and cyanide exposure due to their rarity (Leiba et al., 2006). Becker and Middleton (2008) found that although ED staff felt that they could use detection equipment during an incident, they were unfamiliar with its use. In order to detect harmful substances a variety of analytical techniques must be used, such as extraction procedures, liquid chromatography, electrochemistry, and fluorescence spectroscopy (Hakonen, Andersson, Schmidt, Rindzevicius, & Käll, 2015).

Another associated challenge related to self-presenters and the ED response is decontamination, which is defined as *"The reduction or removal of harmful* *substances from the body"* (Levitin et al., 2003). This is an area of ambiguity. A common assumption made by healthcare professionals is that the majority of decontamination will occur at the event site (hot zone), by ambulance or fire crews. A further challenge for ED staff is the risk of secondary contamination (Larson et al., 2016). However, in previous major incidents minimal decontamination has occurred on scene, so it is pivotal for EDs to be prepared to carry out the majority of decontamination (Auf Der Heide, 2006; Vogt & Sorensen, 2002).

The diagnosis of disease by pattern recognition is a key medical skill (Byers, Russell, & Lockey, 2008). Diagnosing CBRNe related ailments is challenging, again due to the rarity of CBRNe incidents, and limited clinical exposure. Further, the physiological symptoms of CBRNe exposure mimic other diseases making diagnosis more challenging (Mcfee & Leiken, 2009).

The purpose of this review was to scope the ED CBRNe response with respect to detection, decontamination, and diagnosis of self-presenting patients to identify key factors which can inform future CBRN planning and evidenced based recommendations to enhance the ED CBRN response (Chapter 7).

2.1.4 Method

The seven-stage framework was used in line with the Preferred Reporting Items for Systems for Systematic Reviews and Meta-Analyses (PRISMA) statement. This provides structured guidance on the development of appropriate research questions, as well as on the eligibility of search criteria, and the identification, selection, retrieval, appraisal, and synthesis of relevant papers according to title and abstract.

2.1.4.1 Eligibility

References were screened at the first stage by setting the database parameters to all languages (English abstract), dated 2001 - 2016, worldwide, and any study type.

2.1.4.2 Literature searches

The search started by scoping and exploring concepts related to the research question (Section 2.1.2, p. 27). The practical step of meeting a postgraduate librarian at Loughborough University Library to obtain her expertise on how to conduct a thorough literature search was also taken. This review was a global consideration of the ED response to CBRNe events, optimal searching was ensured by using a trial and error technique (Appendix 1, p. 277). For example, emergency department was replaced with accident and emergency or the emergency room or ED with A&E; the terms were mixed and matched until the most relevant searches resulted. Search terms were also identified by professional experience as an Emergency Department Practitioner (EDP).

The search was divided into four areas to combine environment (A), areas of exploration (A+B) context (A+B+C), and types of patients (A+B+C+D):

A. Emergency Department, Accident and Emergency, and Emergency Room.

B. Detection, Decontamination, and Diagnosis.

C. CBRNe, CBRN, Mass-Casualty Incidents [MCI], and MCI.

D. Walking Wounded, Priority 3 (P3; mobile with minor injuries), and self-presenters.

An initial set of keywords was tested in BNI (NHS Evidence; National Institute for Health and Care Excellence) and Google Scholar using the string searches in Figure 5 (p. 30).

1. (hospital OR emergency department OR ED OR accident and emergency dep* OR A&E OR self present OR self presen* OR walking wounded OR p3) AND (CBRN OR CBRNE OR mass casuality inciden* OR mass casuality event OR mass casua*) AND (detection OR decontamination OR diagnosis OR equipment OR technologies) NOT (teaching or training or education)
2. (hospital OR emergency department OR self present*) AND (CBRN OR CBRNE OR mass casual*) AND (detection OR decontamination OR diagnosis) AND (equipment OR technologies) NOT (training OR teaching OR education)
3. hospital OR emergency department OR ED OR accident and emergency dep* OR A&E OR self present OR self presen* OR walking wounded OR p3 OR patient* AND cbrn OR cbrne OR mass casualty inciden* OR mass casualty event OR mass casua* AND detection OR decontamination OR diagnosis AND equipment OR technologies OR tech* AND NOT teaching

Figure 5: Example of string searches

2.1.4.3 Screening and choosing papers

Titles and abstracts of 1,874 papers were reviewed; any duplicates and irrelevant papers were disregarded. Papers were considered irrelevant if they were clinical guidelines, suggestions, studies not based in the ED or not based on CBRNe events. A summary of this process can be seen in Table 2 (p. 31). Where it was unclear by reading just the abstract whether or not the paper was suitable for inclusion, the full text article was retrieved read, and considered with the inclusion and exclusion criteria (Section 2.1.4.4, p. 32).

Table 2: Search results from databases

Database	Results	Reviewed by title	Reviewed by abstract
Abstracts in technology and engineering (Proquest)	0	0	0
ASSIA (NHS evidence)	1	1	0
Bioanalysis-future science	0	0	0
Biomolecular detection and quantification	0	0	0
BNI (NHS evidence)	535	465	70
Cambridge	245	230	60
Chemical Database service	1	1	0
Detection-Scientific research	0	0	0
Encyclopedia of healthcare management	0	0	0
Ergonomics Abstracts	0	0	0
Google Scholar	331	305	66
Health Management technology (EBSCO)	1	1	0
Journal of breath research-IOP science	16	15	0
Medline (Ovid SP)	217	204	53
Psych Info (EBSCO)	12	10	7
Referex- Materials and mechanical engineering (Engineering village)	2	2	0
SAE- digital library-technical papers	0	0	0
Scopus (Elsevier)	8	5	5
Science Direct	406	400	71
Toxline	15	12	4
Trends in analytical chemistry	0	0	0
Web of Science	84	79	30
Total	**1,874**	**1,730**	**366**

2.1.4.4 Inclusion and exclusion criteria

In order to be included in the review, papers had to adhere to the following criteria:

Table 3: Inclusion criteria

Type of study	Any.
Date of research	After 2001.
Environment	Emergency Department only.
Participants	Humans, Emergency Department staff, specialist staff who would partake in a CBRNe event- surgeons/anaesthetists/operational managers, ED chiefs.
Situation	CBRNe, chemical or biological or radiological or nuclear or explosive incident. Mass casualty incident by the intentional release of these materials, ED triaging.
Actions	Detection/decontamination and diagnosis in ED. Donning PPE in ED.

Papers were excluded if they were:

Table 4: Exclusion criteria

Type of study	Guidelines, textbooks, scientific studies of the effects of CBRNe materials i.e. physiological and chemical pathways.
Date of research	Before 2001.
Environment	ITU, wards, hot zone, pre-hospital response. Hospital in which the Emergency Department is not mentioned.
Participants	Specified patient groups i.e. chronic ailment patients, paediatric patients.
Situation	HAZMAT, natural disasters, aerospace disasters, overcrowding disasters, pandemic outbreaks (h1n1/influenza), hot zone triaging. National preparedness/homeland security. Mass casualty infections i.e. hepatitis C outbreak in immigration. SARS epidemic/not related to CBRNe. Pre-hospital response/triage.
Actions	Detection, Decontamination and diagnosis in hot zone. Donning PPE in hot/warm zone. Psychological/psychosocial effects of CBRNe incidents. CBRNe terrorism not related to the ED.

2.1.4.5 Selection and retrieval

The search identified 1,874 papers which were screened by title and abstract and checked for duplication, resulting in 366 papers. Articles that did not adhere to the inclusion criteria were disregarded while simultaneously adding (23) relevant studies through manual citation searches. This resulted in the quality of 67 articles being assessed with the Mixed Methods Appraisal Tool (MMAT) (Pluye, Gagnon, Griffiths, & Johnson-Lafleur, 2009).

2.1.4.6 Critical appraisal

As a variety of methodologies were used in the papers included in this review, the MMAT (Pluye et al., 2009) was used to assess the methodological quality of the included papers. The MMAT provides five categories of studies (qualitative, quantitative, and mixed methods studies) and the criteria against which each type of study can be measured.

A pilot study of the MMAT (Pluye et al., 2009) suggested that while it is a relatively new tool, it is reliable (Pace et al., 2012). There is also a lack of an alternative tool which would be suitable for use in a mixed studies review. As a means of trying to increase the methodological quality of the papers used in this review the Downs and Black (Downs & Black, 1998) checklist for methodological quality of randomised and non-randomised studies of health care interventions was planned to be used. However, although most of the studies included in the review were non-randomised, most of the studies were not intervention or patient based, thus disregarded.

For this reason, the MMAT was used in this review. Included papers were given methodological quality scores of 0-4 and (0-100%), depending on how many of the criteria they met. A score of 0 indicated that no criteria were met, and a score of 4 (100%) indicated that all criteria were met. Papers that scored 0 or 1 were discarded as the methodological quality of the studies was too poor for inclusion. An extract of the table completed when scoring papers using the MMAT is shown as Table 5 (p. 35), (MMAT Table: Appendix 2, p. 279; Table of included studies: Appendix 3, p. 283). The reliability and validity of the papers is addressed in the discussion of this systematic review (Section 2.1.7, p. 48). The definitions of reliability and validity as proposed by Noble & Smith (2015) are applied to the studies in the discussion as follows:

Validity: The precision in which the findings actually reflect the data.

Reliability: The consistency of the analytical procedures, which includes accounting for personal and research method bias that may influence the findings.

Table 5: Extract of MMAT score table

	First author, (year), Country	Study type	Population and setting	Inclusion/ Exclusion	Aim	Study Design	Outcomes measured	Key Findings	Statistical outcomes (If applicable)	MMAT Score
1	Al-Damask & Bleetman, (2005), UK.	Descriptive survey.	192 Hospital 32 Ambulance Trusts.	Not specified.	Assess the impact of DoH initiative on acute hospital and ambulance trusts to equip and manage chemically contaminated causalities.	Survey to assess progress in specific areas of chemical incident preparedness. 2 simulated incidents with live chemically contaminated casualties.	Survey results and performance in simulated incidents.	Improvement in many aspects of preparedness for chemical incidents. Practical difficulties exist with PPE suits.	N/A	2 (75%)
2	Anathallee et al., (2007), UK.	Descriptive survey.	261 hospitals with ED. Duty sister/ charge nurse/Duty shift leader.	Not specified.	Assess current facilities and procedures in EDs in the UK for the management of potential biological incidents.	Telephone survey.	Hospital characteristics, facilities for isolation of patients presenting with potential infectious diseases. Procedures for management of patients of known infectious diseases.	Complete data from 203 hospitals. EDs in UK are not prepared for emerging biological threats and bioterrorism.	N/A	4 (100%)
3	Becker & Middleton, (2008). USA.	Qualitative, focus groups.	77, ED nurses and doctors.	Inclusion of individuals with widely varying levels of ED experience.	Gain a better understanding of the perceptions, reactions, concerns, information needs, preferred information sources, and views of existing guidance and information materials related to radiological terrorism.	Focus group.	Digital audio recordings of focus group discussions.	Neither EDs nor hospital facilities are sufficiently prepared for a terrorist event involving radioactive materials.	N/A	3 (75%)

2.1.5 Systematic review update

To ensure relevance, the search as shown in Figure 5 (p. 30) was re-ran after 2016 to 20th September 2019, which produced 222 additional results but these were discarded following screening and are not included in Figure 6 (p. 37).

2.1.6 Results

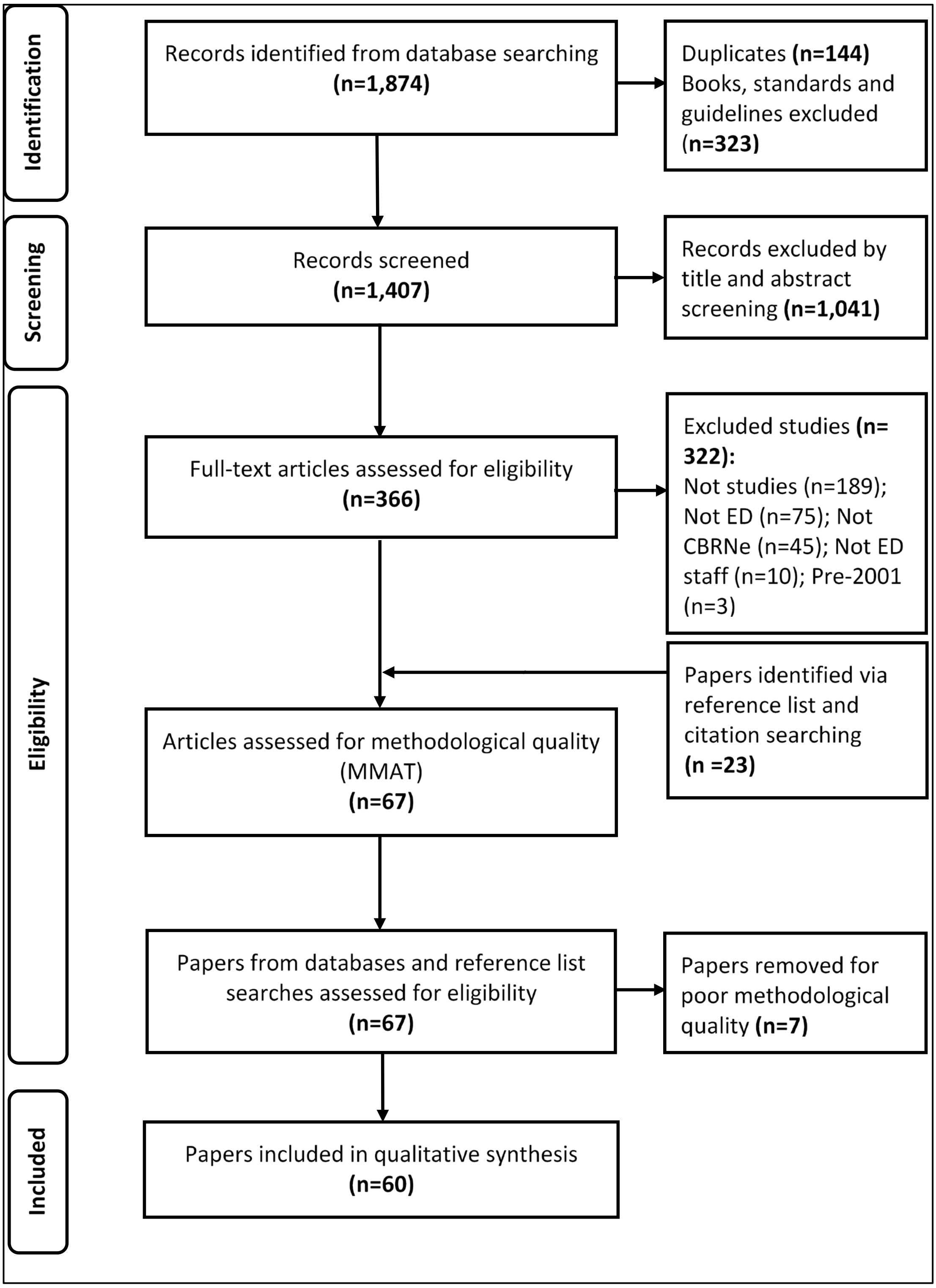

Figure 6: PRISMA diagram of the literature search

MMAT scores given to papers varied, reflecting the diverse methodological quality of the papers. Any papers which were given a score of 0 or 1 on the MMAT (Pluye et al., 2009) were excluded. Seven studies were disregarded (Appendix 4, p. 296) as they had a score of 1 (25%), this resulted in a total of 60 studies being retained for a qualitative synthesis. A quantitative synthesis was not conducted due to the variation in study types, sample populations, study aims, and multi-faceted nature of CBRNe events.

2.1.6.1 Characteristics of included studies

The included papers reflected the multi-faceted nature CBRNe events, in terms of country, sample population, and the methodologies implemented. The majority of studies were carried out in the USA (20), Canada (5), UK (12), Israel (8), Australia (3), Europe (Italy (1), Norway (1), Spain (1), Ireland (1), Turkey (2) and Asia (Singapore (3), Pakistan (3)). The populations of studies also showed variability, for example, in the total number of participants (n=20,501) and varying professional backgrounds (Table 6):

Table 6: Participant characteristics

Type of participant	**Number**
Healthcare professional, Nurses, Doctors,	4,609
Medical directors	17
ED nurses	465
Victim/patient	13,083
Hospitals	1,549
Hospital records	15
Ambulance trusts	32
Paramedics/Paramedic students/Paramedic lecturers/Pre-hospital doctors	72
Emergency response experts	15
Observers	358
Health Departments	4
Federal agency	1
Volunteers	281
Total	**20,501**

2.1.6.2 Synthesis

Residual studies (n=60) were retained for qualitative synthesis. There were four emerging themes of CBRNe preparedness (n=38), response (n=29), decontamination (n=9), and PPE problems (n=9). Some papers provided information for more than one theme.

Included papers were coded in NVivo 10 (QSR International Ltd, Melbourne, Australia) for thematic analysis. Nvivo 10 is a qualitative data organisation and analysis software. The benefits of using NVIVO in healthcare research are evident in terms of facilitating researchers to systematically and rigorously synthesise findings (Houghton et al., 2017). Overlapping themes between studies were coded and then grouped into main themes, which highlighted key factors relevant to the research question.

2.1.6.2.1 Preparedness

Preparedness is a legal requirement in the UK and Northern Ireland, in which the Civil Contingencies Act (2004) and Civil Contingencies Framework (2011) (Office of the First Minister and Deputy First Minister, 2011), emphasise that comprehensive emergency plans are maintained at a local level to ensure that acute hospital Trusts can continue to function in the event of a major emergency (Mitchell et al., 2012; Williams et al., 2007 & Wong et al., 2006).

The role of hospitals as first receivers in a Mass Casualty Incident (MCI) took on a greater importance since 9-11 (Timm & Reeves, 2007) because they were the main patient receiving facilities. EDs have since been forced to examine and update their emergency disaster preparedness plans (Masterson, Steffen, Brin, Kordick, & Christos, 2009). Preparedness of emergency nurses and in this instance, of ED staff is pivotal to the hospital system's capacity to respond to CBRNe incidents (Considine & Mitchell, 2009) requiring meticulous planning, extensive education, and regular review to be effective (Wong et al., 2006).

This systematic review identified the ED as a system, and CBRNe response planning and preparedness consisting of three inter-twining levels: organisation, technology, and individual as shown in Table 7 (p. 41).

Table 7: Primary, secondary, and tertiary findings

Primary Findings
Four Key Factors Present Challenges to the ED CBRNe Response:
1. Preparedness The ED is a complex system consisting of organizational, technological, and individual factors, which is further complicated by the multifaceted demands of CBRNe events, resulting in under preparedness.
2. Response Response is determined by first receivers' willingness to respond to unknown CBRNe exposure and the organizational management of surge capacity.
3. Decontamination Decontamination remains an area of ambiguity, amplified by first receivers' lack of knowledge on decontamination procedures.
4. PPE Problems Inadequate PPE provision, dexterity issues, and cumbersome fit results in PPE problems.
Secondary Findings
Response Planning and Preparation Should Be Considered on Three Levels: [a]
1. Organisational - Policies and procedures.
2. Technological - Decontamination. - Communication. - Security - Clinical Care. - Treatment.
3. Individual - Willingness to Respond. - PPE. - Knowledge. - Competence.
Tertiary Findings
1. Research on decontamination is being carried out.
2. No research on detection or diagnosis of exposure.
3. Self-Presenters: First receivers' willingness to respond to CBRNe contaminated casualties decreases when the substance is unknown.

Studies reporting research on organisational preparedness aimed to provide timely and high standard care to patients (Jasper et al., 2005; Mitchell et al., 2012; Williams, 2007; Wong et al., 2006) particularly emphasising standardised measures (Kollek & Cwinn, 2011; Kotora, 2015), competencies (Djalali et al., 2016; Schultz et al., 2012), and standards (Williams et al., 2007) for ED CBRNe preparedness.

Technology-related preparedness consisted of limitations in communication systems to co-ordinate the CBRNe response (Klima et al., 2012); which included the unreliability of mobile phones and walkie-talkies due to reception difficulties, particularly when surrounded by certain materials. Additionally, computer-based decision-support systems were anticipated to be overwhelmed due to the surge in patients, resulting in a preference for manual pen-paper methods (Reddy, Abraham, McNeese, DeFlitch, & Yen 2009; Zhu et al., 2007). Individual preparedness was associated with the perceptions, perspectives, views, and information needs of first receivers, which affected first receivers' capacity to respond to CBRNe events (Becker & Middleton, 2008; Considine & Mitchell, 2009).

In addition to communication issues, there was also evidence that EDs lacked preparedness (including capacity) for decontamination, security, appropriate equipment, antidotes, and treatment equipment incapacities (O'Sullivan et al., 2008; Oh, Yong, Ponampalam, Anantharman, & Lim, 2010; Treat et al., 2001; Wong et al., 2006).

2.1.6.2.1.1 Current unpreparedness

Preparedness was shown to be lacking in areas such as decontamination, mass medical response, health communications, and facility security among health care professionals (Treat et al., 2001). Wetter, Daniell, and Treser (2001) reported that from 186 hospitals in the USA Public Health Service Region X (Alaska, Idaho, Oregon, and Washington) just 20% of respondent hospitals had plans for biological or chemical incidents, with less than half having an indoor or outdoor decontamination unit.

Further, a survey based on Canadian ED preparedness by Kollek (2003), found that ED leads indicated that their ED was at risk of a CBRNe event, particularly chemical. However, they recognised significant deficiencies in preparedness in terms of appropriate equipment, antidotes, and decontamination capability. This survey was modified in 2011 to determine whether there had been any improvements (Kollek & Cwinn, 2011). Despite improvements, there remained gaps in Canadian healthcare facility preparedness, in the 2001 study only 6% had decontamination equipment and 18% had a plan. In the 2007 study, 38% had decontamination equipment and 61% had a disaster response plan. However, these results must be interpreted carefully as there was a decreased response rate (59 ED responses in 2001 study, 34 ED responses in 2011). Ultimately suggesting that currently EDs were not prepared for a CBRNe event (Kaji & Lewis, 2006; O'Sullivan et al., 2008; Williams et al., 2007).

A telephone survey of all the hospitals in the UK, (with a major ED), reported a lack of vital treatment equipment such as isolation facilities or ventilation systems (Anathallee et al., 2007). By developing an ED preparedness competency questionnaire Mitchell et al. (2012) identified 6 key areas of ED nurse unpreparedness which could be improved via training such as waste management, triage, chain of command, and use of Personal Protective Equipment (PPE). The lack of preparedness in EDs is considered a reflection of overall lack of hospital preparedness to CBRNe events (Kollek, 2003).

2.1.6.2.1.2 Measuring preparedness

There are no standardised measures of hospital preparedness (Kaji & Lewis, 2006). In order to improve ED preparedness, a valid measurement of preparedness is required (Kollek & Cwinn, 2011; Kotora, 2015). Nonetheless, an assessment tool, based on measuring ED nurse's competence to respond to CBRNe incidents was developed by Mitchell et al. (2012). By implementing this assessment tool in a sample of 50 ED nurses Mitchell et al. (2012), identified key areas of the CBRNe preparedness which could be addressed via training. This assessment tool had the flexibility to be applied to other healthcare professionals.

2.1.6.2.1.3 Perceptions of preparedness

The perceptions, perspectives, views, and information needs of first receivers which affect their capacity to respond to CBRNe events allows researchers to formulate methods to improve preparedness (Becker & Middleton, 2008; Considine & Mitchell, 2009). Nonetheless, ED nurses perceived themselves and their hospitals as under prepared for large scale disasters (O'Sullivan et al., 2008).

A survey of 177 nurses reported an overwhelming majority of the sample (98%) perceived that a disaster could threaten their community, with 94% believing that a terrorist attack could occur in the USA at any time (Whetzel et al., 2013). Although nurses had such strong beliefs of CBRNe vulnerability, their own role in such circumstances was not clear to them. For example, Whetzel et al. (2013) found that respondents did not know who had the authority to activate the hospital-wide disaster plan.

2.1.6.2.2 Knowledge, skills, and experience

Clinicians need sufficient knowledge and skills to manage the impact of CBRNe events (Djalali et al., 2016). The concepts of knowledge, skills, and experience are intertwined in the realm of CBRNe events (Rassin et al., 2007; Schultz et al., 2012; Treat et al., 2001). Knowledge was positively associated with experience. For example, nurses showed a higher level of knowledge in comparison to doctors, in paediatric MCIs of a chemical or biological nature. This is because nurses were ED based, were familiar with, and had more experience of paediatric trauma cases (Rassin et al., 2007).

Individuals who were expected to be a part of a CBRNe response were not shy to identify gaps in knowledge (Becker & Middleton, 2008). A survey based on 144 registrars (i.e. doctors in training), reported that only 77 felt confident in the knowledge of their specific role during a mass casualty incident. Reasons for this lack of knowledge were lack of funding, shortage of full time major incident co-ordinators, and limited technologies (Wong et al., 2006).

Actual gaps in knowledge and skills for effective CBRNe management were evident, especially in terms of PPE (Schumacher et al., 2015; Williams et al., 2007), decontamination, mass medical response, health communications, and facility security (Becker & Middleton, 2008; Treat et al., 2001; Whetzel et al., 2013).

In order to address these knowledge gaps, efforts have been made by expert panels to create competencies for first receivers. Schultz et al. (2012) identified 19 core domains which equip acute clinicians/ED personnel with competencies (Knowledge, attitudes, and skills) to care for patients in a catastrophic event, such as recognition, communication, patient triage, surge capacity, and decontamination. Similarly, Djalali et al. (2016) proposed 19 practical competencies which identified knowledge gaps, such as: threat identification, health effects of CBRNe agents, planning, PPE, and decontamination. The formation of such detailed competencies highlighted that efforts were being made to overcome knowledge gaps to improve the ED CBRNe response.

2.1.6.2.3 Response

Numerous studies reported on individual staff skills or preferences in responding to a CBRNe event.

2.1.6.2.3.1 Willingness to respond

The type of event determined how willing first receivers were to respond to events. Masterson et al. (2009) found that first receivers were more willing to work additional hours for victims of an aeroplane crash (98.0%), than for a radioactive bomb (85.3%), or a biological agent (54.0%), reinstating the findings of Cone & Cummings (2006), who found that hospital employees were more willing to work after a fire, collapse or rescue incident than a CBRN event.

An increased willingness to respond to radiological events has been explained via perceived risk, in which patients contaminated by radiation do require activation of radiation precautions but pose little risk to ED staff. In contrast, patients suffering chemical contamination can pose significant risk to staff and thereby decreased willingness to provide care because management of patients with chemical contamination requires higher level PPE and active decontamination prior to entry to the ED (Considine & Mitchell, 2009).

2.1.6.2.3.2 Surge capacity

Surge capacity is the ability to maintain standards of high-level trauma care during a casualty surge and, the hospitals ability to accommodate a transient sudden rise in demand for healthcare following an event (Jasper et al., 2005; Waage, Poole, & Thorgersen, 2013).

The research studies suggested actions to be taken as a means of creating surge capacity. Actions such as a decrease in new admissions, discharge of patients earlier, cancelling elective surgeries, day care for children of staff, and designating victim flow areas are recommended (Kaji & Lewis, 2006; Satterthwaite & Atkinson, 2012; Shah et al., 2015). Kaji & Lewis (2006) found that even when there was a high level of equipment and supplies available to respond to a surge of casualties' surge capacity was in fact limited as a result of failing to fully integrate interagency coordination, training, and planning. Another means of creating surge capacity was that of triage.

2.1.6.2.3.3 Triage

A high influx of patients during a Mass Casualty Incident (MCI) may disrupt patient flow in an already overcrowded ED (Lee, Booth, Challen, Gardois, & Goodacre, 2014). Triage is a brief clinical assessment that determines the time and sequence in which patients should be seen and managed (Malik et al., 2006). Triage in CBRNe events was reported to be a crucial decision tool to sort patients for treatment priority (Lee et al., 2014) which can affect the treatment of other patients and surge capacity.

2.1.6.2.4 Personal Protective Equipment problems

An adequate level of PPE is necessary when treating patients who are contaminated with hazardous substances. Studies reported that ED clinicians held negative perceptions of PPE, finding it cumbersome to don and carry out their clinical tasks.

ED nurses found difficulties in donning PPE with specific limitations including poor suit fit, poor mask fit, claustrophobia, pregnancy, glasses or having a beard that prevented adequate mask seal, as well as respiratory or cardiovascular illness (Castle, 2010a; Considine & Mitchell, 2009; Williams et al., 2007).

Al-Damouk and Bleetman (2005) highlighted challenges associated with PPE through two scenario based chemical incidents which tested the use and ease of donning PPE. PPE suits were again found to be cumbersome to assemble, fiddly, and took trained staff at least 15 minutes to prepare, test, and don.

Performing routine tasks is met with difficulty when wearing PPE. For example a vital task in CBRNe response is administering Intravenous (IV) drugs. Castle et al. (2010a) examined the ability of clinicians to draw up IV drugs from four drug presentations (Minijet prefilled syringe, Aurum prefilled syringe, glass, and plastic ampoules with needle and syringe) with participants wearing normal clothes and PPE. Wearing PPE had a negative effect on drawing up drugs, the Aurum had the fastest drawing up time, and the glass ampoule the slowest.

2.1.6.2.5 Decontamination

The Tokyo sarin underground attacks are used as a core example of the importance of ED based decontamination (Cohen et al., 2012; Williams et al., 2007) as the majority of the victims self-presented at EDs. Thus, emphasising that EDs must have the facilities, capability, and equipment to respond appropriately.

2.1.6.2.5.1 Facilities

In the UK, although the majority of EDs had designated areas for decontamination, it was suggested that 90% of EDs in the UK were unable to manage a serious chemical incident (George et al., 2002; Williams et al., 2007). A poorer situation existed in the USA, in which all EDs in the North Western States were surveyed in terms of chemical or biological preparedness and decontamination procedures. Responses from 186 EDs highlighted less than half of these institutions had an indoor or outdoor decontamination unit (Wetter, Daniell, & Treser, 2001). Similar results were reported in Canada (Kollek, 2003).

2.1.6.2.5.2 Equipment

A minority of EDs were satisfactorily equipped to deal with a serious chemical incident (George et al., 2002). In Canada, only 6% of EDs had decontamination equipment. There was a modest increase by 2007, in which 38% had EDs which had decontamination equipment, however the latter results are questionable due to the decrease in response rate in comparison to 2001 (Kollek & Cwinn, 2011).

2.1.6.2.5.3 Capability

In the UK, capability to decontaminate was found to be limited as a result of inconsistencies in equipment. For example, EDs had a decontamination trolley but no decontamination premises; limiting the usefulness of equipment (George et al., 2002). Further, one fifth of the EDs in the UK lacked equipment for safe decontamination, and had not reviewed equipment to identify problematic or missing components (Williams et al., 2007). Limited capability to decontaminate effectively was suggested to be a result of lack of experience and knowledge of PPE and decontamination (Kotora, 2015).

A crucial factor in decontamination capability is water supply disposal, and backflow protection to avoid leak of any contaminants into the main hospital supply. A large number of first receivers in the UK, were unable to highlight their EDs water management capability (Williams et al., 2007). Similarly, knowledge gaps were obvious in the management of clinical waste, clothing, and water amongst ED nurses being unable to identify the time required for effective decontamination (Mitchell et al., 2012; Williams et al., 2007). Avoiding cross-contamination is vital, and although some EDs had a *"Dirty entrance"* and a *"Clean exit"*, many respondents were uncertain on how to prevent cross-contamination (George et al., 2002; Williams et al., 2007).

2.1.7 Discussion

This state of science review has systematically searched for and reviewed research on the ED response to CBRNe events. It has recognised the ED as a system which depends on key factors when responding to such events. The themes - preparedness, response, decontamination, and PPE problems - were identified as key factors based on research highlighting challenges, uncertainties, inconsistencies, and obstacles associated with the ED CBRNe response. The findings of the studies were grouped based on their quality on the MMAT (Pluye et al., 2009) as shown in Table 8:

Table 8: Studies and quality ratings by themes

	Study numbers	**Low quality***	**Medium quality***	**High quality***	**Total sources**
Preparedness	6,21,8,22,1,13, 61,66,19,12,44, 2,3,9,10,17,20, 11,14,18	5	11	4	20
Response	22,3,44,13,41,6, 37,17,2,66,38, 42,8,64,34,63, 29,26,27,68,67, 31,33,23,24,40, 65,62	6	8	15	28
PPE Problems	6,52,19,1,58,56, 53,55,54	4	3	2	9
Decontamination	41,19,59,10,12, 3,35,52,20	1	5	3	9

* Study quality was assessed using the MMAT (Pluye et al., 2009). A rating of 2 indicated that the study had low methodological quality, 3 suggested that it had medium methodological quality, and 4 showed that it had high methodological quality.

Emphasising the findings of existing literature (Cone & Cummings, 2006; Considine & Mitchell, 2009; Kollek & Cwinn, 2011; Masterson et al., 2009; Whetzel et al., 2013) this review highlighted that first receivers were not as prepared to respond to CBRNe events as well as they would natural disasters, resulting in the ED being under-prepared to effectively respond overall. An explanation for this lack of preparedness to CBRNe events is that the ED is a complex system, consisting of organisational, technological, and individual factors, which is further complicated by the demands of a multi-faceted CBRNe event. Although conforming to policies to address the lack of preparedness to CBRNe events has been suggested (Labrague et al., 2017). A systems approach would allow an enhanced understanding of the ED as a complex system, by improving the design of a system and the interactions amongst people within and across it, rather than focusing on an individual part of it (Wilson, 2014). In particular, a systems approach as suggested in the Human Factors White Paper (CIEHF, 2018) would correspond with the factors resulting from this systematic review. The majority of studies used to review preparedness measured medium (75%) on the MMAT, suggesting that they were of sound methodological quality.

Studies included in the systematic review showed that first receivers display an unwillingness to respond to CBRNe events due to perceived personal risk, which has previously been associated with invisible hazards (Barnett et al., 2012) associated with CBRNe events, and an unwillingness of staff to respond (Maxwell, 1982) resulting in staff shortages (Ochi et al., 2016) compromising an effective response. Baduge, Morphet, and Moss (2018) similarly found that nurses involved in the care of Ebola Virus Disease (EVD) felt that they should have a choice in caring for such patients with factors such as family, stigma, and expectations from media coverage influencing their willingness to provide care in such situations (Speroni, Seibert, & Mallinson, 2015).

EDs must be able to respond to CBRNe events as they face greater challenges due to CBRNe events becoming frequent. An example is the 2018 novichock incident in Salisbury, UK. This is described as the longest running major incident, lasting 72 days and resulting in the death of one individual (Rimmer, 2019). The systematic review reported that concepts such as surge capacity when responding to a CBRNe event would be limited. Davidson et al. (2019) confirmed that creating surge capacity is challenged based on four layers, which are described as the 4 S's: 1) Staff, 2) Stuff, 3) Structure, and 4) System, in terms of factors such as respiratory support, PPE, secondary contamination, triage systems, and tracking patients; highlighting the multifaceted nature of CBRNe events.

Further, literature based on response suggested that aspects such as surge capacity would be compromised as a result of limited interagency coordination (Jasper et al., 2005; Waage et al., 2013). A suggested means of creating surge capacity is that of triaging patients efficiently. Although there is updated guidance such as the *"Clinical guidelines for major incidents and mass casualty events"* (NHS England, 2018a), there is no standardised and universal agreement on how patients should be triaged during mass casualty incidents and disasters (Bazyar, Farrokhi, Khankeh, & Hamidreza, 2019). The majority of papers used in the response component of this analysis scored between medium (75%) and high (100%) on the MMAT, suggesting they were reliable and valid means of measuring response.

Studies based on decontamination emphasised that it remained an area of ambiguity in the ED CBRNe response (Kotora, 2015) particularly in terms of providing adequate facilities and equipment to perform decontamination (George et al., 2002; Williams et al., 2007). This disconnect is amplified by the incapability of first receivers to carry out decontamination, reflecting their lack of knowledge on how to carry out decontamination procedures (Mitchell et al., 2012; Williams et al., 2007). Decontamination is a crucial component to effective CBRNe management and patient care. The findings of the studies implemented in reviewing decontamination can be considered reliable and valid, studies scored between medium (75%) and high (100%) on the MMAT (Pluye et al., 2009), suggesting that the findings were a true representation of current decontamination perceptions, processes, and challenges.

Jones (2019) highlighted that one of the most important points when responding to CBRNe events is for the first receiver not to become a victim themselves, and this is achieved by donning PPE. PPE surrounds the individual in a unique microenvironment. Studies included in the systematic review identified PPE problems such as the inadequate provision of PPE (Becker & Middleton, 2008; George et al., 2002). This is further complicated by first receivers having limited knowledge about the application of PPE, finding it cumbersome, and having limited dexterity when carrying out both routine and life-saving procedures (Castle et al., 2010b, Castle et al., 2010c; Considine & Mitchell, 2009; Williams et al., 2007).

Wiyor, Coburn, and Siegel (2019) divided the impact of PPE on medical device use into: airway management, drug administration, diagnostics, and monitoring. CBRNe PPE increased task completion times by as much as 130%. Compensatory-type studies which focused on overcoming PPE problems were prevalent. For example, Schumacher, Arlidge, Garnham, and Ahmad (2017) proposed the use of a lighter, size-specific PPE suit, which overcomes the physical constraints of PPE. The suggestion is that trial and error will continue until both routine and life-saving tasks can be carried out in PPE competently and comfortably. With reference to Table 8 (p. 49) the majority of the studies based on PPE scored low to medium on the MMAT (Pluye et al., 2009), thus questioning the reliability of these findings.

2.1.7.1 Application of findings

The findings from this review have been used to formulate a standardised CBRN checklist for emergency response planners in order to enhance planning, preparedness, and response to CBRNe events, as shown in Figure 7 (p. 53). The checklist is entirely based on the literature included in this review. It is likely to have omissions and should only be used in context of presenting the CBRNe situation combined with up-to-date governmental guidance.

Checklist for CBRN leads

All factors must be checked to plan, prepare, and respond to a CBRNe event appropriately.

1. Have you planned effectively? ☐

<u>1. Organisational factors</u>

1.1. CBRN plans/policies, and procedures up-to-date
1.2. First receiver competencies up-to-date
1.3. Plans for creating surge capacity in place

2. Are you prepared? ☐

<u>2. Technological issues</u>

2.1. Decontamination capability reviewed
2.1.1. First receivers have decontamination knowledge
2.1.2. Facilities
2.1.2.1 Allocated area for decontamination
2.1.3. Equipment
2.1.3.1. Appropriate equipment and can be used by first receivers

2.2. Communication

2.2.1 Phone lines established
2.2.2. Computer systems functioning
2.2.3. Back up (paper system) accessible

2.3. Security

2.3.1. First receivers prepared for lockdown, isolation, and containment procedures
2.3.2. First receivers aware of the role of external organisations

2.4. Clinical care

2.4.1. Various triage routes considered

2.5. Treatment

2.5.1. First receivers aware of antidotes and guidance

3. Can you respond? ☐

<u>3. Individual factors addressed</u>

3.1. Willingness to respond and perceptions of CBRNe presentations established amongst first receivers
3.2. First receiver qualifications, competencies, and CBRNe knowledge known

3.3. PPE

3.3.1. Sufficient number of PPE suits
3.3.2. PPE suits fit tested
3.3.3. Substitute equipment available
3.3.4. First receivers have PPE knowledge

Figure 7: CBRN planning checklist

The findings from this systematic review can further be used to inform CBRNe guidance. For example, in the UK, the Health Protection Agency (HPA) (Gov UK, 2008) has published clinical guidelines on how to respond to CBRNe events in the ED. The HPA guidance explains how to safely clinically recognise, respond, and treat exposure, which is dependent on presenting symptomologies. Mnemonics for rapidly assessing casualties, triaging sieves, guidance on the type of PPE required, as well as useful contacts are provided in this guidance (Public Health England (PHE), 2018). The link between effective triage and surge capacity highlighted through this review can contribute to revisions of future HPA guidance.

Emergency Preparedness Resilience and Response (EPRR) (NHS England, 2015a, 2017) is another initiative in the UK providing guidance in CBRNe response. The guidance for self-presenters focuses on chemical exposure (NHS England, 2015a) and is based on findings from the *"Optimisation through Research of CHemical Incident Decontamination Systems"* (ORCHIDS) project (Home Office, 2015) (JESIP, 2013) as its empirical framework to better respond to incidents involving hazardous materials. The guidance suggests rapid actions to save lives, known as the Initial Operational Response (IOR) to improve patient outcomes following CBRNe exposure (NARU, 2016). Findings from this systematic review can inform EPRR guidance to recognise first receivers' decreased willingness to respond to unknown chemical exposure in comparison to known chemical hazards (Considine & Mitchell, 2009). Furthermore, in order to implement the IOR, this review emphasises the need for appropriate facilities, equipment, and capability to carry out decontamination to be ready and available.

With reference to the research question and the challenges of detection, decontamination, and diagnosis. Although the studies in the systematic review associated decontamination procedures with ambiguity, the review found that research investment was being made in decontamination. For example in the ORCHIDS project, the focus was on effective decontamination on non-ambulant casualties (Chilcott et al., 2019), and the thorough decontamination of hair (Matar et al., 2019).

Since the literature search (2001-2016) was carried out, there has been the emergence of research based on detection the CBRN response (out of hospital). For example, Boguská and Majlingová (2017) identified that additional devices would be required to detect hazardous substances in a CBRNe event. Montana et al. (2019) reported findings from the development of a course based on enhancing the role of pharmacists in disaster management. One of the modules was based on CBRN events, and consisted of competencies such as recognising detection equipment, suggesting that detection is gradually being recognised as being a crucial component of CBRNe events.

In terms of diagnosis, the Toxi-Triage project (Loughborough University, 2019) presented and tested technologies which enable the diagnosis of CBRN substances through breath, saliva, or skin testing. One of the findings from study 2 is that first receivers at Trust A included the diagnosis of the presenting condition in a potential CBRN event in the ED.

2.1.7.2 Limitations

Most of the data used in this systematic review were retrospective data, which can be considered to jeopardise the scientific quality and validity of findings. However, retrospective event data, particularly in disaster medicine, are considered the norm (Morelli, Sabbadini, & Bortolin, 2015).

It is suggested that every systematic review faces challenges in terms of the quality of data collected, because some authors might report information that they subjectively find interesting (Morelli et al., 2015). Although the MMAT was implemented to ensure that high quality data was used, the inclusion and exclusion criteria could have potentially disposed of good research in the ED CBRN response. However, a stringent criterion was required to set the scope for areas of investigation in this research.

There was also a geographical and publication bias with 20 of the 60 studies conducted in the US. This contributes to an acknowledged bias towards US literature as a point of reference in UK health emergency planning and preparedness evidence (Challen et al., 2012; Lee, 2015).

Additionally, the systematic review identified discrepancies in defining and setting the scope for the term CBRNe events. It is imperative to have clear boundaries and a strong definition of CBRNe events. Explosions were excluded because they require an extended response in terms of treatment, in-hospital, and out of hospital response. There is a grey area when defining CBRN events, this is because of the overlap in the same materials – resulting in confusion (House of Commons, 2017).

The role of intent in defining HAZMAT and CBRN events effects who leads the response in the hot zone (area of highest contamination (JESIP, 2017). The police would lead the response for malicious CBRN events, and the fire service would lead the response to accidental HAZMAT events. Different expertise is required to respond to HAZMAT and CBRNe events.

The CBRN definition underlying this research is:

"The exposure (or risk of exposure) of a large number of individuals to hazardous Chemical, Biological, Radiological, and Nuclear materials which may occur through a variety of means including natural, accidental, and deliberate acts"

(Chilcott & Wyke, 2016, p. 179).

This is because first receivers in the ED will care for patients exposed to CBRN materials regardless of intent.

2.1.8 Conclusion

Understanding the key factors underpinning the dynamic ED system to plan, prepare, and respond to emergencies effectively has major legal, clinical, and moral implications. ED preparedness and response has obstacles, uncertainties, and inconsistencies in addition to the known challenges. The four themes provide an evidence-based summary to inform future CBRNe guidance, policies, and clinical procedures. The themes identify that the ED CBRNe response is limited unless response planning and preparation is considered at three levels: organisational (policies and procedures); technological (decontamination, communication, security, clinical care, and treatment); and individual (willingness to respond, PPE, knowledge, and competence). Further, the complexity of the ED, the multifaceted nature of CBRNe events, combined with the identified concerns from this review, in terms of both knowledge and behaviours, suggest that a systems approach is required to understand the ED CBRNe response in the future.

2.2 Chapter Summary

The systematic review provided a justification of the term CBRN event to be used throughout this thesis. Additionally, the systematic review identified that EDs are under prepared to respond to CBRN events effectively, this combined with the importance of legislation presented in Chapter 1 presents the importance of policy and practice in the ED CBRN response.

The four key factors (preparedness, response, decontamination, and PPE problems) have provided an evidence-based summary to inform the focus of this thesis which is to unpack policies (CBRN plans) and practice (first receiver responses) in the ED CBRN response using HF/E principles, to provide standardised recommendations to enhance the ED CBRN response as illustrated in Figure 8:

Figure 8: How HF/E research will be used to achieve the aims and objectives of this thesis

Chapter 3. Research methodology

"The practice of research is a messy and untidy business which rarely conforms to the models set down in methodology textbooks"

(Brannen, 1992)

3.1 Introduction

This chapter describes the approach and justifications to answer the methodological research question to meet the aims and objectives of this research. The research strategy will explain why an exploratory qualitative multi-method approach is most apt to answer the research question. The research perspective will provide insight into the researcher's view of reality (ontology) and acceptable knowledge (epistemology) throughout the research process. An explanation behind the methods, study design, and sampling will then be provided. The importance of implementing sound ethics in NHS based research will be highlighted and how these were upheld through good practice. The upkeep of rigour and credibility throughout the research process will then be described.

3.2 Research question

This chapter aims to answer:

Which research methodology, methods, and design can be used to understand the Emergency Department (ED) response to Chemical, Biological, Radiological, and Nuclear (CBRN) events?

3.3 Research strategy

Robson (2002) suggested three classifications whilst carrying out research:

1. **Exploratory**: To seek new insights and phenomena in a new light.
2. **Descriptive:** To portray an accurate profile of an event or situation.
3. **Explanatory:** To explain a situation or a problem.

An exploratory lens was implemented throughout because it is advised where there is an excess of descriptive information (Punch, 2010). Such information was collated in the systematic review highlighting key factors in the ED CBRN response. This approach was also selected to assess the ED response to CBRN events in a new light – by applying Human Factors and Ergonomics (HF/E) methods and theory. An exploratory approach was deemed most appropriate because exploratory studies consist of a flexible strategy (Table 9, p. 60) and the approach taken to collect and analyse data had to be flexible due to the unpredictable nature of the ED.

A loose case study approach was adopted (Table 9, p. 60) by which a case is *"The situation, individual, group, organisation or whatever that we are interested in"* (Robson & McCartan, 2016, p. 150). Specific to this research, the situation is a CBRN event, the group are first receivers, and the organisations are Type 1 ED departments (Chapter 4). Finally, a case study approach was adopted because case studies do not require specific methods to be applied to the analysis of the data that the study produces (Robson, 2002), allowing a pragmatic stance to be taken throughout (see Section 3.5.1, p. 65).

Table 9: Research strategies (adapted from Robson & McCartan, 2016)

Fixed design strategies	**Flexible strategy**
Quantitative strategy which requires a strict specification prior to data collection.	Qualitative strategy in which the design evolves during data collection.
Experimental Researcher actively introduces change in the situation or experience of participants to produce a change in their behaviour. Allocation of samples to different experimental conditions. Control of other variables and testing of formal hypotheses. **Non-experimental** Same as experimental strategy but the researcher does not attempt to change the situation or experience of participants. Allocation of samples to different conditions, might not involve hypotheses testing.	**Case studies** Development of intensive knowledge about a single case or a small number of related cases. Study of the case in its context. Information collected via a range of data collection methods. **Ethnographic studies** Aim to capture and explain how a group or organisation lives and experiences their world. Researcher immerses in the setting. **Grounded theory studies** Seeks to generate theory from data collected during the study. A systematic yet flexible research strategy.

Additionally, a qualitative approach was adopted which aims to explore and understand the meaning individuals or groups attribute to a social or human problem. Qualitative research is described as *"The emergent, inductive, interpretative, and naturalistic approach to the study of people, cases, phenomena, social situations, and processes in their natural settings in order to reveal in descriptive terms the meanings that people attach to their experiences of the world"* (Yilmaz, 2013, p. 312). Qualitative research is people-orientated, and the researcher must get close enough to the people and the situation being studied in order to develop an understanding of the phenomena under investigation (Yilmaz, 2013). This was achieved by the data being collected in the ED (see 3.8.1, p. 93).

A qualitative approach is suggested to be optimal when carrying out research which seeks to explore where and why policy, local knowledge, and practice are at odds (Marshall, 1985) because it identifies opportunities and explanations to fill in gaps which aim to enhance the care given to patients. Qualitative research has been suggested to offer opportunities for emergency care researchers to explore new topics and define new assessment methods (Ranney et al., 2015). This supports a novel approach to exploring how the ED responds to CBRN events through new assessment methods such as Hierarchical Task Analysis (HTA).

The distinction between qualitative and quantitative research strategy is ambiguous (Bryman, 2012), with some authors viewing the distinction as non-exclusive polarisations (Walliman, 2006). While some view the distinction as a continuum (Creswell, 2013b) and others stating that the distinction is irrelevant (Layder, 1993). The research strategy considers the distinction between qualitative and quantitative research as fundamental in determining the research logic (see Section 3.4, p. 64) and research perspective (see Section 3.5, p. 65) as summarised in Table 10:

Table 10: Qualitative and quantitative impact on research perspective and research logic (sources: Bryman, 2012; Wahyuni, 2012; Walliman, 2006)

Research perspective	Qualitative research	Quantitative research
Ontology *How one perceives reality.*	**Constructionism:** Social reality is seen as a constantly shifting product of perception.	**Objectivism:** Social reality is regarded as an objective fact.
Epistemology *The nature of knowledge and the development of that knowledge.*	**Interpretivism:** Relies on individual interpretation of social reality.	**Positivism:** Inherent in the natural sciences.
Research logic *Reasoning behind gaining information.*	Uses inductive approach to generate theories.	Uses deductive approach to test theories.

A typology of combined qualitative and quantitative approaches has been provided in Table 11 (p. 62). Combining qualitative and quantitative approaches in the same study has been debated because of the epistemological and ontological differences of each approach (Hussein, 2009). This debate does not apply in this context because a qualitative multi-method approach was taken.

Approaches are combined for triangulation which is "*The combination of methodologies in the study of the same phenomenon*" (Denzin, 1989, p. 234). Triangulation provides a deeper understanding of the research phenomenon as well as increasing the accuracy of the study – making triangulation a validity measure (Hussein 2009), (see Section 3.8.4, p. 105).

Table 11: Typology of combined qualitative and quantitative approaches

Research approach	Explanation
Mixed-methods	Involves the combining or integrating of qualitative and quantitative research and data in a study (Creswell, 2013a).
Multi-strategy	Research that combines quantitative and qualitative research (Bryman, 2004).
Multi-method	Research questions are answered by using two data collection procedures or methods, each of which is from the same qualitative or quantitative tradition (Brannen 1992; Teddlie & Tashakkori, 2003).
Mixed methodology	Represents the highest degree of mixing paradigms as well as mixing aspects of quantitative and qualitative approaches or many methodological steps during the study (Creswell, 1994; Tashakkori & Teddlie, 1998).

A multi-method approach uses two or more research methods, each carried out rigorously and complete in one project. The results are then triangulated to form a comprehensive whole. Triangulation was maximised by using both a within-method approach (same method being used on different occasions) and a between-method approach in which different methods are used in relation to the same objective of the study (Brannen, 1992). HTA was used in the document analysis and semi-structured interviews. In the latter, between methods approach, HTAs were combined with verification interviews.

A multi-method approach is used when a series of projects are interrelated within a broad topic and are designed to solve an overall research problem (Morse, 2003). Multi-method designs are governed by three principles. The first is the identification of the theoretical drive, which is how the researcher thinks about the research overall

(Morse, 1991). The theoretical drive can be inductive (for discovery) or deductive (for testing) and it is advised that the researcher must be aware of the method of inquiry being used and how it complements the overall project aims (Morse, 2003). The second principle is the awareness of working inductively or deductively at any given point, this is to avoid violation of any of the methods being used (Morse, 2003).

Various combinations for both inductive and deductive drives exist, and these vary according to qualitative and quantitative data. An inductive and deductive drive (see Section 3.4, p. 64) was used. Theoretical drive in the case of a qualitative multi-method research inquiry can be expressed as:

1. QUAL + qual* for two qualitative methods used simultaneously, one of which is dominant or forms the base of a project as a whole.

2. QUAL -> qual* for two qualitative methods used sequentially, one of which is dominant.

***** Upper case letters represent dominance and lower-case letters indicate supplemental projects, a [+] indicates that methods are used simultaneously or [->] indicate directions.

The research drive for each study varied, as shown in Table 12:

Table 12: Multi-method research drive for each study

Study	Multi-method research drive
1. The blunt end of the ED response to CBRN events.	**1**
2. The sharp end of the ED response to CBRN events.	**2**

The final principle of multi-method design is that of respecting methodological integrity, because the results of each study are triangulated to inform the research project (Morse, 2003). Methodological integrity was ensured by three means. The first was formulating a stringent research protocol (see Section 3.8.2, p. 95) which underwent peer review and NHS Health Research Authority (HRA) review. Secondly, sample sizes were a result of collaboration between NHS Trust leads and methodological frameworks such as purposeful sampling. Finally, adequacy of data was ensured by the research being carried out at two sites.

To summarise, an exploratory lens was used because information about CBRN events already existed. A qualitative multi-method strategy was used for three reasons.

1. To form a complete understanding of how the ED responds to CBRN events. It is suggested that implementing more than one method within a research project results in a more complete picture of human behaviour and experience (Morse, 2003).
2. Triangulating with multiple data sources, methods, and theories overcomes the uncertainty associated with regular methods, lone analysts, and single perspective interpretations (Patton, 2002a). This helped to implement triangulation effectively.
3. The use of qualitative multi-method research strategies has been effective in ED research as well as research involving healthcare professionals. For example, McFetridge, Gillespie, & Goode (2007) adopted a multi-method approach which combined interviews, focus group interviews, and documentation reviews to explore the process of patient handover between ED and Intensive Care Unit (ICU) nurses when transferring patients between their respective departments.

3.4 Research logic

The use of theory in research or the formation of theory from research was clarified by Dewey (1997) as consisting of inductive discovery (induction) and deductive proof (deduction). Deduction begins with a universal view of a phenomenon and works back to particulars, whearas induction shifts from smaller details to a connected view of a phenomonon (Gray, 2013). The data collection process used both inductive and deductive logic, by moving back and forth from the sources of information to establish a comprehensive data set. Deductive (top down) thinking was used to check emerging findings constantly against previous data and information sources. This was done so that complex reasoning skills were used throughout the process of this thesis (Creswell, 2013a). This is illustrated in Table 9 (p. 60).

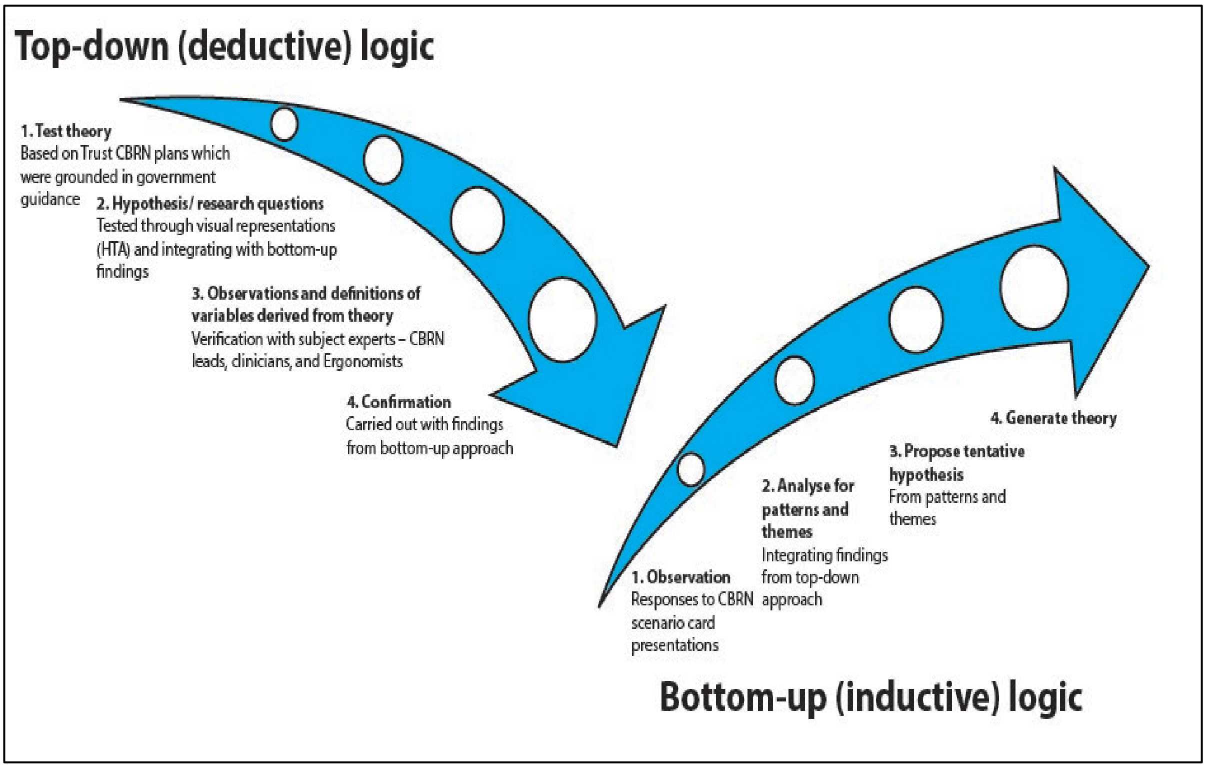

Figure 9: Inductive and deductive reasoning used in this research (sources: Ormston et al., 2013; Bryman, 2012; Creswell, 2013a): Diagram graphics: Courtesy of Victor Jeganathan

Specifically, the HF/E stance incorporates the bottom up perspective of front line staff and the top-down interests of indirect stakeholders (Trudell, Cobb, Momtahan, Brintnell, & Mitchell, 2017).

3.5 Research perspective

The author's view of reality and acceptable knowledge will now be outlined.

3.5.1 Ontological stance and epistomological position

This thesis is focusing on the interactions of humans (first receivers) with each other when responding to a particular situation (CBRN event) leading to further interactions (patients) within an example system (ED). A paradigm is the basic belief system or world view that guides the researcher in their inquiry (Guba & Lincoln, 1994). Ontology and epistemology distinguish existing research paradigms (Wahyuni, 2012). Ontology is the overarching study of what exists and is concerned with the nature of reality (Creswell, 2013b) or the "*Knowable"* (Guba, 1990), what constitutes as reality, and asks *"What is?"* (Scotland, 2012). Ontological assumptions determine the way in which research questions are formulated and how the research is carried out (Bryman, 2012).

Ontology represents two polarising world views - objectivism is the belief that social phenomena and their meanings exist independent of social actors. On the other hand, constructionism is the belief that social phenomena are in a constant state of change because they entirely rely on social interactions as they occur (Walliman, 2006). The ontological stance of this research was of constructionism. This is based on the following:

1. CBRN plans are constructed through CBRN leads when government guidance is updated.
2. The interactions which occur in the ED environment are socially constructed through patients and first receivers.

The underlying methodological position is the epistemology which relates to what constitutes valid knowledge and how it can be obtained. Epistemology aims to understand *"What it means to know"* (Gray, 2013) by focusing on the nature of relationship between the researcher and the *"What can be known*" (Guba, 1990; Guba & Lincoln 1994).

Four research philosophies exist which are characterised through their ontology, epistemology, methodology, and preferred methods of collecting data (see Figure 10, p. 69). These philosophies are positivism, realism, interpretivism, and pragmatism.

The epistemological position of positivism proposes that the social world exists externally to the researcher (Gray, 2013), and advocates objectivity by applying methods of the natural sciences to test theories and establish scientific laws, thus preferring quantitative methods of collecting data (Walliman, 2006). Realism presumes that a knowable and objective reality independent of observation and human thought exists. However, interpretation occurs via social conditioning, hence holding preference for either quantitative and qualitative methods (Chia, 2002; Wahyuni, 2012; Gray, 2013). Thus, realism is an inappropriate paradigm to answer the research questions (see Section 3.2, p. 58) because human thought is vital in determining whether a CBRN event has occurred.

Interpretivists propose that natural reality, which includes the laws of science and social reality vary and are constructed, thus require qualitative methods of inquiry (Bryman, 2012) aiming to reveal interpretations and meanings (Walliman, 2006). This approach did not have the practical implications of the research outcomes as a focal point, restricting the potential impact of the outcomes.

Pragmatism is a result of actions, situations, and consequences rather than antecedent conditions (Creswell, 2013a), in which there is an external nature of reality and is chosen to best answer the research question (Wahyuni, 2012). Pragmatism focuses on methodological appropriateness as being crucial in recognising that different methods are appropriate for different situations (Patton, 2002a).

A pragmatic epistemological position was adopted because it states that either or both objective phenomena and subjective meanings can provide knowledge based on the research question (Wahyuni, 2012). In this case the objective phenomena were Trust CBRN plans, and the subjective meanings were how first receivers implemented this knowledge. Further, pragmatism places importance on the practical implications of the research as well as encouraging applied research which integrates varying perspectives to interpret the data (Wahyuni, 2012). The outcome was to provide a sound knowledge base in the form of standardised recommendations, which would result in evidence-based practice, when responding to CBRN events, making a pragmatic approach the most fitting.

3.5.1.1 Conceptual underpinning: Participatory design

In line with adopting pragmatic stance, a participatory design approach was used in the review, verification, and validation processes of both studies. Participatory design has been used as a user-centred method to actively involve front-line groups with the greatest subject matter expertise to inform design issues so the outcome addresses usability concerns by Bowie et al. (2015), for developing a safety checklist in General Practice. This research aimed to unpack and develop an enhanced CBRN process by encouraging participation of CBRN leads, first receivers, and Ergonomists.

Participation is described as *"The involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power* *to influence both processes and outcomes in order to achieve desirable goals"* (Wilson, 1995, p. 1071). Kuorinka (1997) suggested that participation adds realism to complex systems design. This thesis used participation of individuals at multiple levels to enhance a complex system response.

Participatory design has been criticised for losing focus on workplace democracy and hierarchies, and focuses on technology usefulness in which employees are participating only to provide input into design (Beck, 2002). This thesis overcame such criticism by having a diverse type of first receiver in terms of seniority, experience, and decision making/escalating capabilities. More so, by implementing participatory design, a complete (Hignett, Wilson, & Morris, 2005) macro (organisational) top down information as well as micro (first receiver) bottom up perspective of the ED response to CBRN events was provided. CBRN planners in study 1 verified that GOR HTAs were a true representation of CBRN plans. The HF/E review added order and flow to the ED CBRN response through standardisation, and first receivers contributed to member checking their responses to scenario card presentations in study 2.

3.6 Research methodology

Research methodology is concerned with why, what, from where, when, and how data is collected and analysed (Scotland, 2012). The research methodology was determined by the epistemological stance of pragmatism which encourages methods that best answer the research questions. Consequently, a generic qualitative methodology was applied.

3.6.1 Generic qualitative approach

A generic qualitative research methodology aims to understand a phenomenon, a process, or the perspectives and worldviews of the individuals involved (Merriem, 1998). Generic qualitative research does not fully comply with established qualitative methodology such as grounded theory, ethnography or phenomenology (Cooper & Endacott, 2007). Instead, such studies draw on a combination of strengths from these approaches but diverge from certain aspects in a way which is beneficial to the study (Kahlke, 2014).

Caelli, Ray, and Mill (2003) suggested that generic qualitative studies tend to focus on understanding an experience or an event. This research implemented key concepts such as rigour as suggested by Caelli et al. (2003) and Cooper and Endacott (2007) (see Section 3.8.4, p. 105) as a means of informing a thorough research process. A generic qualitative approach has effectively been used in both critical care and ED environments previously (Alzghoul, 2014; Mortimore & Cooper, 2007).

The ontological stance allowed the epistemological position to be defined. A generic qualitative approach combined with qualitative multi-methods as illustrated in Figure 10 were justified as the optimal philosophical perspective underlying this research.

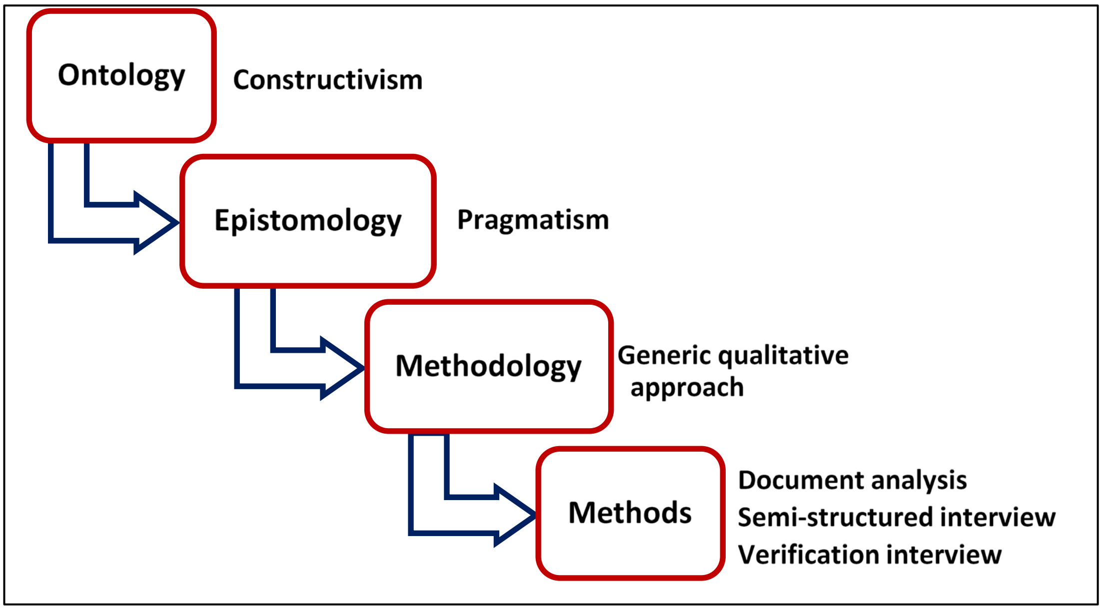

Figure 10: Philosophical stance of this research (adopted from Crotty, 2003)

3.7 Methods

The methods that were used to better understand the ED response to CBRN events in this thesis will now be outlined.

3.7.1 Document analysis

"The aim of document analysis is to gather facts" (Caulley, 1983, p. 19). Document analysis is a systematic procedure for reviewing or evaluating documents which includes printed and electronic material. In line with qualitative approaches, document analysis requires that data are examined and interpreted to elicit meaning, gain understanding, and develop empirical knowledge. Various advantages and

disadvantages (Bowen, 2009; Caulley, 1983; Green & Thorogood, 2009) are associated with document analysis:

Advantages

- Efficient, cost effective, convenient, and available.
- Stable, researcher presence does not alter what is being studied.
- General background information about a topic can be obtained from document analysis.
- Non-reactive, even if there are substantial errors in the document, masking or sensitivity will be minimal because the authors of the document understand that they are being studied.

Disadvantages

The disadvantages consist of insufficient data and irretrievability. For example, obtaining access to CBRN plans was not permitted until Research and development (R&D) approval was obtained. Further disadvantages include:

- Limited actions of what is available and accessible.
- Data collected from documents for a particular purpose can be difficult to use to answer different research questions.
- Documents may be inaccurate, out of date, or months behind on entries.
- No control over, or much knowledge on how the data were collected for the documents.
- Bias selectivity, in which documents are likely to be aligned with corporate policies, procedures, and organisations principles (Bowen, 2009).

Although there are disadvantages, document analysis was selected as a fundamental baseline method. Firstly, because it was adaptable to enough to set the scene of the ED CBRN response in a graphical (HTA) format by analysing CBRN plans. Secondly, by providing a reference point for the semi-structured interviews. Additionally, document analysis informed data triangulation (Bowen, 2009), which was vital in achieving rigour and credibility throughout (see Section 3.8.4, p. 105).

3.7.2 Interview methods

Qualitative interviews allow an exploration of experiences, motives, and opinions of others, as well as to see the world from perspectives other than one's own (Rubin & Rubin, 2012). Interviewing begins with the assumption that the perspective of others is meaningful, knowable, and able to be made explicit. Most importantly, interviews allow researchers to enter into the interviewee's perspective, and are advantageous because they offer a flexible means of finding things out by seeking answers to research questions (Patton, 2002b).

Structured interviews use a specified set of questions, in an order, so that each interview produces comparable responses. Informal interviews are much like natural conversations, which happen in the field. Semi-structured interviews, in-depth interviews, and narrative interviews (Table 13) lie in between the extremes of structured and informal interviews (Green & Thorogood, 2009).

Table 13: Types of interviews used in healthcare research (adopted from Ayres, 2008; Cook, 2008; Green & Thorogood, 2009)

Interview type	Description
Semi-structured interview	The researcher sets the agenda for the topics to be covered. The interviewee's responses determine the information produced about the topics.
In-depth interview	Interviewees are encouraged and prompted to talk in depth about the topic under investigation. The researcher is required to be aware of the major domains of experience to be discussed and can probe these in relation to the topic.
Narrative interviews	The researcher aims to facilitate the interviewee in telling their story, often used in life story or life history research.

3.7.2.1 Semi-structured interviews

A semi-structured interview format was used because it is a conversation with an underlying collaborative tone (Choo, Garro, Ranney, Meisel, & Morrow Guthrie, 2015). In-depth interviews were not used because they are often associated with personal questions which would require time for the interviewee to think about issues that are important to them (Green & Thorogood, 2009; Morris, 2015). Narrative interviews were discounted because they are based on reconstructing social events from the interviewee's point of view (Muylaert, Sarubbi, Gallo, Neto, & Reis, 2014) and are associated with subjective narratives based on health and illness (Green & Thorogood, 2009).

Semi-structured interviews consist of pre-determined questions with a flexible order. An interview schedule lists the questions or issues that will be explored. The function of the interview schedule is to ensure that the basic lines of enquiry are maintained with each participant (Patton, 2002b). The scenario cards (Chapter 5) were used as interview schedules in the semi-structured interviews because they succinctly defined the issues to be explored. General verbal probes such as *"Why"*, *"How", and "Where"* were used by the researcher if further explanations in response to the scenario cards were needed.

The verification interviews used the results of the semi-structured interviews (HTA representations) as an interview schedule and are discussed further in Chapter 5. A number of advantages (DiCicco-Bloom & Crabtree, 2006; Patton, 2002b) and disadvantages (Green & Thorogood, 2009; Doody & Noonan, 2013; Pope, Burn, Ismail, Harris, & McCoy, 2017; Robson, 2002; Morris, 2015; Patton, 2002b) have been associated with semi-structured interviews:

Advantages

- Facilitate rich description and detailed accounts of the participants' experiences and perspectives on a phenomenon.
- Interviews are conversational and situational.
- Questions which seem inappropriate with one interviewee can be removed or additional ones can be added.
- Wording of the questions can be altered, and explanations provided when needed.
- Researcher has the autonomy to word questions instinctively and develop a conversational style during the interview that focuses on the topic.

Disadvantages

- Time consuming and requires careful preparation such as obtaining permission to carry out the interviews.
- Gives access to what people say and not what they do.
- Difficult to check the accuracy of what interviewees say.
- Generalisability of the data can be questioned.
- Novice researchers might be unable to identify where to prompt questions, resulting in some relevant data not being gathered.
- Important and prominent topics may be unintentionally missed.

3.7.2.2 Scenario card presentation

Obtaining a realistic reflection of how first receivers would respond to CBRN exposed patients was prioritised. CBRN events could not be anticipated ethically or created due to their life endangering nature. Therefore, a variety of means were explored to reach the optimal method, such as software simulations, table-top exercises and drills, and scenario cards:

Software simulations

Software simulation exercises have been used to explore the level of preparedness of first receivers to CBRN events (Alexander, Bandiera, & Mazurik, 2005; Cohen et al., 2012; Heinrichs, Youngblood, Harter, Kusumoto, & Dev, 2010). These studies have focused (successfully) on using software as a means of training first receivers, and simulating CBRN events to test whether the software was effective in increasing CBRN knowledge (Mossel, Vienna, Peer, & Göllner, 2017). This thesis was not assessing the knowledge of first receivers in terms of CBRN events or encouraging training as a means of enhancing the ED response to CBRN events. Therefore, software simulations were excluded.

Table-top excercises and drills

A table-top exercise is a means of facilitating discussion on a simulated emergency situation, with the aim of assessing plans, policies, and procedures. Drills are defined as coordinated supervised activity employed to test a single, specific operation or function under time pressure to test staff training, response time, resources, and equipment (Skryabina et al., 2016).

A CBRN table-top exercise (Exercise Tri-Star – Heart of England Foundation Trust, 2016) and a real-time mass casualty trauma hospital drill (Exercise Soteria-University Hospitals of Leicester, 2017; see Chapter 5) were attended to obtain a first-hand insight. During these exercises, scenario cards were used to outline the gender of the presenting patient and the symptoms resulting from the event. Participants in both exercises responded to the patients, with the available resources and current situation. It was realised that the use of scenario cards presenting a hypothetical scenario was a valid means of eliciting a realistic response. A variety of advantages and disadvantages (Riley, Dalby, & Turner 2010; Clay et al., 2015; Skryabina et al., 2016) have been associated with table-top exercises and drills.

Advantages

- Provide a realistic format to practice CBRN response.
- Familiarise participants with their policies, plans, and procedures during a CBRN event.
- Increase post-exercise knowledge.

Disadvantages

- Disruptive to normal working and expensive.
- Consist of artificialities that compromise the realism.
- Used as a means of training.

Scenario cards

Scenario cards have been reported as efficient tools for planning, improving, and handling CBRN events by Sandström, Eriksson, Norlander, Thorstensson, and Cassel (2014) and the use of such cards has proven to be effective. Scenario cards were used to present hypothetical patients and scenarios as a prompt for first receivers to *"Talk the researcher"* through what they would do if faced with the presented scenario. They were considered the most apt method because they:

- Elicited realistic responses, whilst being presented in the ED.
- Were cost-effective.

- Not time consuming, allowing the continuation of patient care.

3.7.3 HF/E methods

A variety of HF/E methods were initially considered, such as AcciMaps because it has effectively been used in mapping out multi-services CBRN responses by Hancox et al. (2016). AcciMaps were not used based on limitations such as it being an accident analysis technique to be used retrospectively.

Functional Resonance Accident Model (FRAM) (Hollnagel, 2004) elicits information about how variations in the performance of individuals, technology, and organisations impact accidents in complex socio-technical systems (Hollnagel, Pruchnicki, Woltjer, & Etcher, 2008) was considered to be used in this work. FRAM uses the concept of functions which are the means needed to achieve a goal. The functions are based on 6 parameters which include *preconditions* and *time constraints* (Hollnagel et al., 2008).

Although FRAM was initially proposed as an alternative way to analyse accidents in complex systems, FRAMs efficacy in aviation (Hollnagel et al., 2008) and operating theatres (Woltjer, 2010) rendered the method to be applicable to the dynamic ED environment. Reasons for considering FRAM was its focus on essential socio-technical system functions, the importance FRAM places on variability, and how it aims to analyse how something has been done, is done, and could be done (Hollnagel, 2018).

FRAM defines socio-technical systems through the functions they perform rather than by their structure (Hollnagel, 2004). This categorisation limits the applicability of FRAM in this thesis because the ED CBRN response is defined by both (organisational) structures such as adhering to instructions by Command and Control teams as well as departmental and individual (first receiver) functions. Therefore, FRAM would jeopardise obtaining a complete functional and structural understanding of the ED response to CBRN events. Hence, HTA was chosen to represent both structure and function of the ED CBRN response.

FRAM accounts for different levels of analyses through concepts such as foreground functions (what is being analysed - the focus of the investigation) and background functions (context/environment) (Hollnagel, 2012). Additionally, when using FRAM, the analyst must have in-depth knowledge about the system (Stanton et al., 2013); combined, these factors suggest that FRAM prioritises and can potentially filter out important information along with having demanding prerequisites for it to be used effectively. As this thesis was focusing on better understanding and enhancing the ED CBRN response, and although the analyst did have in-depth knowledge of the system, HTA was used because it was *neutral* method that did not depend on the analysts knowledge of the system; providing an objective representation of important information, which was synthesised to provide standardised recommendations.

FRAM describes what happens in terms of WAD functions (Hollnagel, 2018) and is suggested to be a method to visualise WAD (Hollnagel, Hounsgaard, & Colligan, 2014). However, this is questionable and leaves FRAM unsuitable for this thesis on two grounds.

Firstly, a method to map out both WAI and WAD was required to allow a consistent means of comparison and synthesis (Chapter 6). Secondly, FRAM has been reported to be an effective method to address variation in clinical settings (medical and surgical wards) during clinical processes, such as double-checking medications by Schutijser et al. (2019) in which WAI and WAD are both represented by FRAM efficiently.

Although, FRAM focuses on variability in policy and practice, it is daily policy and practice. The context of this thesis is responding to a CBRN event, which consists of tasks that are not daily practice, in fact, consist of tasks that are rare such as, donning and doffing PRPS suits and wet decontamination. Therefore, although FRAM takes into consideration crucial principles such as variability and WAI and WAD, HTA served to be a better method in this context because it shows an understanding of how tasks are organised in terms of levels and how they can be structured. Whereas FRAM represents neccesary functions to carry out the target activities, which in this context are already known through CBRN plans (Hollnagel, 2018).

3.7.4 The development of Ergonomics, Scientific Management, and Hierarchical Task Analysis

Task analysis is defined as:

"A method of describing what an operator is required to do, in terms of actions and /or cognitive processes, to achieve a system goal. It is a method of describing how an operator interacts with a system and with the personnel in that system"

(Kirwan & Ainsworth, 1992, p. 408).

There is a difference of opinion on whether the analysis of tasks was established before (Astley, 1991) or after the establishment of HF/E as a scientific discipline (Hoffman, & Militello, 2009). The term Ergonomics was derived from the Greek words ergon (work or task) and nomos (law) by Jastrzebowski in 1857, who proposed that the science of work was a broad discipline consisting of a diverse scope, wide potential of applications which encompass all aspects of human activity. Jastrzebowski (1857) further divided work into the useful and harmful, the harmful brings deterioration. Useful work aims to improve aspects for the common good and uses motor, sensory, forces of reason, and spirtuailty, which was further classified into the physical, aesthetic, and rational (Karwowski, 2000).

Based on Jastrzebowski's contributions, it can be said that the notion of task analysis followed soon after the establishement of HF/E as a scientific discipline through the*"Taylor system"* in the 1880s which was later named the scientific management movement in 1911 (Merkle, 1980; Taylor, 1911). The scientific management movement was described as a mental revolution in factory organisation which proposed a series of tools, methods, and organisational arrangements to change the way researchers viewed and studied work through introducing effective methods for analysing a task and highlighting efficiencies to increase production (Hoffman & Militello, 2009; Merkle, 1980).

The scientific management movement began with a system of timing work, as a means to eliminate the discrepancies between workers and owners on what could be considered appropriate returns to capital and labour through scientific measures (Spender & Kijne, 2012; Taneja, Mildred, & Toombs, 2011). Taylor, aimed to apply the rigour of scientific methods in the analysis of work (Stanton, 2006). Taylor's renowned contribution to work efficiency detailed observations of workers using a stop-watch to determine the time required to accomplish specific tasks with the aim to reduce process time (Lopetegui et al., 2014; Taylor, 1911). A renowned example of effective application of time studies is that of the observation of 75 men at a steel company who transferred pig iron by a shovel. Taylor's team of engineers suggested improvements and increased productivity from 12.5 to 47 tons of pig iron a day (Baumgart & Neuhauser, 2009; Taylor, 1911). Scientific management was grounded on four principles (Huang, Tung, Lo, & Chou, 2013; Kemp, 2013; Taylor, 1911):

1. Development of a true science.
2. Scientific selection of the worker.
3. Worker's scientific education and development.
4. Development of co-operation and intimate relationship between the management and the workers.

Fundamental to the scientific management movement were questions such as *"How was the work performed?"*, *"What was needed to perform the work?"*, *"Why was the work performed in this way?"*, and *"How could working methods be improved?"* . Such questions remain core to modern task analysis techniques (Stanton, 2005). The questions posed by the scientific management movement were crucial in effectively fulfilling the research aims of this thesis. HTA was being used to understand how work was being carried out and to improve working methods during CBRN events through standardised recommendations.

In 1907, the Gilbreths became involved in scientific management research (Gillbreth, 1909). As suggested by Baumgart & Neuhauser, (2009) the Gillbreths were both promotors and competitors of the scientific management movement based on their differing views on work and workers. Taylor initiated scientific management through his focus on time, the Gilbreths continued scientific management by focusing their work on more efficient means of performing tasks through motion. After the death of Taylor, the Gillbreths' reputation grew. As a result of two factors, firstly, they began to differentiate their work from that of Taylor between the 1920s and 1930s, by characterising their own methods while relying on the basic fundamentals of scientific management. Secondly, by taking advantage of the technical innovations by the Kodak camera company to apply micro motion studies at lower costs, owing the name *"Time-motion studies"* which gained broader acceptance (Baumgart & Neuhauser, 2009; Gillbreth, 1911; Price, 1992).

The Gillbreths' studies of motion have been suggested to lay the foundation for modern applications of job simplification, work standards, and incentive wage plans (George, 1972). A prominent example is the observation of bricklayers who implemented different methods of working. Innovative tools such as shelves for bricks, mortar, job aids, and work procedures to find the best method of performing the task were developed. The combination of these adjustments resulted in the action of bricklaying to be reduced from approximately 18 movements to four, meaning the task was performed more efficiently (Gillbreth, 1911).

The Gillbreths' contribution was to break down and analyse individual elements of a task and record them against time (Gillbreth, 1911; Stanton, 2006). The individual elements discovered through the study of hand motions were termed Therlbigs, which were a classification of 17 basic human motions, such as *"grasp"* and *"hold"* to micro-analyse worker behaviour. Through the micro-analysis of time and motion it was proposed that science could be implemented to create the correct way of doing tasks, which became the foundation of the standardisation movement in various fields in the 1910s and 1920s (Baumgart & Neuhauser, 2009; George, 1972; Gillbreth, 1911, 1913; Stanton, 2006). Although this thesis is not a motion study, the Gillbreth contribution resonates with the overarching objectives of this thesis, based on the three stages of motion studies, which were:

1. Discovering and classifying best practice.
2. Deducing the laws.
3. Applying the laws to standardise practice.

Similar to the work of the Gilbreths and the microanalysis of work; this thesis attempted to micro analyse CBRN actions from both organisational top down (CBRN plan) and individual (first receiver) perspectives. Despite the competition and outgrowths of Taylor's work, the Gillbreths had a constructive role in maturing scientific management, and accelerated the process of innovation (Price, 1992). Work by the Gillbreths is valued in this thesis because they investigated means of improving processes in hospital settings (Gillbreth, 1914, 1915), just as this thesis is aiming to enhance the ED CBRN response process.

Although Schachter (2010) suggested that scientific management had a revolutionary existence to the science of work. The reliability (as defined in Chapter 2) of the underpinnings of Taylor's contributions and the scientific management approach have been criticised.

Beginning with the reliability of Taylors approach, Wrege & Perroni (1974) suggested that the pig-iron observation was false largely because details were changing in newer versions of Taylors account of the observation, the authors suggested the entire re-evaluation of the scientific management. However, Hough & White (2001) proposed that discrepancies in the pig iron observation were acceptable and could be considered intentional in order to persuade the audience at the time that the most basic processes could be improved for the prosperity of both the employer and employee. Nonetheless, the changing details of Taylor's investigations into work practices is a limitation into the rigour applied to Taylor's contributions, therefore the observation or timing of tasks which were integral to Taylor's work are not implemented in this thesis.

Additionally, scientific management has been criticised for ignoring the psychological components of work (Hackman & Oldham, 1980), which focuses on efficiency drives and job simplification whilst ignoring and de-humanising the individual person and the *"human factor"* (Derksen, 2014; Dunford, 1988; Patmore, 1988; Stanton, 2006).

Scientific management has further been criticised for adopting a reductionist approach towards acquiring efficiency and applying behavioural characteristics depicting *"kind natured"* individuals in the form of managers to reinforcing capitalistic ideas (Stanton, 2006; Wagner-Tsukamoto, 2008). Such criticisms have been opposed by authors such as Huang et al. (2013) who suggest that the happiness of workers was prioritised.

Derksen, (2014) suggests that Taylor's contributions articulated the human factor differently and aligned it to its own instruments and practices in such a way that it was external yet essential to the functioning of workers. In comparison to this criticism, the Gillbreths' contributions were based on the well-being of the worker, and emphasis on the human factor (Gillbreth & Gillbreth, 1917), and the effectiveness of work (Stanton, 2006).

It has also been suggested that scientific management was in fact, more of a labour reformation than being a means of scientifically managing work (Locke, 1982; Taneja et al., 2011); this is because scientific management focused on time studies to standardise tasks and procedures to pay for rates of work. Having a direct financial link to standardising tasks is understandably interpreted as a labour reformation. This thesis focuses more so on the efficiency of standardising tasks as proposed by scientific management as means of enhancing the quality of care delivered to patients during a CBRN emergency.

The aforementioned limitations are overcome in this thesis by taking into consideration the individual person (first receiver) when responding to a CBRN event. This was ensured by obtaining a diverse and representative sample of first receivers who would contribute to the CBRN response based on their skills. The work involved during a CBRN event is not aimed to be simplified through standardisation. Locke (1982) highlighted the scientific management focused on redesigning machines and equipment to enable workers to be more skilled at the tasks that they perform. This thesis has extended Taylor's contribution to standardise the CBRN response process to use the skills of first receivers to give the best care to patients during CBRN events.

3.7.4.1 Hierarchical Task analysis

During and after World War 1, studies of the effects of fatigue, working conditions, and the environment were becoming popular through the establishment of the Industrial Fatigue Research Board which was set up in the UK in 1916 (Annett, 2014). Studies were based on movement, fatigue, personnel selection, and industrial unrest (Myers, 1921). For example, the causes of accidents in industry were addressed by Newbold (1926) who suggested that a personal susceptibility to accidents exists. Vernon (1928) determined the optimal temperature, humidity, and air movement to formulate the optimal conditions at work for maximum production. It was through the work of Myers, Vernon, and Newbold that the term *"Human Factors"* was established (Hoffman & Militello, 2009); and in 1950, the Ergonomics Research Society in England (Browne et al., 1950), began to promote the term *"Ergonomics"* in the industrial world.

The introduction of technology in the 1950s, resulted in changes in the design of both military and industrial tasks. As suggested by Annett (2003), the rise of automation reduced physical effort whilst increasing mental effort to control complex machinery. Methods proposed by the scientific management movement were no longer adequate, presenting an opportunity for developing psychological approaches to form a method for man-machine task analysis which primarily broke down the main task functions into subtasks. This method emphasised performance outcomes and data processing characteristics of the operator (person who is carrying out the task) (Shepherd, 2001). The term task analysis was coined by Miller (1953) and was associated with methods used in industrial psychology and Ergonomics (Hoffman & Militello, 2009).

The 1960s presented a clear move away from contemporary approaches which focused on observable features of performance. As suggested by Stanton (2006) the behaviouristic paradigm was dominating, and the cognitive revolution had not happened; most importantly it was considered unscientific to infer cognitive processes, thus the focus on observable behaviour. HTA however, aimed to provide a means of goals and sub goals, with feedback loops in a nested hierarchy.

The control theory of human behaviour by Miller, Galanter, & Pibram (1960) set the scene for Hierarchical Task Analysis. Pivotal to this theory was the ideas of Test, Operate, Test, and Exit, known as (TOTE) unit and hierarchical levels of analysis (Stanton, 2006). A TOTE unit specifies a goal which is represented by the set point in a control loop, and an action generation system controlled by the feedback on the discrepancy between set points and current goal state (Annett & Stanton, 2000). The three units of analysis in TOTE were Test, Operate, and Exit. A classic example of a TOTE unit is the explanation of hammering a nail with a piece of wood (Stanton, 2006). The most important contribution of TOTE was that it consisted of information feedback, a system of control, and analysis of systems (Stanton, 2006) which resulted in the operation being the selected unit of analysis in HTA (Annett, 2003).

In 1971, Annett et al. proposed the original paper outlining how to carry out HTA as a training information paper, making clear that the approach was a methodology based on human performance. The original paper was based on three core questions which were:

1. Does it lead to any positive recommendations?
2. Does it apply to more than a limited range of tasks?
3. Does it have any theoretical justifications?

Stanton (2006) neatly paraphrased the Annett et al. (1971) contribution as *"The theory is based on goal-directed behaviour comprising a sub goal hierarchy linked by plans. Thus, performance towards a goal can be described at multiple levels of analysis"* (p.58). The underlying principles of HTA are governed by three main principles shown in Table 14 (p. 84).

Table 14: Core principles of HTA and explanation (sources: Annett et al., 1971; Stanton, 2006)

Principles of HTA	Explanation
1. At the highest level: Task is an operation; the operation is defined in terms of its goal. The goal implies the objective of the system in real terms such as production units, quality or other criteria.	HTA is proposed as describing a system in terms of its goals. Goals are expressed as objective criteria. This emphasises that HTA is a goal-based analysis of a system and that a system analysis is presented. HTA describes goals for tasks, so that each task is described in terms of its goals.
2. The operation can be broken down into sub operations which are each defined by a sub goal, measured in real terms through its contribution to the overall system output or goal; it is therefore measurable in terms of performance standards and criteria.	HTA is proposed as a method of breaking down sub operations in a hierarchy, through which sub operations are described as sub goals. HTA is a description of sub goal hierarchy.
3. The vital relationship between operations and sub operations is inclusion; it is a hierarchical relationship. Even though tasks are commonly proceduralised, that is the sub goals must be attained in a sequence, which is not always the case.	There is a hierarchical relationship between goals and sub goals, and rules govern the sequence in which sub goals are attained. In order to achieve the goal in the hierarchy, its immediate sub goals must be attained.

HTA forms a hierarchy of operations which are described as the different tasks people must do within a system to achieve a goal (Shepherd, 2001). Tasks are described in terms of operations and plans. Operations are linked with plans, which are statements of the conditions that are necessary to undertake operations (Table 15, p. 85 and Figure 12, p. 87). HTA has been suggested to be an effective way of stating how work should be organised to meet a systems goals (Kirwan & Ainsworth, 1992). A system's goal is *"A statement of what the system is required to achieve, it follows that since the operator is a part of the system, he or she must carry out actions which are consistent with the system's goals"* (Shepherd, 2001, p. 1). Table 15 (p. 85) explains key concepts used in HTA.

Table 15: Key concepts in HTA (sources: Shepherd, 1985, 1998; Stanton, 2006)

Concept	Meaning
Operation	At the highest level a task is considered as consisting of an operation which is defined in terms of its goal. This sets the objective of the system. Operations in general are statements of the goals that an operator is seeking to achieve.
Operator	The person who is carrying out the task.
Task analyst	People engaged in the processes of analysing tasks.
Goal	Instruction or imperative, given in the form verb-action or a combination of such instructions.
Task	A problem to be solved or a challenge to be met.
Sub goal	Part of a wider goal. A core strategy in HTA is to describe goals in terms of their sub goals.
Plan	Describes the statement of the conditions under which each of a set of sub goals is undertaken to achieve their common superordinate goals.
Re-description	A re-description of a goal is the set of sub goals and their plan which accounts for the activities that that need to be conducted to achieve the goal.
Subordinate operations	Re-description of the operation above and set out the objective for the subordinate goal.
Superordinate operations	Operations which are re-described hierarchically and set out the objective for the superordinate goal.

HTA is a generic, systematic, and practical process through which the analyst collects a variety of information about a task and its context. HTA guides the analyst through the following three analytical methods (Shepherd, 2001):

1. Does the task warrant examination?
2. Is the analyst able to make judgements about weaknesses in human performance or the task which might result in difficulty?
3. Can the analyst re-describe the operation into greater detail?

Re-description is the defining method for HTA (Shepherd, 2001). Goals are described to produce a hierarchical structure for clarification and analysis. Sub goals are re-described, and this process can continue indefinitely until the stopping rule is achieved (see Section 3.7.4.1.2, p. 87). HTA is an analysis, a procedure which aims to identify performance problems, sources of error, and propose solutions (Annett, 2003). Guidelines (Appendix 5, p. 298) to carry out HTA are based on a flow of decisions (Figure 11, p. 86).

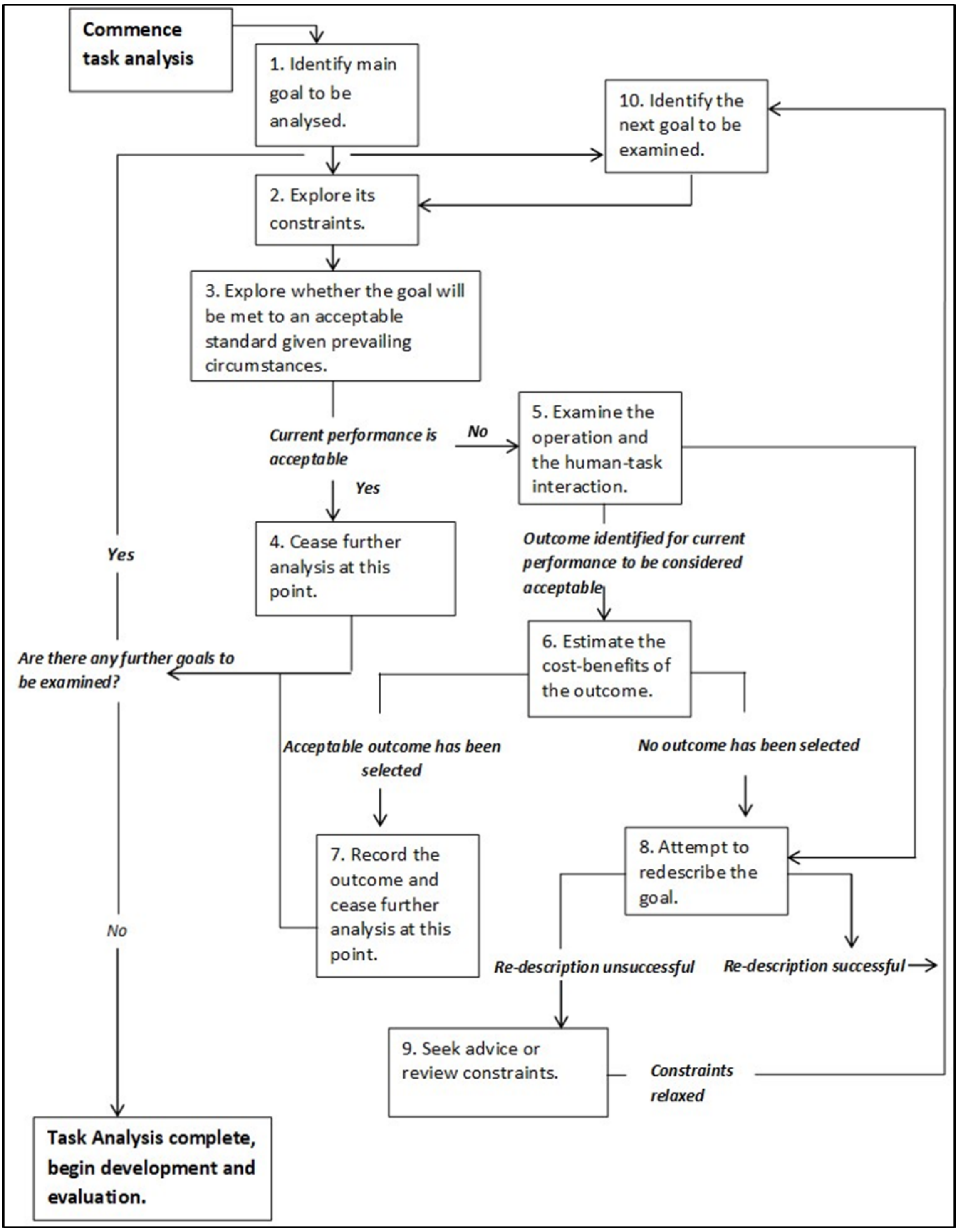

Figure 11: Flow of decisions in the HTA process (Source: adapted from (Shepherd, 2001)

3.7.4.1.1 Plans

Plans are control structures which enable the analyst to capture the conditions which trigger the sub goals (Stanton, 2006), and indicate how subordinate operations are organised to achieve their common goal (Shepherd, 2001). Plans consist of several timing and sequencing relationships. Plans set the context in which an activity affects the performance of the task (Shepherd, 1985). A variety of plans exist (Figure 12) which can be combined to understand complex activities (Stanton, 2006). The plans used in the HTAs of this research were predominantly fixed sequence plans and concurrent operations.

Figure 12: Types of plans used in HTA (Annett et al., 1971; Shepherd 2001; Shepherd 2015)

3.7.4.1.2 When to stop re-description?

Annett et al. (1971) stated that knowing when to stop the analysis was problematic. The stopping rule associated with HTA is the P x C rule, in which P is an estimate of the *Probability* of inadequate performance and C is the *Cost* of inadequate performance (Shepherd, 2001). The P x C rule has been described as a *"Rule of thumb"* (Kirwan & Ainsworth, 1992). It is recognised that the estimation of these values is not easy, because the P x C stopping rule.

3.7.4.1.3 Representing HTA

It is necessary to use tables as well as diagrams to represent the analysis as a means of providing a record of the analysis (Shepherd, 2001).

3.7.4.1.4 Hierarchical Diagrams

Hierarchical diagrams are a useful means of showing the structure of a hierarchy because re-description can be followed easily. The flow of re-description allows navigation around the task and shows how varying parts of a task relate to one another. However, hierarchical diagrams have been suggested to be unsatisfactory on their own. This is because they do not represent aspects and issues that have been realised during the analysis such as task constraints, stopping decisions, and design hypotheses, this is where tabular formats provide the solution (Shepherd, 2001).

3.7.4.1.5 Tabular formats

A tabular format was the proposed technique to record the analysis and illustrate the concept of a hierarchy of operations (Annett et al., 1971). The original suggested tabular format is shown in Figure 13, which shows that the left-hand column is based on identifying the goals in terms of hierarchical number. The next column was a description of operation and training notes, which contains the goal name and "R" if it is to be re-described elsewhere in the table as well as containing notes relevant to training performance. The next column is titled I or F, which would be marked with an X if there was any input or feedback constraints in performing the task, the action column (A) would also contain an X if there were any action difficulties.

Number	Description of operation and training notes (R = re description).	I* or F**	A***	Re-described

Figure 13: Example of HTA table (source: Annett et al., 1971)

*Input **Feedback ***Action

Shepherd (1976) outlined limitations of the original tabular format and proposed an alternative table (Figure 14, p. 89). Tables in a HTA are suggested to be a means of allowing back up notes about the task to be made (Shepherd, 2001).

Two limitations exist when HTA is represented in a tabular format. The first is with the vertical layout of the table and how the hierarchical structure of a HTA can be represented in a linear sequence. The second is associated with the horizontal layout of a table and what additional information could be provided in an analysis record (Shepherd, 2001).

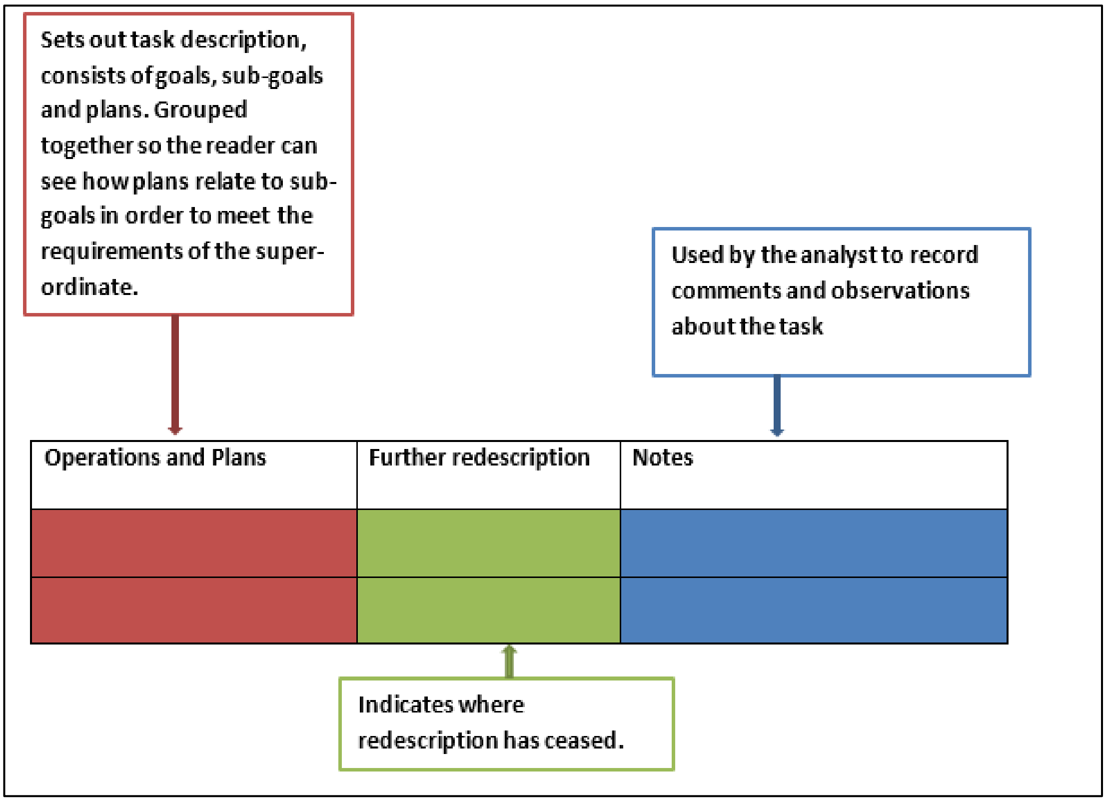

Figure 14: Main columns of HTA table (source: Shepherd, 2001)

Hignett and Banerjee (2019a) used both tabular and hierarchical representations of HTA in their research based on care provided during labour and childbirth. This thesis initially implemented a tabular format to compare General Organisational Responsibilities (GORs:The actions and activities expected from the ED as a system within a larger system, e.g. hospital) and action cards, an extract is provided in Figure 15 (p. 90).

Operations and plans	Further redescription	Action cards and *notes*
0. Implement Trust A CBRN plan Plan 0: Do 1-8 in order	Yes	Receptionist NIC Decon nurse team leader Triage/disrobing nurse (dry decon) Triage/disrobing nurse (wet decon) HCA (hot zone) Timing board nurse (cold zone) Exit nurse (cold zone) Assessment doctor (cold zone) PPE buddy donning PRPS suits (cold zone) PPE buddy doffing PRPS suit (cold zone) PPE buddy enhanced biological precautions PPE buddy strict biological precautions Porter Security Medical Physics
1. Understand roles and responsibilities	Yes	Receptionist NIC Decon nurse team leader Triage/disrobing nurse hot zone (dry decon) Triage/disrobing nurse hot zone (wet decon) HCA (hot zone) Timing board nurse (cold zone) Exit nurse (cold zone) Assessment doctor (cold zone) PPE buddy donning PRPS suits (cold zone) PPE buddy doffing PRPS suit (cold zone) PPE buddy enhanced biological precautions PPE buddy strict biological precautions Porter Security Medical Physics
2. Take notification of casualties	Yes	Receptionists

Figure 15: Extract of tabular HTA comparing GOR and action cards

The use of tables was, however, disregarded because the large number of tasks in the GOR representations made comparison impractical. Differences could not be visualised. Based on the need to see similarities and differences across HTA representations to make effective comparisons a visually obvious means of highlighting was required – colour coding the HTA as a means of thematic analysis was the optimal method.

A number of general advantages and disadvantages (Kirwan & Ainsworth, 1992; Stanton et al., 2013; Stanton, 2006; Stanton & Young, 1999) have been associated with HTA:

Advantages

- Flexible technique which can be used to describe any system.

- Hierarchical structure allows the analyst to focus on vital aspects of the task in the context of the overall task.
- HTA is developed in collaboration between the analyst and the people involved in the operations allowing an in-depth insight into the processes of fulfilling goals.
- HTA benefits the analyst by allowing them to gain rapid insight into the processes involved in achieving a systems' goals.
- HTAs are advantageous to operators because they are asked to express how they think tasks should be conducted, consequently rechecking their understanding of the systems.

Disadvantages

- Analyst needs to develop a skill in order to analyse a task effectively.
- An in-depth implementation requires some months of practice with expert guidance.
- Provides mainly descriptive information rather than analytical information.
- Does not account for cognitive components of the task.
- Laborious and time consuming for large complex tasks.
- Reliability of HTA can be questioned – different analysts might produce different analyses.
- Initial data collection phase is time consuming and requires the analyst to be competent in several techniques such as interviews and observations.

Despite the disadvantages outlined above, HTA was chosen to be the central method of this thesis because its reliability can be enhanced by using different sources of information, while developing and re-checking the analyses (Kirwan & Ainsworth, 1992). Reliability in this context was established through a thorough inquiry audit which enhances the dependability of qualitative research (Lincoln & Guba, 1985) which in turn examines the process and the product of the research (Hoepfl, 1997).

Advantages presented by HTA as the optimal method for this thesis are that it provides the opportunity to unpack the performance towards a goal at a multiple level of analysis.

HTA is also a continual process of refinement, which offers three benefits:

1. The breakdown of a complex task such as responding to a CBRN event into subtasks, resulting in enhanced knowledge of this domain.
2. By going back to the source of information, such as CBRN leads and first receivers to verify HTA representations, it provided an opportunity for evaluation and reflection on practice as well as providing consistency throughout the various components of the research.
3. HTA provides a graphical breakdown of tasks and potential discrepancies between WAI and WAD.

In spite of the criticisms associated with scientific management. The evolution and rooting of HTA within scientific management combined with the emphasis on understanding how work is carried out is the foundation of this thesis. Additionally, as suggested by Taneja et al. (2011) current focus on processes, systems, and organisational improvements are rooted in the scientific management movement. Further, the contributions of the Gillbreths and breaking down tasks to enhance understanding of tasks and then enhancing task performance is core to meeting the aims of this thesis. The stance on standardisation for enhancing pay is modified to enhance the quality of care delivered patients in the ED response to CBRN events.

This thesis overcame disadvantages of HTA such as the provision of descriptive information rather than analytical information through additional applied thematic analysis, adopting a participatory design, and through a thorough HF/E review. Cognitive components of CBRN tasks were accounted for in the HTAs through presenting scenario cards in the ED and asking first receivers to talk through their actions in such a situation. By doing so CBRN tasks were articulated and further compared to tease out vital CBRN tasks across Trusts as a means of standardising the CBRN process. Finally, the reliability of the HTA's was sound, again as a result of the participatory design component of the research in which there was agreement through a number of experts and participants that the HTAs were a true representation of CBRN actions.

3.8 Study design

This research protocol is presented in Figure 16 (p. 94).

3.8.1 Study setting

The study setting was the ED to elicit a *"Real-time"* response from ED first receivers. The studies were specifically designed to be carried out in the ED, because HF/E research relies heavily on studying human work in its natural environment (Hoffman, Benda, Fairbanks, & Auguste, 2017).

The ED is the optimal setting to address the research question (see Section 3.2, p. 58) due to its key role in providing care to CBRN victims (Whetzel et al., 2013). This was a multi-site project which involved two NHS Foundation Trusts in the Midlands region of England (Trust A and Trust B). A multi-study and multi-centre approach was adopted to review similarities and variations between Trusts (Chapter 6) as well as overcome issues such as ED specific team culture (Gauntlett-Gilbert, Rodham, Jordan, & Brook, 2015). These sites were chosen because they are Type 1 Emergency Departments.

In the England there are four types of EDs:

- **Type 1:** Consultant led 24-hour service with full resuscitation facilities and designated accommodation for the reception of emergency patients.
- **Type 2:** Consultant led single speciality (e.g. dental) with designated accommodation for the reception of patients.
- **Type 3:** Other type of Emergency Department with designated accommodation for the reception of emergency patients, it can be doctor or nurse led with the ability to treat minor injuries and illnesses. Type 3 ED types can be routinely accessed without an appointment.
- **Type 4:** NHS walk-in centres (NHS Data Dictionary, 2017).

Additionally, There are 27 MTCs in England which treat severe and complicated injuries (NHS England, 2018b; Moran et al., 2018; NHS England, 2016).

Mass casualty guidance allocates patients based on a triage system as P1 (life threatening: breathe only after airway cleared, require immediate treatment), P2 (urgent: unable to walk, require urgent treatment), P3 (minor: wounded but able to walk, delayed treatment), and P4 (dead: not breathing even after airway cleared). An MTC should expect to receive predominantly P1 patients, a trauma centre should expect to receive P2 patients. Other medical facilities are assigned P3 patients, and P4 patients might require special handling/decontamination before removal. It is however recommended to prepare for a mix of casualties because there would be a lack of ability to transfer patients between sites for the first 24 hours of a major incident (NHS England, 2018).

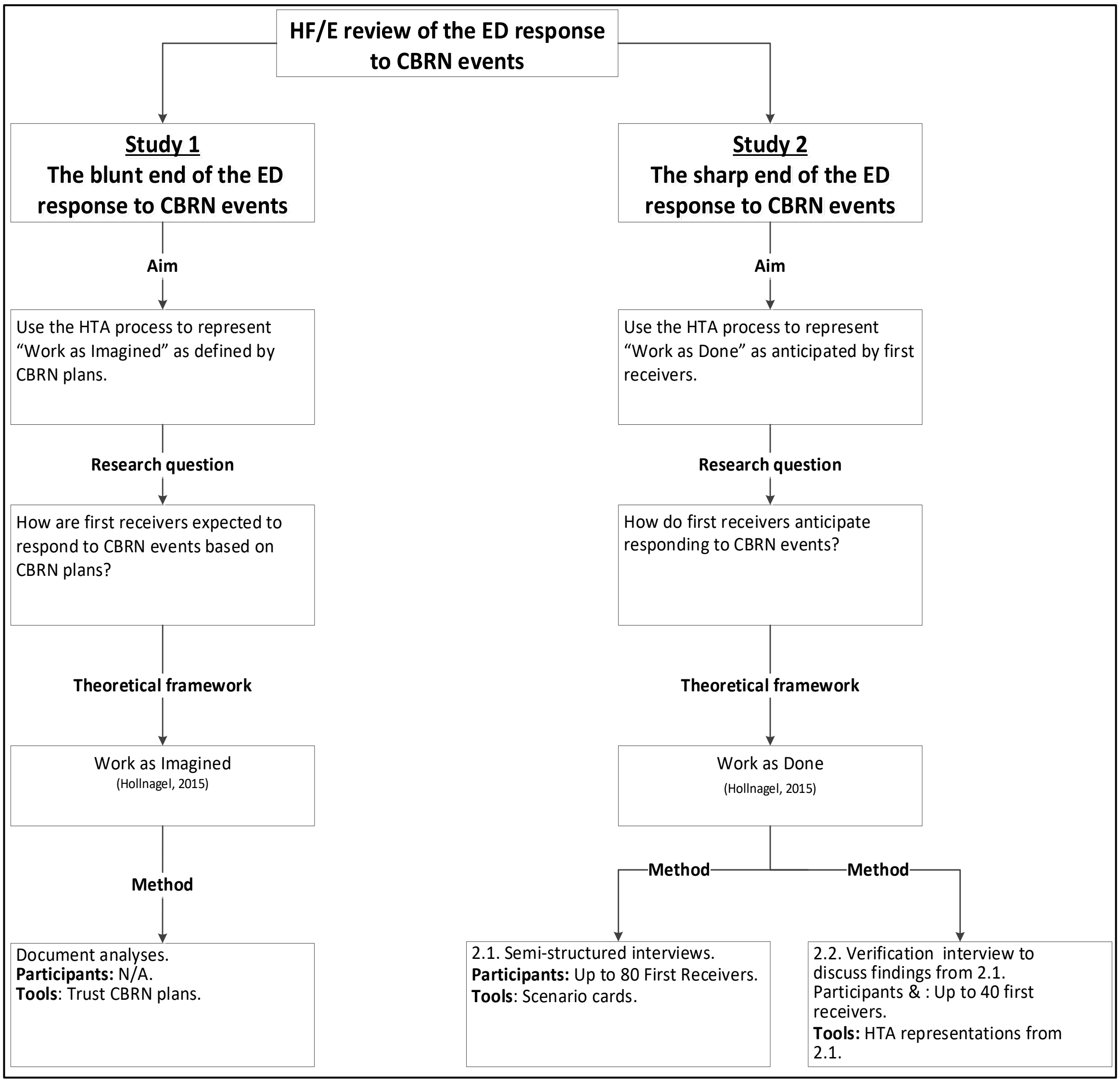

Figure 16: Components of research studies

3.8.2 Data collection and analysis

Two data collection methods were used:

1. Document analysis (Study 1).
2. Semi-structured interview with scenario card presentation and verification interviews (Study 2).

Data were collected with field notes to produce HTAs and audio recordings for verification interviews. Data were analysed by applied thematic analysis (Guest, MacQueen, & Namey, 2012) and colour coding. A similar approach was implemented by Trudel et al. (2017), when adopting HF/E to better understand infection prevention practice in a neonatal Intensive Care Unit.

The themes were visually networked through colour coding the tasks of the HTAs, with deeper interpretation (such as first receiver group specific analyses) to combine the field notes and HTAs.

Ranney et al. (2015) suggest that rigorous data collection is an integral component of qualitative research in which a detailed systematic, well-developed, and thorough data collection protocol must be formulated. A Health Research Authority (HRA) research protocol was formed and approval was granted through the Integrated Research Application (IRAS) process (see Section 3.8.3, p. 104). Ranney et al. (2015) suggested three vital components for qualitative data collection protocol (Table 16, p. 96).

Table 16: Vital components for formulating an effective qualitative data collection protocol (source: Ranney et al., 2015)

Component of qualitative data collection protocol	Actions implemented to produce a rigorous PhD protocol
1. Develop a clear collection strategy.	The protocol clearly highlights how data will be collected, see Figure 16 (p. 94).
2. Appropriately identify and sample the population of interest.	The aim of a sampling strategy is to maximise the opportunity of producing enough data to answer the research question (Green & Thorogood, 2009). The sampling strategy ensured that the type and size of the sample was justified through: **1.** Purposive sampling because this involves the identification and selection of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Creswell & Plano-Clark, 2011). Purposive stratified sampling was further used to provide a comparison between types of first receivers. **2.** A representative sample was crucial to the sampling strategy and was ensured by calculating the percentage distributions of first receivers on a typical shift. Those percentages were used to determine the actual number of first receivers required in the sample. **3.** Diversity in clinical, managerial, and unskilled aspects of the ED CBRN response which results from the length of experience in the ED exists. This experience correlates with the roles taken by certain individuals in responding to CBRN events. Therefore, it was intended that individuals who have minimal experience and responsibility, as well as those with greater experience were recruited. **4.** Adopting a flexible sampling strategy.
3. Obtain data in a reproducible and rich (detailed) manner.	Clear data collection tools were implemented such as: **1.** Scenario cards. **2.** HTA representations of scenario card responses.

3.8.2.1 Thematic analysis

Thematic analysis is used for identifying, analysing, and reporting patterns (themes) within data by organising and describing data in rich detail (Braun & Clarke 2006), with emerging themes becoming the categories for analysis (Fereday & Muir-

Cochrane, 2006) (see Section 3.8.2, p. 95). Thematic analysis has been used in healthcare HF/E research effectively. For example when developing a framework to understand how design can be used to prevent infection in a neonatal unit (Trudel et al., 2017) as well as the ED to explore the usefulness of implementing a checklist to identify deteriorating patients (Redfern et al., 2018).

Data analysis was considered according to the research strategy (see Section 3.3, p. 58), in which the analyses were initially related to the flexible qualitative strategy resulting in establishing the interpretation of meaning in text or in images (Figure 17):

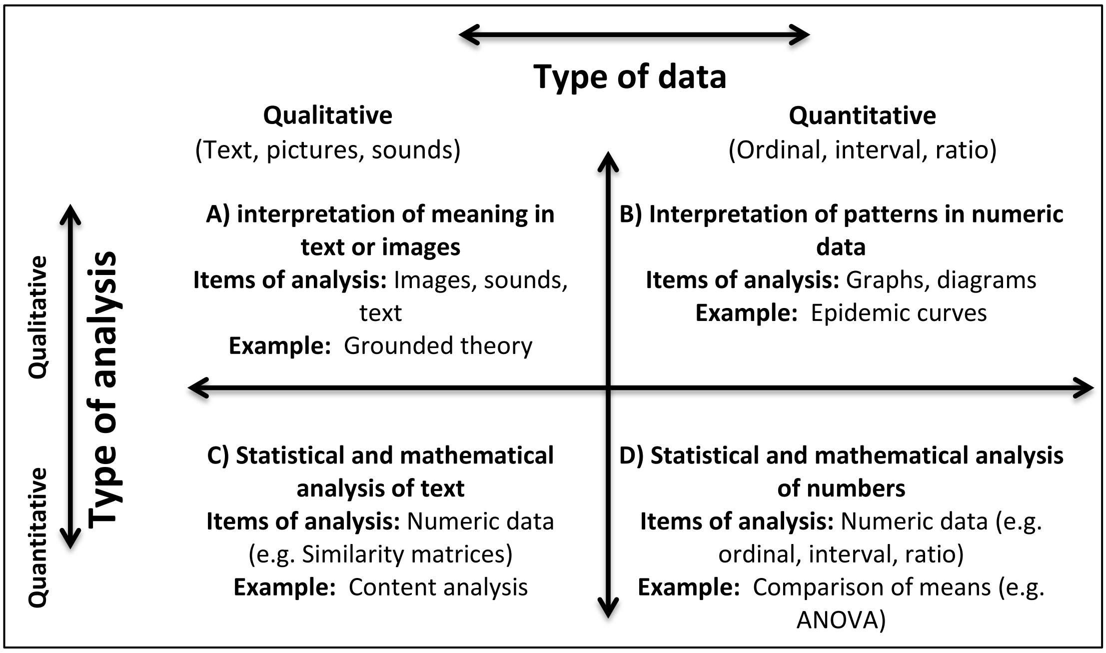

Figure 17: Qualitative and quantitative data analyses (adapted from: Guest et al. 2012)

Thematic analysis encodes qualitative information resulting in an explicit code, which can be a list of themes, a complex model with themes, indicators, and factors that are causally related. A theme is a pattern that is found within the information which describes and organises possible observations or interprets aspects of a phenomenon. Themes can be generated from the data (inductively) or from theory (deductively) (Boyatzis, 1998) (see Section 3.4, p. 64). Thematic analysis has been described by Boyatzis (1998) as a *"Way of seeing"*, "*Making sense of seemingly unrelated material"* and as *"A way of systematically observing a person, interaction, a group, a situation, an organisation, or a culture"*. Various types of thematic analysis exist (Table 17). Applied thematic analysis was the chosen approach on three grounds:

1. Can be used with various forms of qualitative data. This was ideal for this research because field notes, transcripts, and HTAs were being analysed.
2. Aims to respond to research problems of a more practical nature, the CBRN response requires practical action from first receivers.
3. Applied thematic analysis has a pragmatic focus on using appropriate tools to achieve the analytical goal in a transparent, efficient, and ethical manner.

Table 17: Examples of theme-based approaches to analysis (sources: Guest et al., 2012 & Hesse-Biber & Leavy, 2006)

Approach to analysis	Advantages	Disadvantages
Phenomenology (Husserl, 1970) *Participants' perceptions, feelings, and lived experiences are core to the study.*	• Good for cognitively oriented studies. • Suited to smaller data sets.	• Focuses only on human experience. • Not entirely systematic.
Grounded Theory (Glaser & Strauss, 1967) *Analysis starts with the engagement with data and ends with a theory that is grounded in the data.*	• Can be used to study topics beyond individual experience. • Interpretation supported by data.	• Time consuming. • Does not include quantification.
Applied Thematic Analysis (Guest et al., 2012) *Borrows the most useful techniques from each theoretical and methodological approach and adapts them to an applied research context.*	• Well suited to large data sets. • Applicable to team research. • Has analytic breadth – can include non-theme based and quantitative techniques.	• Can miss some nuanced data.

3.8.2.2 Sampling and recruitment

First receivers are core to treating CBRN casualties. First receivers are doctors, nurses, allied health care professionals, and non-clinical staff.

3.8.2.2.1 Eligibility Criteria

The study population were defined as *"first receivers"* (Chapter 1). The participant group was selected according to profession, clinical exposure, and being employed by an ED for a minimum of 3 months on a permanent contract basis (as it was envisaged that Trust induction consisting of CBRN training would have occurred by this point).

3.8.2.2.1.1 Inclusion criteria

- Aged 18 years and over.
- Experience: More than three months ED experience.
- Location: ED.
- Staff group: Allied healthcare professionals, doctors, nurses, porters, receptionists, and security staff.

3.8.2.2.1.2 Exclusion criteria

- Under 18 years.
- Less than three months ED experience.
- Bank/agency/locum staff.
- Students.
- First receivers on a secondment in ED.

3.8.2.2.2 Sampling

3.8.2.2.2.1 Sampling technique

Purposeful sampling was used to identify and select individuals especially knowledgeable about or experienced with a phenomenon of interest (Creswell & Plano-Clark, 2011). Focusing on first receivers for their expertise, perceptions, understandings, and experiences to CBRN events as staff.

3.8.2.2.2.2 Size of sample

After discussions with local collaborators at Trust A and Trust B it was evident that the ED is an unpredictable environment. Generic qualitative research typically aims for larger representation of the population under study to get a broad range of opinions, idea or reflections about real-world events, processes or experiences (Percy Kostere, & Kostere, 2015).

The initial plan was to recruit a maximum of 70 first receivers overall, 25 first receivers for component 2.1 and up to 20 first receivers for component 2.2. This was considered an adequate sample size in similar research by Cooper, O'Carroll, Jenkin, and Badger (2007). Further, it was believed that theoretical data saturation, which is the point at which new themes do not emerge from the data (Ranney et al., 2015) would be achieved. If theoretical data saturation had been reached, recruitment would stop from that group or band of individuals.

However, when component 2.1 (Figure 16, p. 94) had begun and the data collected, theoretical saturation had not been adequately reached. Accordingly, the sample size was revised to 120 first receivers (80 for component 2.1 and 40 for component 2.2) (Figure 18, p. 101). The representative sample was calculated from the percentage distributions of first receivers on a typical shift, to determine the actual number of first receivers required (Table 18, p. 102).

The sample size was based on factors such as staff allocation, differences in rotas, preferred methods of data collection, recognition of diversity in clinical, managerial, banding based on Agenda for Change (NHS Employers, 2017), and unskilled aspects of the ED CBRN response. Therefore, individuals who had minimal experience and responsibility, as well as those with greater experience were recruited. Participants included Foundation Year 1 (FY1) doctors, ED Consultants with 4-6 years emergency medicine speciality training (Salman, Jenkinson, Jamalapuram, & Leech, 2011), band 5 nurses, band 6 sisters, and band 7 Nurses in Charge (NICs).

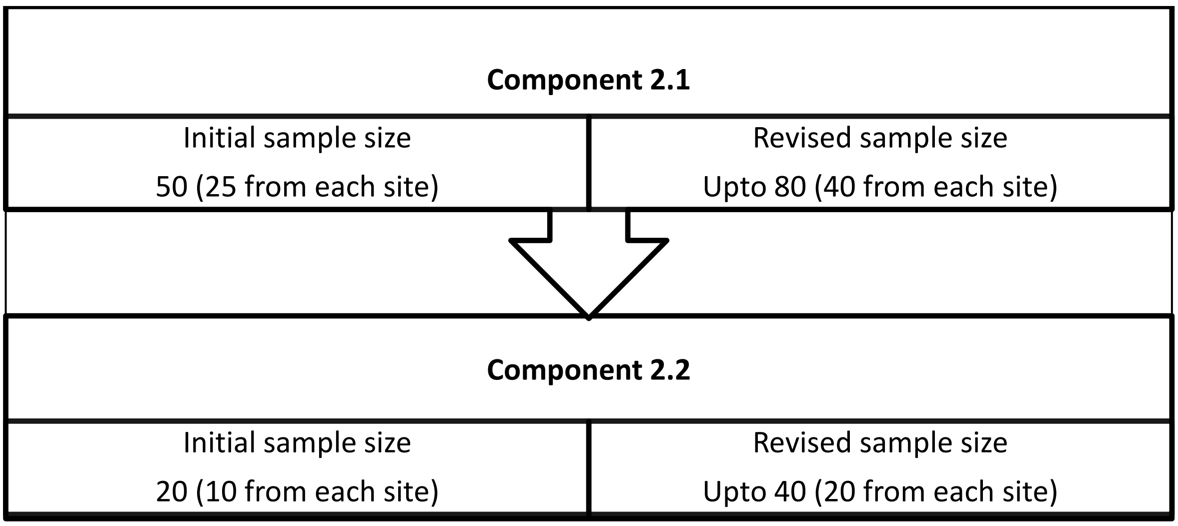

Figure 18: Sample size

There was variation in first receivers' rotas. At Trust A, the doctors' rota consisted of numerous components, meaning that the exact number of doctors based on their grading at any given point was not definite. However, there was always a diverse range of experience, with every shift including a senior doctor (registrar level: years of experience 4-6) who held the resuscitation area bleep.

Variation between samples between Trusts was also anticipated and catered for. For example, at Trust A, porters were managed by the Trust and were recruited as they have specific CBRN training. At Trust B, porters are not given CBRN training, and were employed by an external management company, which did not allow porters to participate in this research.

A shift-based approach was implemented and reflected the proportional make up of first receivers. For example, the largest contributing first receiver group, was nurses (n=13), as shown in Table 18:

Table 18: Percentage distribution based on Trust B shift make up for recruiting first receivers

First receiver type	Number of first receivers on shift	Percentage distribution	Relative distribution for a sample of 25 first receivers	Numbers required
Allied healthcare professionals	6	17%	4.25	4
Doctors/ACPs	8	23%	5.75	6
Nurses	13	37%	9.25	9
Receptionists	6	17%	4.25	4
Porters	2	6%	1.50	2
Total	**35**	**100%**	**25**	**25**

3.8.2.2.3 Recruitment strategy and challenges to recruitment

Participant recruitment is crucial to the success of any research study (Newington & Metcalfe, 2014) and is a challenge in health services and health-related research (Miller et al., 2017). An additional complexity is that HF/E research often involves domain experts as research subjects, and in studies that target healthcare providers as participants, recruitment can be challenging (Hoffman et al., 2017). Another factor which constrains access to healthcare professionals is that hospitals are becoming progressively more risk-averse regarding patient confidentiality and patient safety, and are less willing to have outsiders in the hospital environment (Loring, 2017).

In order to recruit effectively, factors influencing recruitment must be understood and overcome. These may include compensation in terms of monetary reward and professional respect resulting from collegial reasons, an interest in research, and novel-learning experiences were factors found to motivate participation (Hoffman et al., 2017). Other factors which influence the recruitment of participants are 1) Infrastructure, 2) The nature of the research, 3) Recruiter characteristics and 4) Participant characteristics (Newington & Metcalfe, 2014).

The researcher introduced herself as a PhD student alongside her clinical background as an Emergency Department Practitioner (EDP); this formed common ground between the researcher and the participants which resulted in the smoother recruitment of first receivers. Challenges specific to this research and actions taken to overcome them are explained in Table 19:

Table 19: Challenges to recruitment

Challenges to recruitment	Actions taken to overcome recruitment challenges
Recruiting participants.	Posters, information sheets, and eligibility sheets were placed in the EDs. First receivers did not express interest, so this was overcome by the researcher attending day, night, and weekend shift handovers to explain the studies and encourage recruitment.
Carrying out semi-structured interviews with senior first receivers during clinical shifts.	Waiting until the ED was quieter, and cover could be organised.
Recruiting security officers.	This was a challenge as security teams had different management to the ED. Contact was made with security management and agreements made in terms of who could be interviewed and specific locations.

3.8.2.2.3.1 Recruitment and consent

Recruitment strategies were discussed with the local collaborators during the design phase. The known unpredictability combined with adaptable recruitment strategies were the most effective. Other suggestions made by local collaborators included using social media for volunteers and providing CBRN training in exchange for participants' time.

The following recruitment methods were agreed upon:

1. **Posters with researcher's details**: First receivers recruited through placing posters around the ED with the researcher's details; this was not very effective.
2. **Eligibility sheets:** Participant eligibility sheets were used as an interest and screening record and placed in a sealed container in staff rooms. Only two eligibility sheets were completed.
3. **Researcher attending shift handovers:** This was the most effective method for recruiting first receivers.

Once a letter of access was granted by both sites, first receivers were initially identified through the research team at Trust A, and then the shift Nurse in Charge (NIC) at each data collection period. At Trust B, first receivers were identified by the local collaborators, who provided contact details of shift NICs for the researcher to organise data collection on a shift by shift basis.

3.8.2.2.3.2 Consent

Participant information sheets (Appendix 6, p. 299) were placed in staff rooms a week before the data collection period to give first receivers an opportunity to read about the study, and think of any questions. First receivers were provided with a second opportunity to read the information sheet before being asked to sign the consent form (Appendix 7, p. 304).

3.8.3 Ethical approvals and good practice

NHS organisations need to be aware of all research carried out under their jurisdiction and have a duty of care to patients, responsibility for their staff and for research governance (Altman, 2013). The Research Governance Framework (RGF) was introduced in 2001 by the Department of Health (DOH). The RGF outlines principles of good governance that applies to all research within the NHS in England, with the aim to improve the quality of research, promote good research practice, and reduce poor research practice (DoH, 2005). A research protocol using NHS HRA qualitative protocol guidance was drafted following the approval processes outlined in Appendix 8 (p. 306).

Loughborough University was the sponsor for the research, so ethical standards and guidelines outlined by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee were implemented in the structuring of the study components. Ethical approval was attained by the Loughborough University Sub-committee on the 21st April 2017 (C17-22). The sponsor organised a peer review of this protocol to assess the feasibility and ethical standing of the studies. HRA ethical approval was required and was granted through the Integrated Research Application (IRAS) system on the 8th May 2017 (219968). R&D approval from both Trusts was given.

Data collection methods anonymised responses by giving all data a code prior to analysis. Personal data were needed to assess eligibility. This included age and gender (for demographics of sample population), profession, number of NHS service years, type of contract, and length of ED experience. Participants' details were strictly kept confidential in accordance with the Data Protection Act (1998) (Legislation UK, 1998).

3.8.4 Rigour and credibility

Rigour is relevant to the reliability, validity, and reduction of bias in qualitative research (Bowling, 1997). Lincoln and Guba (1985) proposed the gold standard in assessing the rigour of qualitative research (Yilmaz, 2013) as credibility, transferability, dependability, and confirmability to be parallel to the quantitative concepts of internal validity, external validity, reliability, and objectivity. The application of these is shown in Table 20 (p. 106).

Table 20: Addressing criteria for rigorous research (sources: Lincoln & Guba, 1985; Yilmaz, 2013)

Rigour criteria	Rigour in this research
Credibility *Participants find the results of the study to be true.*	Document analysis HTAs were shown to CBRN leads. Scenario card HTA representations were shown to a representative sample of first receivers.
Transferability *Results of the study are transferable to other similar studies.*	The results of the study can be applied to pre-hospital research based on the CBRN response. The representation of the results of the study (HTAs) can be applied to other healthcare environments.
Dependability *Is the reliability achieved if the process of selecting, justifying, and applying research strategies, procedures and methods which is clearly explained, and its effectiveness is evaluated by the researcher and confirmed by an auditor in the form of an audit trail?*	This was achieved by the production of a succinct research protocol. An audit trail was kept throughout the study as a Trial Master File which was reviewed by the R&D department of Trust A.
Confirmability *Findings are based on the analysis and reviewed through an auditing process. The auditor must confirm that the study findings are grounded in the data, are logical, clear, and have a high utility and explanatory power.*	HTAs formulated through document analyses were reviewed by the researcher's supervisory team to confirm that they were grounded in the data, were logical, clear, and consisted of a high explanatory power.

The credibility of a qualitative study depends on systematic data collection methods, multiple data sources, triangulation, a thick and rich description of the phenomenon under investigation, member checking, external reviews, and external audits to ensure that trustworthy data are being used (Patton, 2002a; Yilmaz, 2013).

Credibility was fundamental, so a variety of data sources were used, triangulation was implemented and combined with a multi-method approach (see Section 3.3, p. 58). Member checking was achieved via participatory design (see Section 3.5.1.1, p. 67), for example by discussing the HTA representations of scenario card responses at verification interviews and external reviews (CBRN leads and Ergonomists).

3.8.4.1 Pilot studies

Undertaking pilot studies have been reported to inform methodological rigour in larger studies (Ismail, Kinchin, & Edwards, 2017). Although the pilot studies have been discussed in the corresponding study chapters (Chapter 4 and 5), they formed an integral part of this research because it involved the explanation and visual representations of the HTAs to (HF/E) lay people.

This research carried out two pilot studies. The first pilot study was a document analysis of a CBRN plan (Study 1) in which the publicly accessible CBRN plan was converted to a HTA (Chapter 4) (Vol 2: Appendix 18, p. 1) The author (Head of Emergency Management at Trust X) of the CBRN plan was contacted by phone, the research was introduced, the HTA method was explained, and the HTA representation of the CBRN plan was then emailed. Through this brief interaction, the HTA was confirmed by the Head of Emergency management at Trust X to be a true representation of the CBRN plan (Acknowledgement: Jayne Heaney).

Holden et al. (2015) piloted a socio-technical (Chapter 2) systems-based instrument to assess the nature of barriers amongst patients presenting at the ED with acute cardiac issues. The piloting of the intervention was crucial to test the feasibility of the instrument in the time-sensitive ED setting. Accordingly, the second pilot study was testing the usability and feasibility of the scenario cards (Study 2) because the semi-structured interviews were carried out in the EDs of the respective Trusts. Special consideration was applied to shift patterns, ED team make up, first receivers skill mix, the limited availability of first receivers, and most importantly a data collection method which does not disrupt patient care.

The second pilot study was used to learn about the HTA process, formation, and interpretation more so than explaining it to participants (Chapter 4). The pilot studies were carried out in different environments on a diverse set of participants to determine the optimal utilisation of the scenario cards as data gathering tools.

This pilot study confirmed the usability of the scenario cards as a means of triggering discussion as found by Villalba, Jaiprakash, Donovan, Roberts, and Crawford (2019) who piloted literature based diabetes health experience cards amongst a diverse range of participants, which included healthcare professionals and individuals with experience with diabetes.

The pilot studies were crucial in selecting the optimal software to represent the HTAs. HTAs were formed using Microsoft PowerPoint and Microsoft Visio and were determined by the factors outlined in Table 21 (p. 110).

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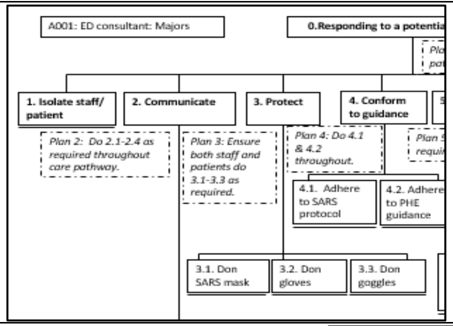
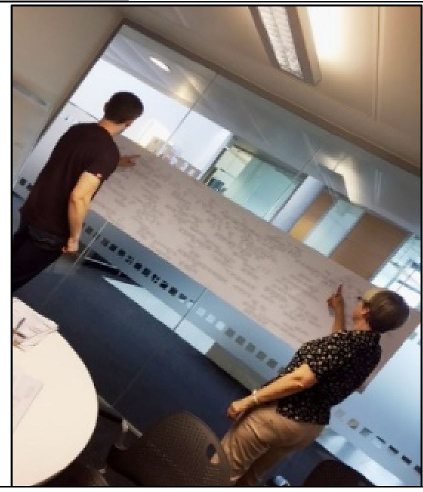
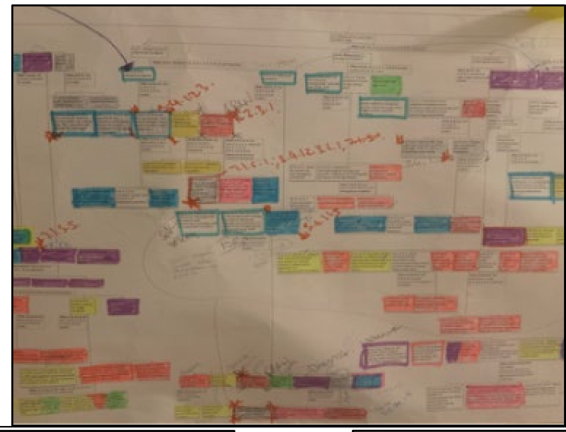
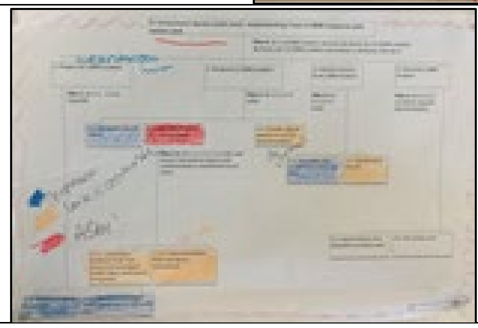
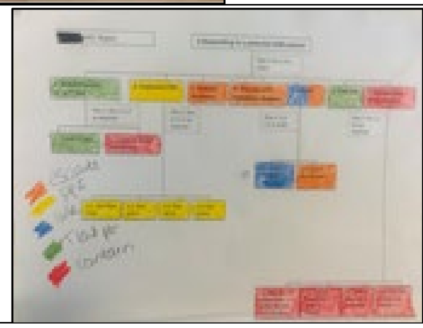
Table 21: Selection of software with examples

Software determining factor	Explanation	Example
Amount of information	**PowerPoint:** WAD HTAs were formed using PowerPoint. HTAs derived from semi-structured interviews did not require a large amount of space for the number of tasks discussed by first receivers.	
Review/verification of HTA representations	**Visio**: WAD HTAs (both GOR and action cards) were formed using Visio due to the vast amount of information in operational procedures. The Visio representations were compact yet detailed enough for both the required verification and review purposes.	
Analyses of HTAs	**PowerPoint and Visio:** All HTAs underwent rigorous analyses through colour coding systematically and thoroughly to ensure an in-depth comparison.	
Comparison of HTAs	**PowerPoint and Visio:** The HTAs were (manually) thematically coded by colour and compared.	 

The outputs for Trust A (HTAs) (Figure 19) were trialled with Human Factors Risk Manager (HFRM) software. Although this software has been used in numerous studies (Hignett et al., 2019a; Hignett, Hancox, & Otter, 2019b), PowerPoint and Visio representations were chosen because they were quick and simple to use and provided clear and legible illustrations on one sheet of paper (of varying sizes) making them usable in the review/verification phases of the thesis. Finally, the manual input of the information resulted in more thorough analyses of and familiarity of the data.

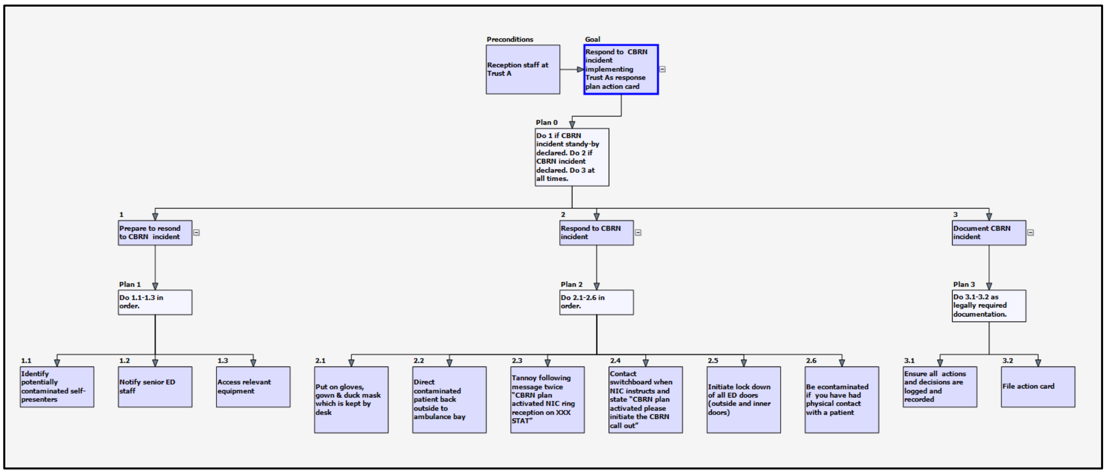


Figure 19: Example of HFRM trial of Trust A action card

A comparison between pen and paper methods and the new software was made by Upadrasta, Kolrep, and Oehme (2019), who evaluated the efficiency, quality, and effectiveness of a new task analysis tool (Human Factors Consult GmbH).

Although, a better quality of HTA, maintenance of a standardised and consistent level of quality and effectiveness was reported with the software. Limitations emphasised the constraints of the HFRM experienced during the trialling for Trust A (Figure 19). Limitations included the software being difficult and tedious to use, required greater time, and presented a greater workload, as well as generally lower usability.

3.9 Chapter summary

This chapter introduced the research strategy as an exploratory multi-method approach. The research logic explained how the data would be used holistically and the research perspective explained why a constructive and pragmatic approach was combined. Methods used to explore the ED response to CBRN events included document analysis, interview methods, and HTA which were triangulated so that the research process was rigorous and credible. As the research was carried out in the ED, special consideration was given to shift patterns, ED team structure, first receiver’s skill mix, limited availability of first receivers, and most importantly not to disrupt patient care.

Chapter 4. Study 1: The blunt end of the ED response to CBRN events

"Good planning is key to delivering an optimal emergency response"

(Sellwood & Wapling, 2016)

4.1 Introduction

The Emergency Department (ED) is a complex, fast paced, and hectic environment (Chartier et al., 2017; Weigl et al., 2016). Although initiatives such as EPRR exist (Chapter 1) to prepare and better respond to Chemical, Biological, Radiological, and Nuclear (CBRN) events. CBRN events are difficult to manage because they rarely occur (Boyd et al., 2014). This rarity means that first receivers are unfamiliar with the clinical assessment, containment, and treatment unique to patients who have been exposed to CBRN materials.

Unfamiliarity with CBRN exposure combined with the possibility of an emergency means that plans to respond to CBRN exposure are used as a reference point. In the UK, it is legislative practice to implement organisational emergency planning and have effective and well-practiced emergency plans. Category 1 responders must publish their emergency plans, to the extent necessary or desirable for the purpose of dealing with an emergency by law (Cabinet Office, 2013). More so, as suggested by Calder and Bland (2018) hospital staff who will be involved in the ED CBRN response should be familiar with their local plans, have trained in the relevant Personal Protective Equipment (PPE), and be familiar with the processes of decontamination.

Accordingly, this study is using the HF/E method of HTA to unpack the ED CBRN response at two different NHS Foundation Trusts in the Midlands region in England. HTAs have previously been used to better understand the emergency services response to chemical incidents (Baber et al., (as cited in Stanton, 2006). Recently, HTA was used as a method to support emergency response planning for train accidents; of particular relevance is that HTA was used to construct new plans

(Jonson, Rosenqvist, Forseberg, Alex, & Prytz, 2017), exemplifying that HTA can be used in conjunction with research based on emergency plans and planning.

In order to unpack the ED response to CBRN events this study aimed to use the HTA process to represent Work as Imagined as defined by CBRN plans, and answered the following research question:

How are first receivers expected to respond to CBRN events according to CBRN plans?

4.2 Method

4.2.1 Design

An exploratory qualitative design of document analysis was used to develop HTA (Chapter 3) to ensure a data driven understanding of CBRN plans, with a rigorous and objective method of representation. The use of qualitative methods in HF/E research has been explored by Hignett and Wilson (2004) and was suggested to be a useful methodology to find out why people make choices and carry out tasks in certain ways in healthcare.

4.2.2 Trust information

The participating Trusts (Table 22, p. 115) were chosen because they were Type 1 Emergency Departments (see Chapter 3) which provide *"A consultant led 24 hour service with full resuscitation facilities and designated accommodation for the reception of accident and emergency patients"* (NHS Data Dictionary, 2017). Type 1 Trusts were chosen because they were comparable to one another and at least one of the sites in each Trust had an ED.

Table 22: Characteristics of participating Trusts

2016-2017	Trust A		Trust B	
Hospital serving population	1 million residents		600,000 residents	
Number of hospital sites within Trust	3		2	
Number of wards within Trust	90		22	
In-patient beds (Trust) Hospital	1820 982		1,100	
ED Care Quality Commission (CQC) status (2017) inspection (2016)	Needs improvement		Good	
Medical specialities	Cardio-respiratory diseases, Cancer, Renal disorders		Inpatient and outpatient surgical and medical specialities, intensive care, maternity services, children's services and accident and emergency care, vascular, cancer and stroke care	
Hospital staff	15000		(excess of) 8000	
ED Staff	320 (approx.)	Doctors: 70 Nurses: 180 Receptionists: 40 Porters:30	303 (approx.)	Doctors: 103 (Inc. ACPs) Nurses: 95 HCAs:44 ENPs: 20 Receptionists: 41 Porters 2/3 (Not in house)
Patients treated in the ED between 2016-2017	237,000		116,800	
Patients admitted from the ED	95,100		41,758	
Last CBRN event	White powder incident in 2004		Accidental contamination from industrial site 2018	

4.2.2.1 Trust A

The CBRN plan at this Trust was formulated by an Emergency Response Officer (ERO). This individual had an extensive interest in CBRN response from an acute sector perspective. The ERO was chosen to discuss the CBRN response and verify the HTAs because they were at the forefront of creating WAI in the ED response to CBRN events. Trust A had moved into a new build ED two weeks prior to the initiation of the study, the CBRN plan was being updated in order to correspond to this move and the version provided was Trust A: CBRN Plan: Version 4 (Date authorised: 10th May 2017).

The ED at Trust A adopts a *"Single front door model"* in which patients are streamed to the right service. Streaming is a two staged process; initial screening occurs at reception and is supported by a *"Visual acuity nurse"* who assesses the patients' symptoms on arrival. Detailed streaming decisions and triage are carried out by clinicians in the assessment zone of the ED. Assessment zone staff consist of nurses such as Acute Nurse Practitioners (ANPs), Emergency Care Practitioners (ECPs)) General Practitioners (GPs), and ED doctors.

The assessment zone has 23 cubicles (CQC, 2018a) through which patients are signposted to an appropriate area of care such as primary care/injuries (for ailments such as strains and sprains, minor scalds and burns, and minor head injuries, majors or the emergency room (to treat ailments such as chest pain, loss of consciousness, severe bleeding, and major trauma) as shown in Figure 20 (p. 117). Trust A further aims to implement the process of deflection which involves signposting patients to other healthcare services such as emergency dentists and local NHS urgent care centres for non-life-threatening emergencies.

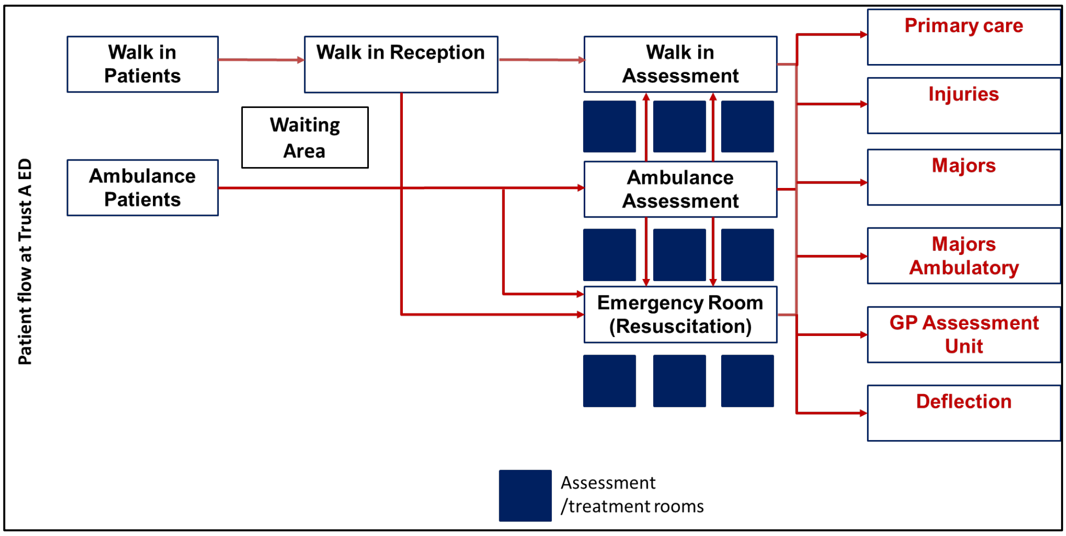


Figure 20: Trust A ED patient flow (source: Trust A Clinical Commissioning Group, 2017; Personal communication)

During a CBRN incident, flow through the ED changes. Casualties are re-directed to a single entrance. This allows wet and dry decontamination before casualties enter the ED. To do this, Trust A ED has been designed with a permanent wet decontamination room in the corner of the ambulance assessment area, with room for segregated male and female shower areas.

4.2.2.2 Trust B

The plan was formed by an ED consultant who had been employed at Trust B ED for 15 years. This individual was chosen to discuss the CBRN plan and verify the HTA representation of the plan because they had created WAI in response to CBRN events, however, this individual would also be a part of the CBRN response at Trust B in a clinical capacity. Therefore, they were not included in study two. Version 1.3: Date: November 2015 of the CBRN plan was used for Trust B.

Trust B has two reception areas for patients to be registered into the ED, pitstop reception, and the main reception area Figure 21 (p. 118).

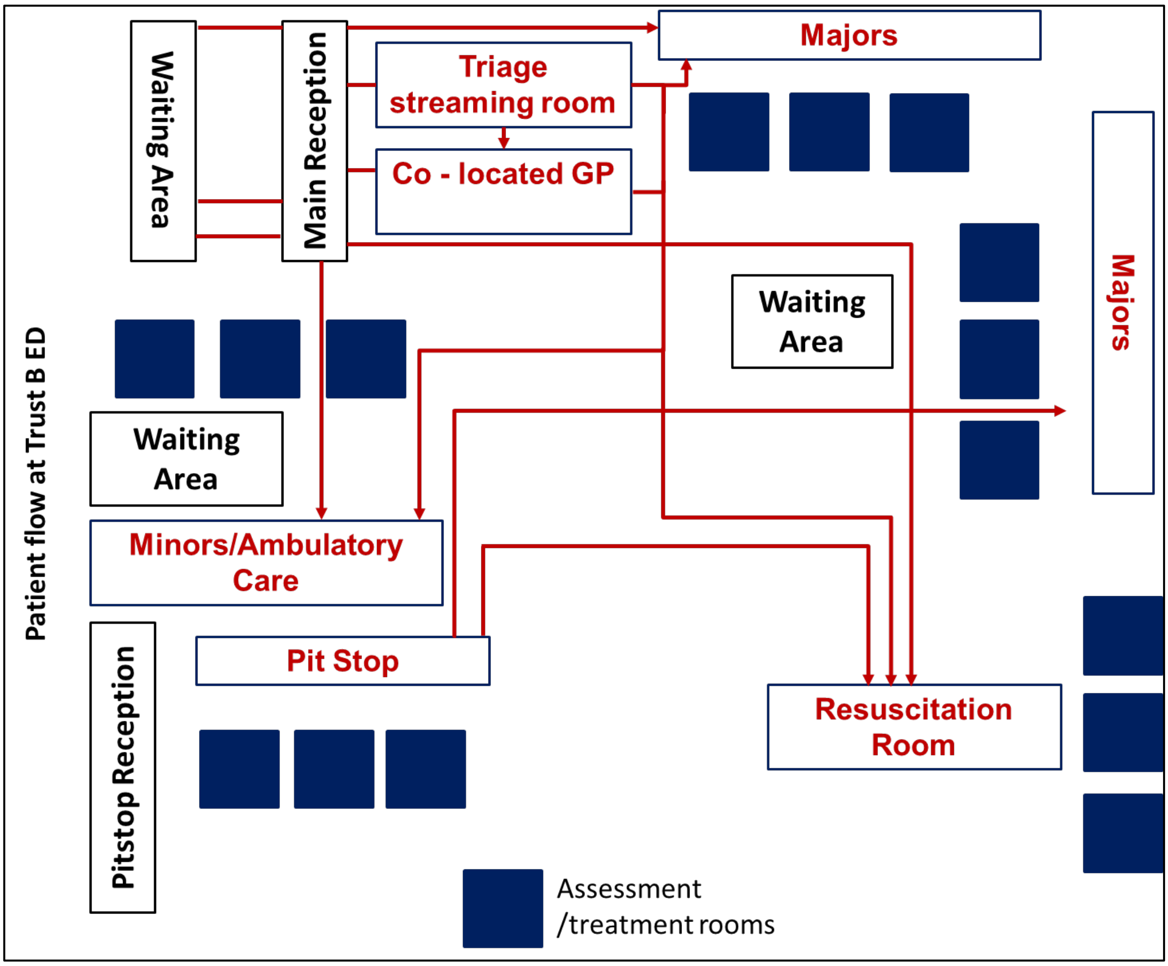


Figure 21: Trust B ED patient flow (Source: Trust B Website, 2019; Personal communication)

The Trust B ED consists of an advanced assessment area *(pitstop)* in which patients are brought in by ambulance and their presenting conditions triaged. The patients are then allocated to the most appropriate area of care for them, such as the 6 bedded resuscitation room for life threatening injuries (severe bleeding, traumatic head injuries, and loss of consciousness), or the majors area for serious ailments such as cardiac changes, seizures, and allergic reactions. The minors and ambulatory care area in Trust B ED consisted of assessment and procedure cubicles. An eye and Ear, Nose, and Throat room, 2 dressing rooms, and a separate sub waiting area as illustrated in Figure 21.

Self-presenting patients arrive at the main reception and are directed by an assessment nurse to the triage streaming room or GP triage room. They are then streamed in the ED, or discharged home.

During a CBRN incident, at Trust B, a known CBRN event would be dealt with by setting up a decontamination tent outside of the ED, and patients decontaminated prior to entering the ED. If the contaminant is unknown and already in the department, through self-presentation, specific isolation equipment (inflatable door) is used. Additionally, first receivers treating the potentially contaminated patient are kept to a minimum.

4.2.3 Pilot study

A publicly accessible CBRN plan was downloaded. The pilot plan was read and re-read, notes were made, analysed, and converted into a HTA representation. The pilot exercise allowed reflection on data collection and various software for HTAs (e.g. Human Factors Risk Manager, Microsoft PowerPoint, and Microsoft Visio). The pilot HTA was formed using Microsoft PowerPoint (see Vol 2: Appendix 18, p. 1). The pilot highlighted that using PowerPoint was limiting in terms of the amount of information that could be included. The pilot exercise also allowed the formulation of a step-by-step plan for analysis, the timescale consideration for analysis, and familiarisation with the chosen software (Microsoft Visio).

4.2.4 Data collection

Once ethical clearance was obtained (Chapter 3) data were collected by obtaining CBRN plans from both Trusts. Data were extracted through document analysis and represented as HTAs. Two types of HTA resulted which reflected the structure of the CBRN plans as two parts:

> **Part 1:** Set the scene for a CBRN event and how the ED should respond as a system within a system (hospital) and a larger system (Category 1 responder) (see Vol 2: Appendix 19, p.2).
>
> **Part 2**: Consisted of *"Action cards"* which were to be given to first receivers if a CBRN event occurred (Vol 2: Appendix 20, p. 3).

The two parts resulted in two types of HTAs being formed as data outputs, which were 1) General Organisational Responsibilities (GOR: The actions and activities expected from the ED as a system within a larger system, e.g. hospital) HTA, and individual 2) First receiver action cards HTAs.

4.2.5 HTA formation and analysis

The HTAs were produced using Stanton's (2006) guidance (Appendix 5, p. 298) to inform decisions made in the representation and hierarchies of the data set. This guidance was further chosen, because it advised that the boundaries of the system description to be defined and gave the researcher autonomy by allowing her to cease re-description of sub goals when the analysis was deemed fit for purpose. Most importantly, Stanton's (2006) guidance encouraged verification of the analyses with subject matter experts and the revision of the analyses, which was fundamental in producing a rigorous and real representation of the CBRN plans. Table 23 (p. 121) describes how Stanton's guidance was implemented.

Table 23: Stanton's guidance as a framework for HTAs development (source: Stanton, 2006)

Stanton (2006) HTA guidance	
1. Define the purpose of analysis.	To represent CBRN plans through HTA.
2. Define the boundaries of the system description.	Analysing CBRN plans specifically and not major incident plans.
3. Access a variety of sources of information about the system to be analysed.	Trust CBRN leads, first receivers, Trust websites, and CQC reports.
4. Describe the system goals and sub goals. The same description was applied to action cards to ensure consistency throughout the analyses.	System goals were set as superordinate tasks in General Organisational Responsibilities HTAs. Sub goals were grouped under the superordinate goals.
5. Try to keep the number of immediate sub goals under any superordinate goal to a small number (between 3 and 10).	All immediate sub goals under superordinate goals were between 3-10.
6. Link goals to sub goals and describe the conditions under which sub goals are triggered.	Goals and sub goals were linked using fixed sequence plans and concurrent operations (Chapter 3).
7. Stop re-describing the sub goals when you judge the analysis fit for purpose.	Analysis was judged fit for purpose once all the information in the CBRN plan was represented in a HTA format, and repetition was highlighted with CBRN leads and omitted.
8. Try to verify the analysis with subject matter experts.	Analyses verified with CBRN leads, Human Factors experts, an Ex ED nurse, and with some first receivers (Chapter 5).
9. Be prepared to revise the analysis.	Revised through the process of verification: **Version 1:** Document analysis of CBRN plans converted to HTA representations. **Version 2:** CBRN lead verification. **Version 3:** HF/E review.

HTAs were formed and analysed in a 4 staged process, 1) Familiarisation, 2) Formation of superordinate tasks, 3) Formation of HTAs, 4) Analysis of HTAs as shown in Figure 22:

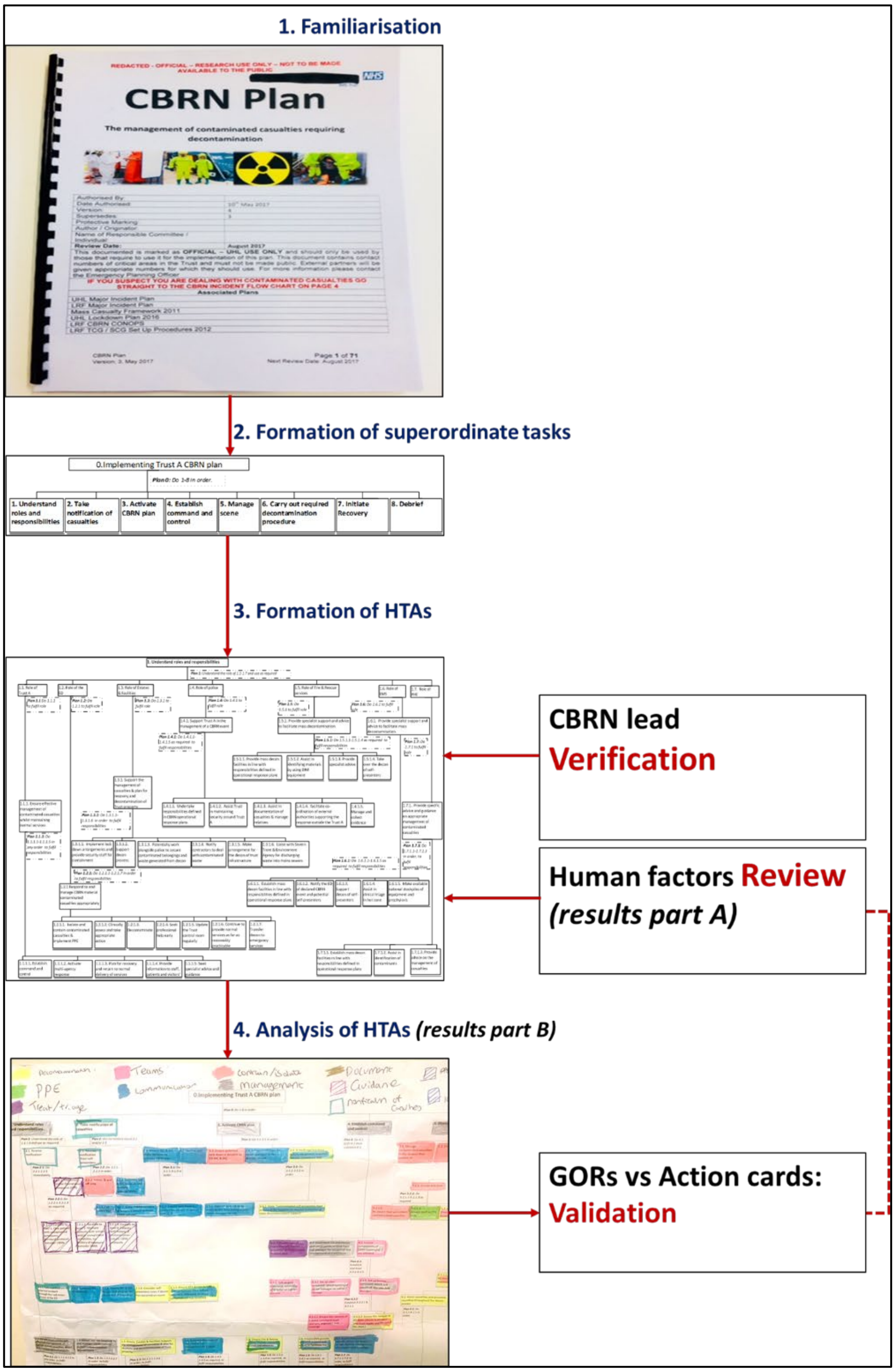


Figure 22: Process of HTA formation, analysis, and results

4.2.6 Analysis of HTAs

The HTAs were printed off for task-by-task manual document analyses. Document analysis was chosen because it requires data to be thoroughly examined and interpreted to elicit meaning, understanding, and develop empirical knowledge (Bowen, 2009; Corbin & Strauss, 2008). Applied thematic analysis was used because it resonates with the pragmatic approach, as well as being applicable to practical problems in applied research (Guest, MacQueen, & Namey, 2012). Both types of HTA were then thematically coded by colour so that a comparison could be visualised specifically in Chapter 6. The themes and colour representation are illustrated in Figure 23 (p. 124).

Theme/colour	
Isolate and contain	Yellow
Treat/provide patient care	Green
Capacity/patient flow	Dull blue
Escalate - clinical	Bright magenta
Escalate - organisational	Dark turquoise
Recognise event occurring	Pale grey
Decontaminate	Red
Liaise and communicate	Royal blue
Implement PPE	Pale green
Take lead/manage incident	Purple
Protect (self/patient/ staff/environment)	Maroon
Respond to patient/ respond	White
Clinically assess/triage	Dusky blue
Teams	Pale yellow
Investigate/•	Turquoise
Diagnose	Turquoise blue
Cross contamination	Dark grey
Practice based on environment	Pale khaki
Communicate	Baby blue
Provide/access equipment/stock	Pale blue
Patient awareness/ sensitivity	Pale pink
Provide access	Light green
Liaise and support	Pale lilac
Secure	Bright green
Monitoring	Dark maroon
Manage influx of patients	Baby pink
Assist/assist ED	Black
Document	Pale orange
Make decisions	Rusty pink
Advise	Mustard
Guidance	Pale green
Notification of casualties	Light lilac
Check	Teal
Detect/identify agent	Gold
Provide/access equipment/stock	Dull blue
Clinical knowledge	Magenta
Incident type (major incident/CBRN)	Cream
Incident knowledge	Burnt orange
Support	Yellow dots
Time	Green stripes
Manage staff	Sky blue
Shadow	Pale cream

Figure 23: Theme colour chart

Key

Investigate - Investigate presentation

Investigate• - Investigate symptoms

4.2.7 Stages to ensure rigour throughout the study

Rigour was core throughout (Chapter 3) to ensure processes such as verification, review, and validation as shown in Figure 24:

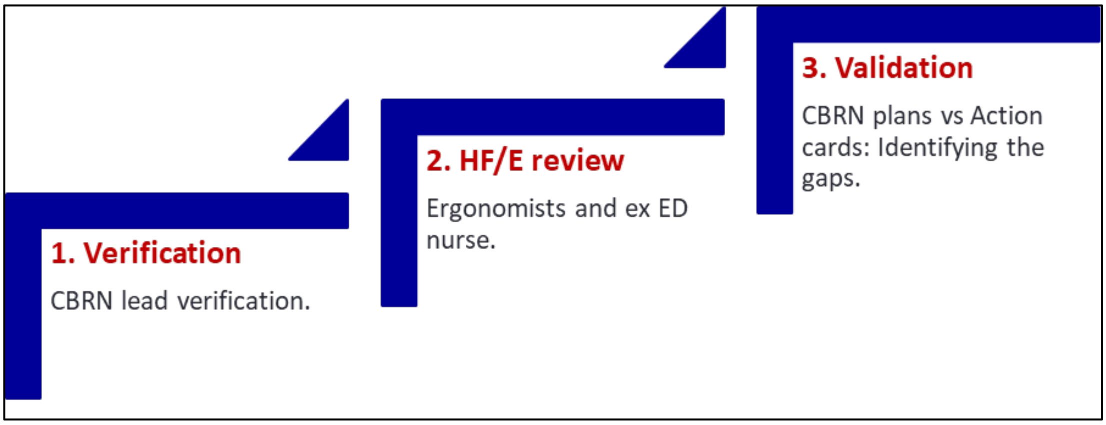


Figure 24: Stages to ensure rigour in study 1

4.2.7.1 CBRN lead verification

Verification is the process of checking, confirming, making sense, and being certain (Rolfe, 2006). The HTA representations were verified with the CBRN leads, this was to embed a participatory design underpinning to ensure that subject matter experts informed the data analysis process. The GOR HTA representations were printed on large scale paper and the action plan HTAs were put into a folder and taken to be reviewed by the CBRN leads at each Trust.

Trust A required three meetings until the CBRN lead felt that the HTA was a correct representation of the Trust plan and action cards. An example of a superordinate task was changed on the General Organisational Responsibilities HTA: *"6. Decontaminate" was* changed to *"6. Carry out required decontamination procedure"*. This change was suggested because diverse contributing factors such as, first receivers, zones, types of patients, and implications were involved in the decontamination process. Eight subordinate tasks were amended by the CBRN lead, which included:

1. **5.3. Implement non-caustic exposure adaptations:** Changed to identify decontamination process (Figure 25, p. 126).

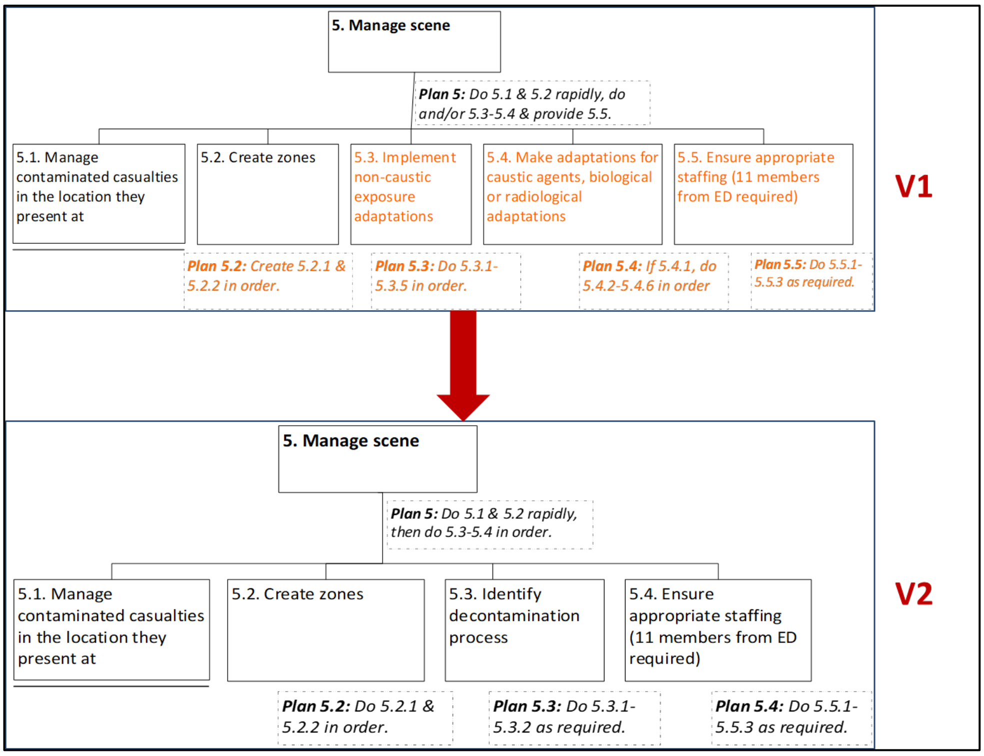


Figure 25: Verification of subordinate tasks 5.3, 5.4, and 5.5

The changes suggested to the action cards in stage two, were largely due to the update to the new ED. At Trust B, seven subordinate tasks were changed.

4.2.7.2 Human Factors review

Meetings were organised to discuss the HTAs with two Ergonomists and an academic with a clinical background in the ED (former-ED nurse). Ergonomists are professionals who *"Seek to understand how a product, workplace or system can be designed to suit the people who need to use it"* (CIEHF, 2017). This review served as an opportunity to evaluate whether the HTA representations of the CBRN plans were optimal in terms of eradicating duplications and highlighting inconsistences as a means of making the structure of the HTA more logical and usable. The restructuring of the HTA contributed to the final version of the HTAs (version 3).

4.2.7.3 Validation of GOR vs action cards: Identifying the gaps

Brinkman and Steiner (2008) state that the process of validation tests the researcher's skills throughout an investigation by continually checking, questioning, and theoretically interpreting the findings. Validation in this study was ensured by using applied thematic analysis (Chapter 3) across GOR HTAs and action cards. GOR specific themes and action card specific themes identified gaps between the GOR and actions expected from first receivers during a CBRN event.

4.2.7.4 HTA outputs

Table 24 provides a description of the HTA outputs. Two General Organisational Responsibilities HTAs were produced and 30 action card HTAs were formed to represent the blunt end of the ED response to CBRN events.

Table 24: HTA outputs

Process	Description	Output		
		Version	**Trust A**	**Trust B**
HTA formation	CBRN Document analysis to convert to HTAs	V1	General organisational responsibilities HTA (x1) **Vol 2: Appendix 21 (p. 4)**	General organisational responsibilities HTA (x1) **Vol 2: Appendix 28 (p. 73)**
		V1	Action cards HTAs (x17) **Vol 2: Appendix 22 (p. 12)**	Action cards HTAs (x13) **Vol 2: Appendix 29, p. 82)**
Verification	CBRN lead verification	V2	General organisational responsibilities HTA **Vol 2: Appendix 23 (p. 26)**	General organisational responsibilities HTA (x1) **Vol 2: Appendix 30, (p. 95)**
		V2	Action cards HTAs **Vol 2: Appendix 24 (p. 35)**	Action cards HTAs **Vol 2: Appendix 31, (p. 103)**
Review	Ergonomist and ex ED nurse review	V3	General organisational responsibilities HTA **Vol 2: Appendix 25 (p. 44**)	General organisational responsibilities HTA **Vol 2: Appendix 32, p. 116)**
		V3	Action cards HTAs **Vol 2: Appendix 26, (p. 51)**	Action cards HTAs **Vol 2: Appendix 33, (p. 124)**

4.3 Results: Trust A

4.3.1 Part A: HF/E review

Two meetings were organised for expert review. The first meeting introduced the types of HTAs to be reviewed, version 2 of the GOR and first receiver action card HTA representations were presented. The next level of suggested amendments was concerned with prioritisation of tasks when considering cultural implications during decontamination (subordinate task 6.2. Consider cultural implications) in which lifesaving care was promoted over language and communication support. The subordinate task was amended as shown in Figure 26:

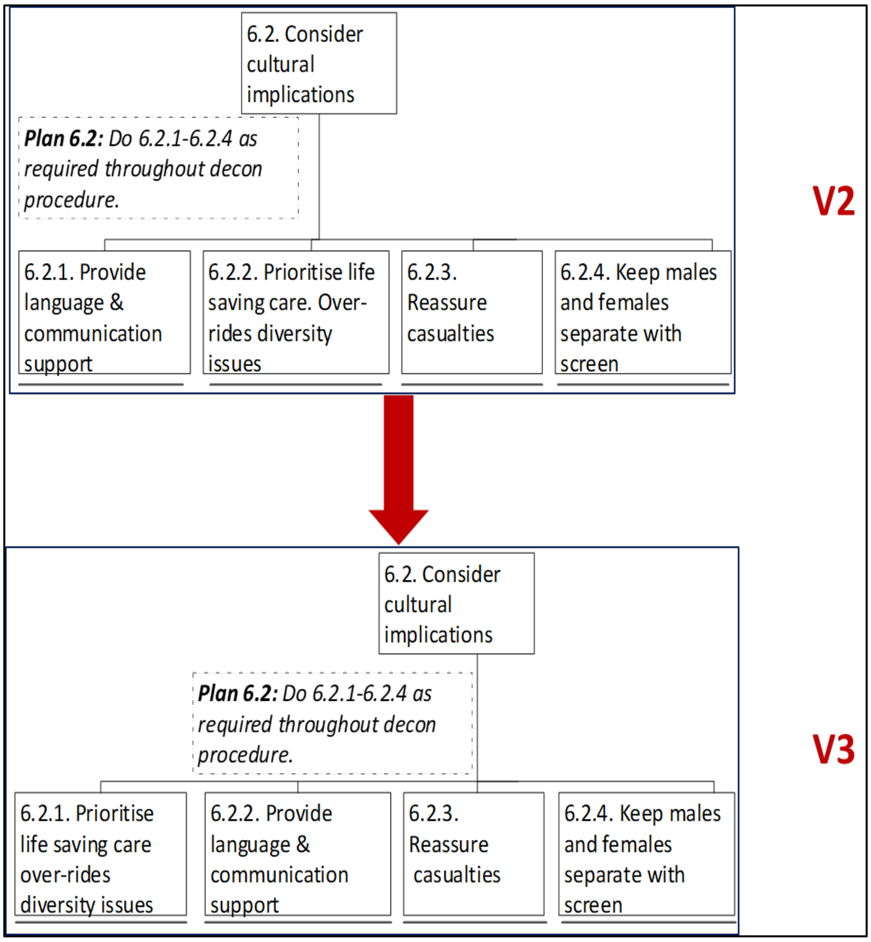


Figure 26: Example of HF/E amendment to subordinate task 6.2

In the expert HF/E review of Trust A action cards, it was recommended that a standardised approach for superordinate tasks for each first receiver role could be taken as exemplified in Figure 27 (p. 129).

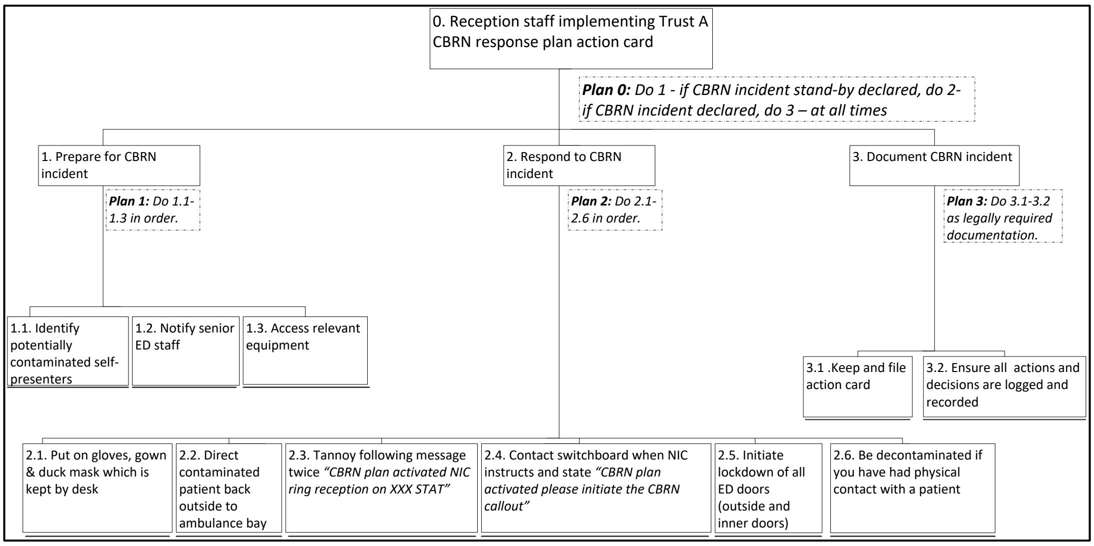


Figure 27: Version 3 HTA representing the actions required from Trust A reception staff during a CBRN event

The standardised action cards consisted of 4 stages:

1. Prepare to respond to CBRN incident.
2. Respond to CBRN incident†.
3. Initiate recovery from CBRN incident*.
4. Document CBRN incident.

*Not a task for receptionists. †Not a task for PPE buddies

The remaining standardised HTAs are provided as Vol 2: Appendix 26, (p. 51).

4.3.2 Part B: Analyses of HTAs

The final version of both the GOR HTA and action cards (n = 17) HTAs were analysed using applied thematic analysis (Chapter 3).

- 13 themes were identified on the GOR HTA (PPE, decontamination, clinically assess/triage, isolate and contain, escalation, document, take lead, guidance, liaise and communicate, detect/identify agent, teams, manage staff, and notification of casualties).
- 25 action card themes (PPE, decontamination, clinically assess/triage, isolate and contain, escalate, document, guidance, take lead/manage incident, liaise and communicate, detect/identify agent, teams, manage staff, notification of casualties, recognise event occurring, manage casualties, check, provide access, secure, advise, access relevant equipment, protect (self/patient/

staff/environment), assist/assist ED, treatment/patient care, time, and diagnose) were found as shown in Table 25:

Table 25: Colour coded WAI themes (Trust A)

Trust A	
General organisational themes	**Action card themes**
Common themes	
1. PPE	PPE
2. Decontamination	Decontamination
3. Clinically assess/triage	Clinically assess/triage
4. Isolate and contain	Isolate and contain
5. Escalate	Escalate
6. Document	Document
7. Guidance	Guidance
8. Take lead/manage incident	Take lead/manage incident
9. Liaise and communicate	Liaise and communicate
10. Detect/identify agent	Detect/identify agent
11. Teams	Teams
12. Manage staff	Manage staff
13.Notification of casualties	Notification of casualties
Specific themes	
-	**14**. Recognise event occurring
-	**15.** Manage casualties
-	**16**. Check
-	**17.** Provide access
-	**18.** Secure
-	**19.** Advise
-	**20.** Access relevant equipment
-	**21.** Protect (self/patient/ staff/environment)
-	**22.** Assist/assist ED
	23. Treatment/patient care
-	**24.** Time
-	**25.** Diagnose

The PPE theme will be used as an example theme for Trust A, the remaining are summarised in Vol 2: Appendix 27 (p. 67). Themes are emphasised in bold text.

1. **PPE,** the General Organisational Responsibilities HTA stressed the importance of PPE by prioritising it as one of the first receiver's responsibilities when responding to CBRN contaminated casualties:

"Isolate and contain contaminated casualties & implement PPE" (subordinate task 1.2.1.)

Another example of PPE being crucial Trust As CBRN response is its implementation in the dry decontamination procedure as represented in Figure 28:

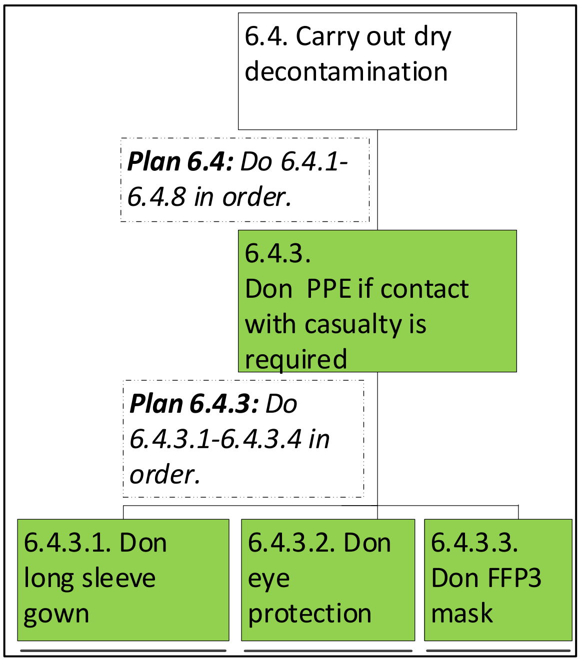


Figure 28: Example of PPE theme in General Organisational Responsibilities (Trust A)

The implementation of PPE was also crucial amongst first receivers at Trust A. This was evidenced by having specific allocated action cards for the donning and doffing of PPE (such as PPE buddy doffing PRPS suits, PPE buddy implementing enhanced biological precautions, and PPE buddy implementing strict biological precautions (Vol 2: Appendix 26, p. 61-p. 63). Thematic analysis across action cards further supported the importance of PPE amongst Trust A first receiver action cards, as shown in Figure 29 (p. 132).

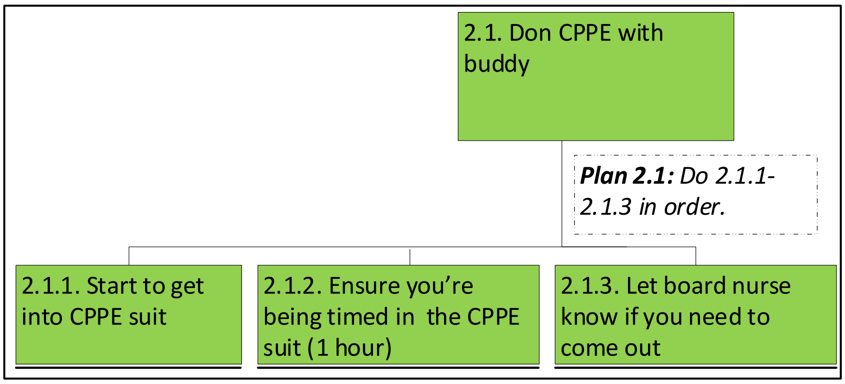


Figure 29: Example of PPE theme in first receiver action cards (Trust A)

4.4 Results: Trust B

4.4.1 Part A: HF/E review

Three meetings were organised for the HF/E review. The experts were familiar with the two types of HTAs to be reviewed. The meetings took the same format as with Trust A, in reviewing the General Organisational Responsibilities HTA and first receiver action cards HTAs (n=13). The review identified that Trust Bs CBRN plan was very detailed. This resulted in recommendations to the rewording of some tasks, the integration of superordinate tasks into subordinate tasks, as well as the change in order of superordinate tasks to allow a structured flow of the plan.

The HF/E review resulted in two major changes to the HTA representation of Trust B's CBRN plan. The first was changing the order of the tasks, so that the plan could be read as a staged process in response to a CBRN event. The second change was to reduce the number of superordinate tasks by synthesising Task 6 (consider associated injuries and illnesses) into the superordinate task 4, as shown in Figure 30 (p. 133).

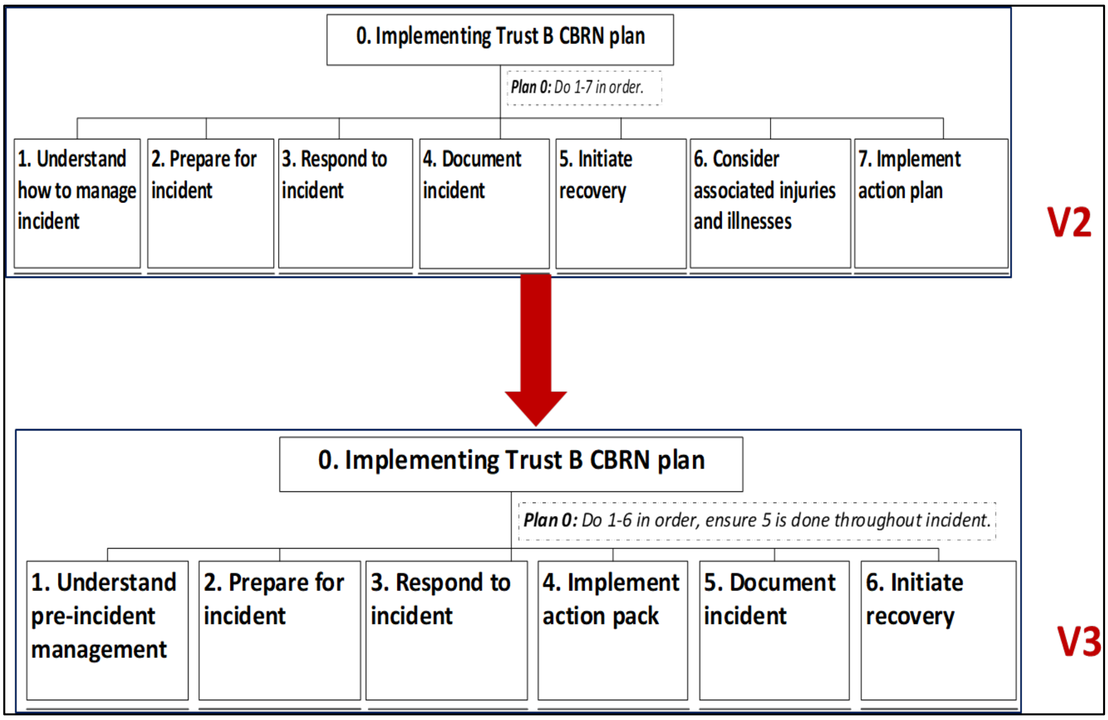


Figure 30: HF/E review changes to Trust B CBRN plan superordinate tasks

The superordinate tasks on most Trust B action cards were standardised as:

1. Prepare to respond to CBRN incident.
2. Respond to CBRN incident.

HTA representations of Trust B CBRN response action cards required pre-conditions as a means of clarifying who the role was to be allocated by and/or taken up by in the event of a CBRN event. An example of the HF/E reviewed, and standardised action cards is provided in Figure 31 (p. 134).

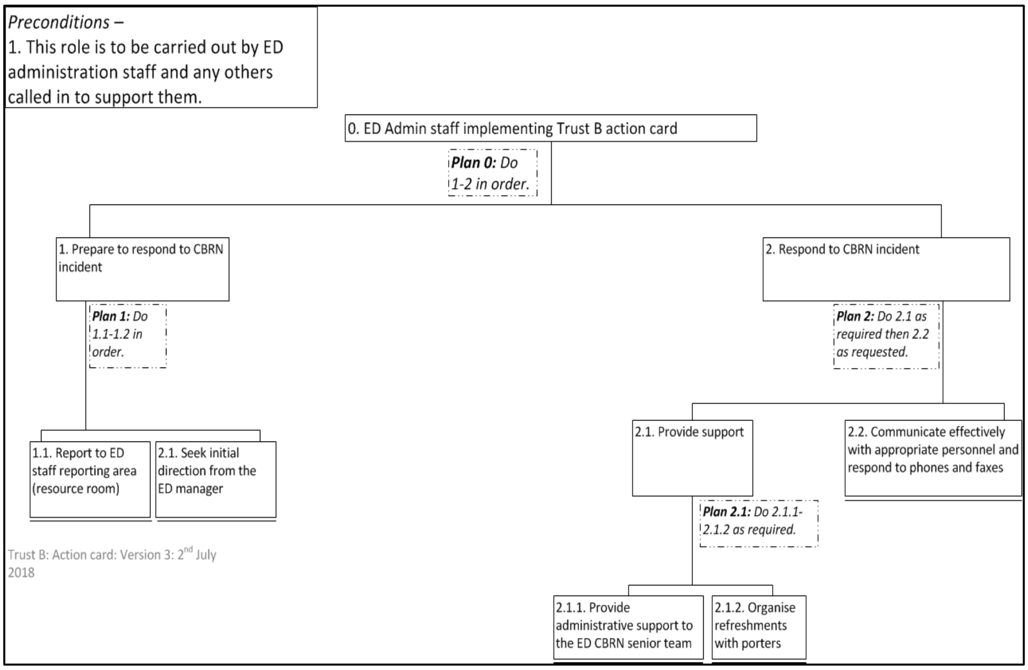


Figure 31: HF/E reviewed HTA representation of receptionist's actions during a CBRN event

The remaining action cards and their corresponding HTA representations are located in Vol 2: Appendix 33, (p. 124).

4.4.2 Part B: Analyses of HTAs

Version 3 of the GOR HTA representation of Trust Bs CBRN plan and first receiver action cards (n=13) were analysed using applied thematic analysis to form themes across both types of HTA representations.

- 20 themes were identified within the GOR HTAs, these were (PPE, decontamination, escalation, take lead/manage incident, document, liaise and communicate, capacity/patient flow, protect (self/patient/ staff/environment), isolate and contain, provide/access equipment/stock, guidance, clinically assess/triage, manage staff, teams, notification of casualties, clinical knowledge, detect/identify agent, respond, incident type (major incident/CBRN), and incident knowledge).
- A total of 21 themes emerged from the analysis of Trust B action card HTA representations (PPE, decontamination, escalate, take lead/manage incident, document, liaise and communicate, capacity/patient flow, protect (self/patient/ staff/environment), isolate and contain, provide/access equipment/stock, guidance, clinically assess/triage, manage staff, teams,

notification of casualties, time, support/assist, shadow, clinical escalation, check, and make decisions) as shown in Table 26:

Table 26: Colour coded WAI themes (Trust B)

Trust B	
General organisational themes	**Action card themes**
Common themes	
1. PPE	PPE
2. Decontamination	Decontamination
3. Escalation	Escalate
4. Take lead/manage incident	Take lead/manage incident
5. Document	Document
6. Liaise and communicate	Liaise and communicate
7. Capacity/patient flow	Capacity/patient flow
8. Protect (self/patient/ staff/environment)	Protect (self/patient/ staff/environment)
9. Isolate and contain	Isolate and contain
10. Provide/access equipment/stock	Provide/access equipment/stock
11. Guidance	Guidance
12. Clinically asses/triage	Clinically asses/triage
13. Manage staff	Manage staff
14. Teams	Teams
15. Notification of casualties	Notification of casualties
Specific themes	
16. Clinical knowledge	**16.**Time
17. Detect/identify agent	**17.**Support/assist
18. Respond	**18.**Shadow
19. Incident type (major incident/CBRN)	**19.** Clinical escalation
20. Incident knowledge	**20.** Check
-	**21.** Make decisions

The **decontamination** theme is presented as an example below. The remaining analyses are summarised in Vol 2: Appendix 34 (p. 137).

2. The theme of **decontamination** was included as subordinate tasks such as *"Treat and decontaminate"* (subordinate task 3.3.6) and *"Initiate decon for large numbers"* (subordinate task 3.3.6.5.2.4.). To decontaminate was allocated to two specific first receivers, the decontamination triage officer (Vol 2: Appendix 33, A33 6, p. 129) and the decontamination lead (Vol 2: Appendix 33, A33 5, p. 128) as exemplified in Figure 32 (p. 136).

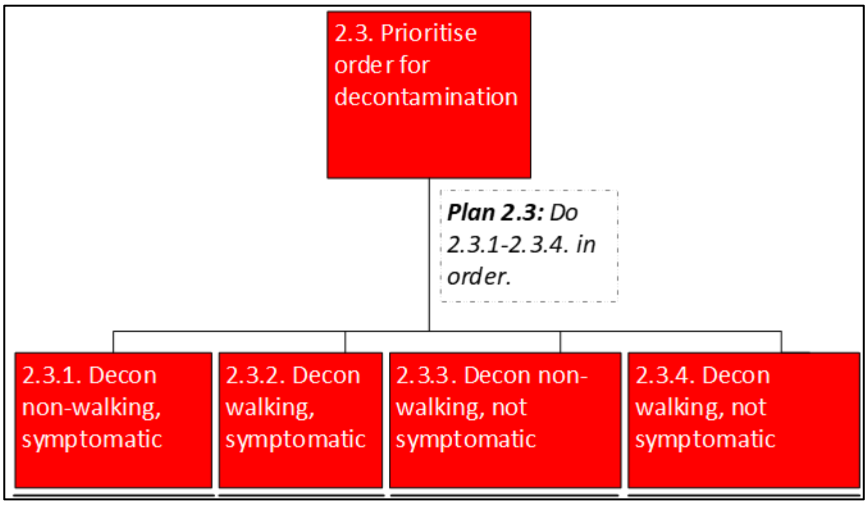


Figure 32: Decontamination theme illustrated on decontamination triage action card HTA (Trust B)

4.5 Study summary

In line with legislation, effective and well–practiced emergency plans are crucial to managing rare CBRN events, this study identified discrepancies in CBRN response planning, which were identified by the CBRN leads and the HF/E review. For Trust A, the HF/E review resulted in two amendments being made to the HTA representation of the General Organisational Responsibilities. The changes were in receiving notification of the casualties, and prioritising lifesaving care during decontamination. Additionally, the HF/E review resulted in the superordinate tasks of the action cards being standardised into four tasks across most first receivers 1) Prepare to respond to CBRN incident, 2) Respond to CBRN incident, 3) Initiate recovery from CBRN incident, and 4) Document CBRN incident.

The combination of applied thematic analysis, colour coding, and HTA identified key themes in WAI in the ED CBRN response. Trust A had 12 additional themes in the action cards, evidencing variation between the macro GOR actions expected from first receivers and micro (action card) actions expected from first receivers during a CBRN event.

The HF/E review identified the order of superordinate tasks of Trust B's CBRN plan HTA representation to be ambiguous. The HTA was changed to allow flow to better understand the ED response to CBRN events. The repeated tasks were omitted, changed or integrated into the HTA in the form of a plan. Pre-conditions which set out who could fulfil a role were incorporated. Superordinate tasks across most first receiver action cards were standardised into 1) Prepare to respond to CBRN incident and 2) Respond to CBRN incident.

4.5.1 Conclusion

In this study, discrepancies in CBRN response planning identified by CBRN leads and thorough HF/E review were overcome and implemented by enhancing GORs and standardising the action cards. Standardisation of superordinate tasks introduces clarity and order across varying roles and actions by setting out tasks that need to be carried out during a CBRN event.

Chapter 5. Study 2: The sharp end of the ED response to CBRN events

"It's not my responsibility but will suggest it; I'm bottom of the food chain, a worker bee, not the queen"

(A018, Trust A SHO)

5.1 Introduction

The multi-faceted task of responding to a CBRN event, presents numerous challenges to ED staff (Luther et al., 2006), overwhelming the capabilities of the ED by causing large scale trauma, which require complex responses - including multiple injuries, triage - (or reverse triage), and decontamination (Linney et al., 2011).

A contributory factor to making the ED response to CBRN events so challenging is the varying clinical responses that are required for each component of CBRN exposure. For example, a chemical attack may result in the rapid onset of severe symptoms, to which treatment is time critical. This is further complicated by the fact that chemical agents can only be detected and identified with specialist equipment (JESIP, 2016). Biological exposure may not be identified for some time, and may only be recognised through health monitoring (JESIP, 2016). Radiological release may be accompanied by explosives or the dispersal of radioactive particulates into the air, with no obvious sudden onset of symptoms (JESIP, 2016). This would result in ED staff responding to two types of injuries - internal radiological injuries combined with blast injuries. A nuclear event would be readily identifiable due to its catastrophic nature, which would be accompanied by long lasting radiation hazards (JESIP, 2016).

This study is using semi-structured interviews (see Section 5.2.2, p. 148) to better understand Work as Done (WAD) – which is *"What actually happens in the workplace"* (Saurin et al., 2017, p. 2).

In this study, WAD is described as the sharp end, focusing on the people who carry out the daily work and experience it directly. Research focusing on the sharp end has predominantly focused on treatment related errors (Leape, 1997; Meurier, 2000), improving patient safety (Nieva & Sorra 2003; McCarthy & Blumenthal 2006), and the implementation of HF/E as a discipline in sharp end environments, such as the ED and operating theatres (Timmons et al., 2015).

Based on the under preparedness, uncertainty, and unwillingness of first receivers when responding to CBRN events in the ED, this study aims to answer the following research question:

How do first receivers anticipate responding to CBRN events?

5.2 Method

The method used in this study, is described in two parts. The first part describes the development of scenario cards. The second part explains how the scenario cards were used with semi-structured interviews to investigate the first receivers' response to CBRN events.

5.2.1 Part 1: Development of scenario cards

The scenario cards were developed through a five staged process as shown in Figure 33 (p. 140).

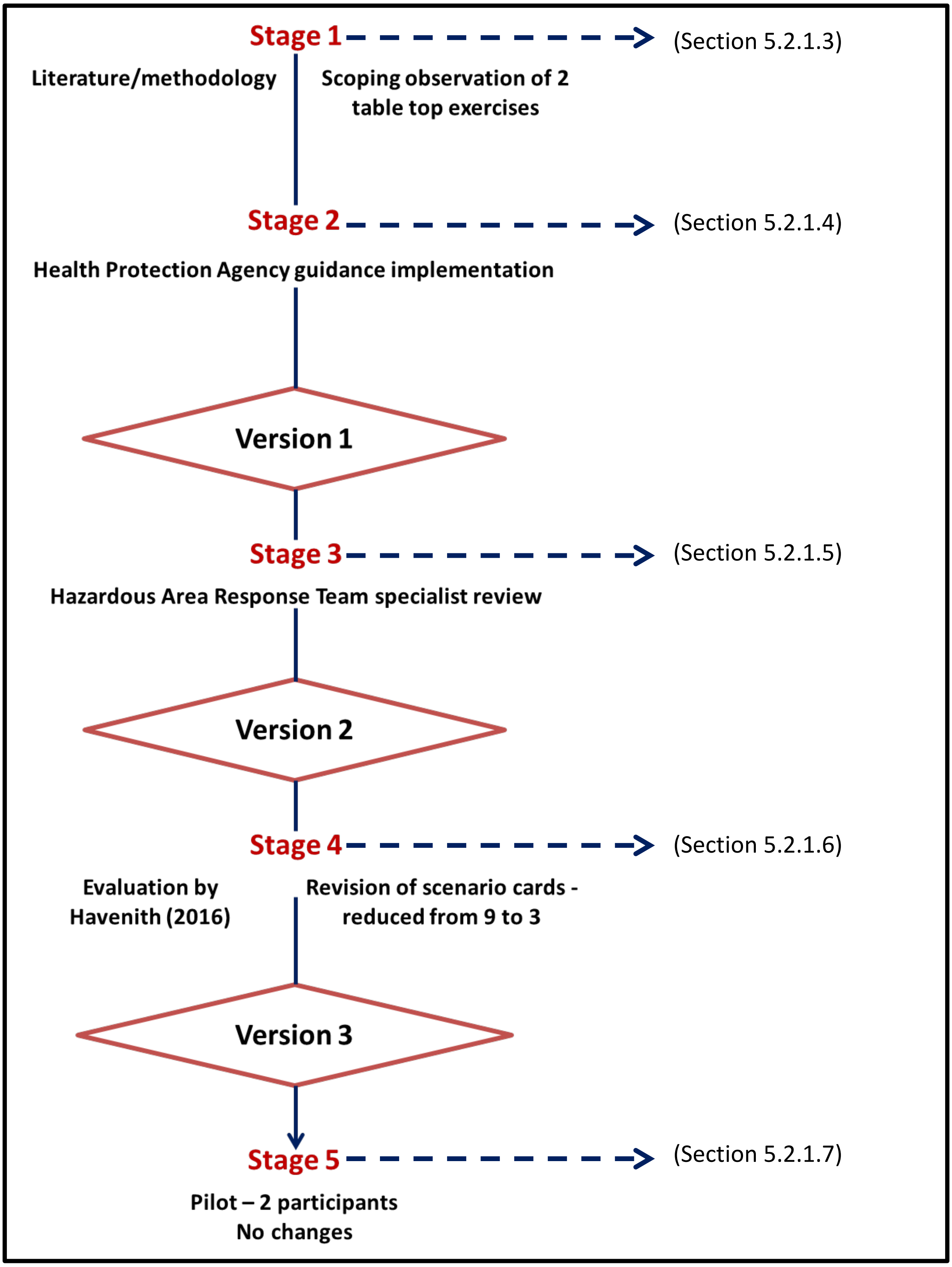


Figure 33: Stages of scenario card development

5.2.1.1 What are scenario cards?

A scenario card in this setting was a card which described a patient or patients exposed to a CBRN situation. Context was provided, such as warnings about an outbreak as well as symptoms derived from Health Protection Agency (HPA) guidance (Gov UK, 2008). Scenario cards have previously been used in disaster prevention programmes as a part of board games to increase public awareness (Yamori, 2012). Further, scenario presentations have been combined with semi-structured interviews in the ED to investigate patients' perceptions of ED waiting times (Cross, Goodacre, O'Cathain, & Arnold, 2005).

5.2.1.2 Why scenario cards?

Scenario cards were used to present hypothetical patients and scenarios as a prompt for first receivers to *"Talk the researcher"* through what they would do if faced with the presented scenario. Scenario cards were used to create a CBRN situation at the current time, in the current environment, and with the current resources, so that the first receiver could guide the researcher through the actions that they would take. The scenario cards were used as an interview schedule providing context and focus to the semi-structured interview (Chapter 3).

Scenario cards have effectively been used whilst testing incident command systems in hospital based disaster simulation exercises (Thomas et al., 2005). Further, standardised scenario cards have been developed as efficient tools for planning, improving, and handling CBRN events by Sandström et al. (2014). The use of such cards have proven to be effective in small homogenous emergency planning groups, as well as with groups of larger heterogeneous emergency healthcare professionals, and within the international emergency response platform (Sandström et al., 2014).

5.2.1.3 Stage 1: Review of literature, consideration of methodology, and scoping observation of 2 tabletop exercises

The systematic review (Chapter 2), identified obstacles in the ED response to CBRN events which warranted further inquiry. Such inquiry required succinct investigation tools which could extract a meaningful amount of information in the time critical ED environment. The methodology (see Chapter 3) emphasised that a pragmatic stance to data collection would be most fitting. In line with this, it became clear that an adaptable means of data collection would be needed in an interruption prone and volatile environment. Accordingly, scenario cards were the optimal probe to collect data through semi-structured interviews in this study.

Another reason for using scenario cards, was a result of first-hand observed effectiveness in simulating hazardous situations via Tabletop Exercises (TTX). A TTX is a multi-agency exercise consisting of between ten to ninety participants rehearsing responses which are organised around a scenario. Scenarios are used to stage events in line with realistic details which resonate with the participants tacit and codified knowledges of the area (Anderson & Adey, 2012). Scenario based TTXs have been shown to be an effective means of examining operational plans, highlighting problems, and allowing in-depth problem solving (Malizia et al., 2016).

Two TTXs were observed as part of the methodology development:

1. **Exercise Tristar - Heart of England Foundation Trust (2016)**

Exercise Tristar was a TTX in which first receivers, hospital leads, and managers were asked to respond to an explosive scenario taking place in Birmingham, England. Exercise Tristar implemented patient presentation cards Figure 34 (p. 143), which consisted of information such as injuries and physiological parameters. The patient presentation cards proved to be a quick, efficient, and a realistic means of representing hazardous situations. The patient presentation cards were an effective tool to extract the actions of clinicians, thus being the optimal tool to extract information from first receivers in this study.

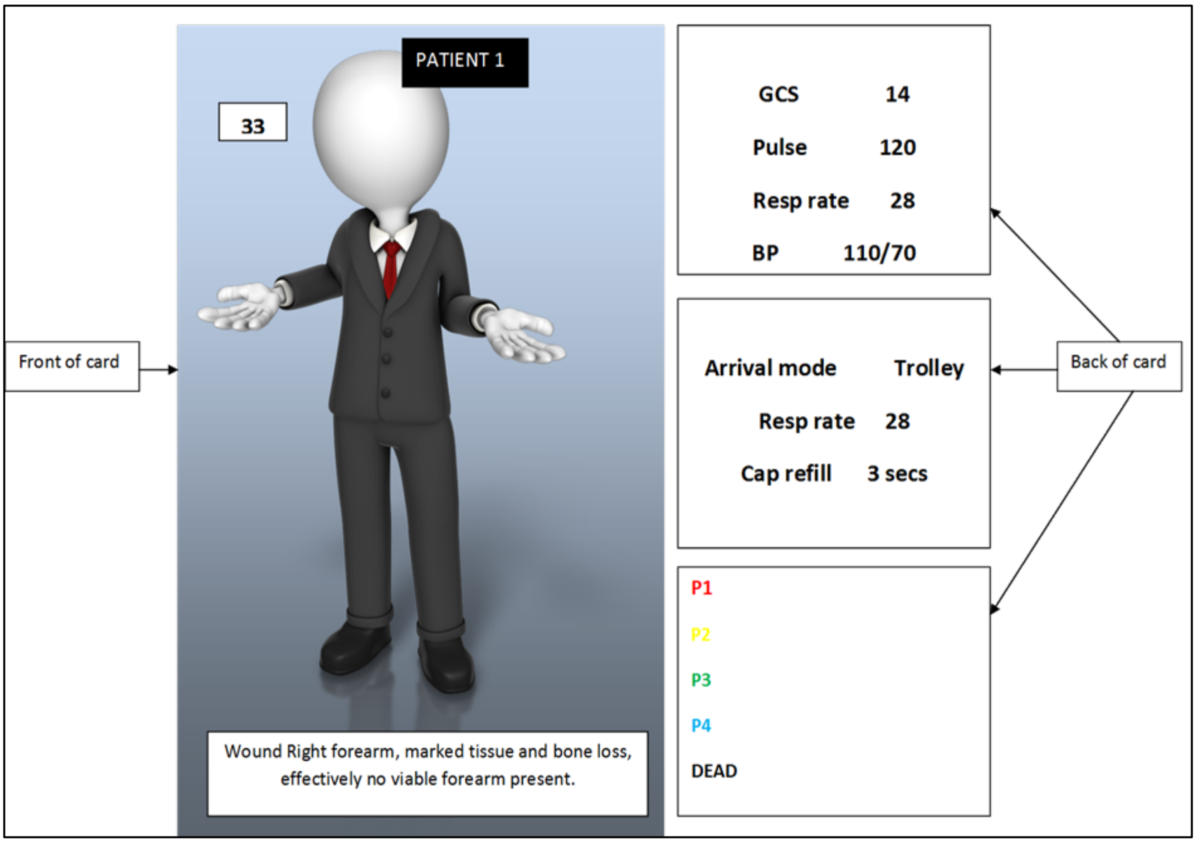


Figure 34: HEFT exercise Tristar scenario card (image courtesy of Heart of England Foundation Trust)

However, this patient presentation card was aimed at clinicians, hence the inclusion of information such as pulse and respiratory rate. This study aimed to explore the responses and actions of all individuals who would have patient contact during a CBRN event. As a result, the cards to be used in this thesis would not be as physiologically focused and inclusive of the first receivers outlined in the inclusion criteria (Chapter 3). Another consideration resulting from this observation was that the cards would need to present both the scenario (CBRN event) and the patient.

2. Exercise Soteria - University Hospitals of Leicester (2017).

Exercise Soteria was observed after WAD data collection had begun. Attending this TTX was a means of validating the use of scenario cards across medical specialities in real time. Exercise Soteria consisted of hypothetical presentations with time restrictions and expanded across the hospital site; for example, the ED team was in the library, the surgical team in theatres, and silver command in the emergency control room. The ED scenario cards provided a pathway of the patients' presentation and symptoms until they reached the ED.

The Tabletop Exercises helped to develop the scenario cards. The clinical content of the scenario cards was based on guidance from the Health Protection Agency (HPA) (Gov UK, 2008) in terms of clinical management and health protection in response to CBRN events. Information about symptoms was extracted and adapted to the ED to form version 1 of the scenario cards (Figure 35):

Scenario/Questions	Rationale and actions
Explosive: Blast injuries 12.12.2015: 18:00: A major incident has occurred in the city centre at 16:00, it is reported that separate explosions have occurred in three locations, amongst ambulance crews who have T1 patients you have an influx of self-presenters with tertiary blast injuries: caused when people are displaced by the blast (e.g. thrown against the wall) often skull or long bone injuries.	-Explosive events are on the increase. -Check with the Incident Command Team at the site for information about associated radiation/chemical/toxic hazards. --If in doubt, wear PPE and check cases for radioactivity with survey meter, decontaminating them (and yourself) if necessary. - In a radiation incident, treat life-threatening injury.

Figure 35: Version 1 of scenario cards

5.2.1.4 Stage 2: HPA guidance implementation

It was aimed to include physiological symptoms which would be realistic yet understandable by non-clinical staff. Therefore, HPA guidance which was referred to as a framework in acute Trust CBRN planning was used as a reference point. Scenario cards were drafted in a tabular format with the rationale, and actions for the presentations (Figure 35).

5.2.1.5 Stage 3: HART specialist review

The third phase of development of the scenario cards was the validation of the content by senior members of the Hazardous Area Response Team (HART). Scenario cards were validated because it has been suggested that it is usual practice to draw on the expertise of different organisations to check that the details of the scenario are plausible (Anderson & Adey, 2012). HART team personnel were chosen as they have specialist training in the CBRN response hot zone - which is the zone of highest contamination (Home Office, 2004). Senior members of the HART team provided constructive feedback in terms of physiological symptoms and number of patients. Changes were made and this resulted in a validated and realistic representation of

CBRN exposure symptoms in the form of version 2 (see Figure 36). The final version of the scenario cards (Figure 37, p. 146) was used.

12.12.2015: 18:00

A major incident has occurred in the city centre at 16:00, it is reported that three separate explosions have occurred in varying locations, amongst ambulance crews who have P1 patients; you have an influx of self-presenters with difficulty in breathing, eye injuries and blast wounds.

Figure 36: Version 2 of scenario cards, blast injuries adapted to the ED environment

5.2.1.6 Stage 4: Evaluation and revision of scenario cards

An evaluation of the scenario cards was provided as part of a postgraduate project (Havenith, 2016). The aim of the project was to develop current knowledge around the CBRN response and explore ambulance responders' feelings of preparedness. A modified version of two scenario cards was used as a framework for qualitative data collection.

Overall, the scenario card content remained the same in terms of the presentation of symptoms. However, the wording was modified to ensure relevance to the target participant group, who were 9 specialist paramedics from the National Ambulance Resilience Unit (NARU). Terms such as *"Patient presented to ED"* were changed to *"You have been called out to"*. Findings suggested that the paramedic response to CBRN events is complex and unpredictable. The scenario cards were reported as applicable and appropriate. Havenith (2016), confirmed that the scenario cards could be adapted as a useful data gathering tool, for a diverse range of healthcare professionals who are involved in the CBRN response.

Initially, 9 scenario cards were created. These were reviewed and it was suggested that 3 cards (see Section 5.2.1.7, p. 146) to represent a chemical, biological, and radiological scenario to be used on the envisaged sample size (Chapter 3) to allow consistency in the content obtained from data collection.

13:00

You have an influx of patients who have been exposed to an unknown vapour at the city centre; the majority are coughing excessively and pointing to their chest. On closer examination some patients have pinpoint pupils and are exhibiting excessive salivation.

Figure 37: Version 3 of Sarin scenario card

5.2.1.7 Stage 5: Pilot study

Each scenario card was piloted on two participants. The researcher carried out a pilot study with the Sarin scenario card (Figure 37) on herself, by thinking through the actions that she would carry out if presented with one of the scenario cards in the ED. Field notes were made, and then converted to a HTA.

The Severe Acute Respiratory Syndrome (SARS) scenario card (Figure 38) was piloted on a former ED nurse. To assess the order and the general flow of the scenario card presentation, particularly in terms of how much time the presentation would take. Field notes were made and represented as a HTA. The pilot data allowed initial HTAs to be developed and compared.

23:40

Public Health England has issued warnings about the emergence of SARS virus. You assess a 30 year old female who has returned from a trip to the Far East, her husband is being assessed by a colleague both had diarrhoea on their flight home 48 hours ago. Diarrhoea has settled they are both now experiencing difficulty in breathing.

Figure 38: Version 3 of SARS scenario card

The Acute Radiation Syndrome (ARS) scenario card (Figure 39) was tested in the ED with a first receiver (ED consultant). The aim of carrying out a pilot study in the ED was to ascertain whether the environment had any influence on responses.

> **01:40**
>
> **30 year old female has self-presented with excessive nose bleed and bleeding gums. Past medical history: Self presented at ED with nausea, vomiting and diarrhoea after attending a peace rally last month, patient rehydrated and discharged on last attendance. The patient seems on edge, and subdued, she whispers she has been poisoned.**

Figure 39: Version 3 of ARS scenario card

The ease of forming the pilot HTA (Figure 40) confirmed that presenting the scenario card in the ED provided accurate, real-time, and realistic responses, representing work at the sharp end aptly.

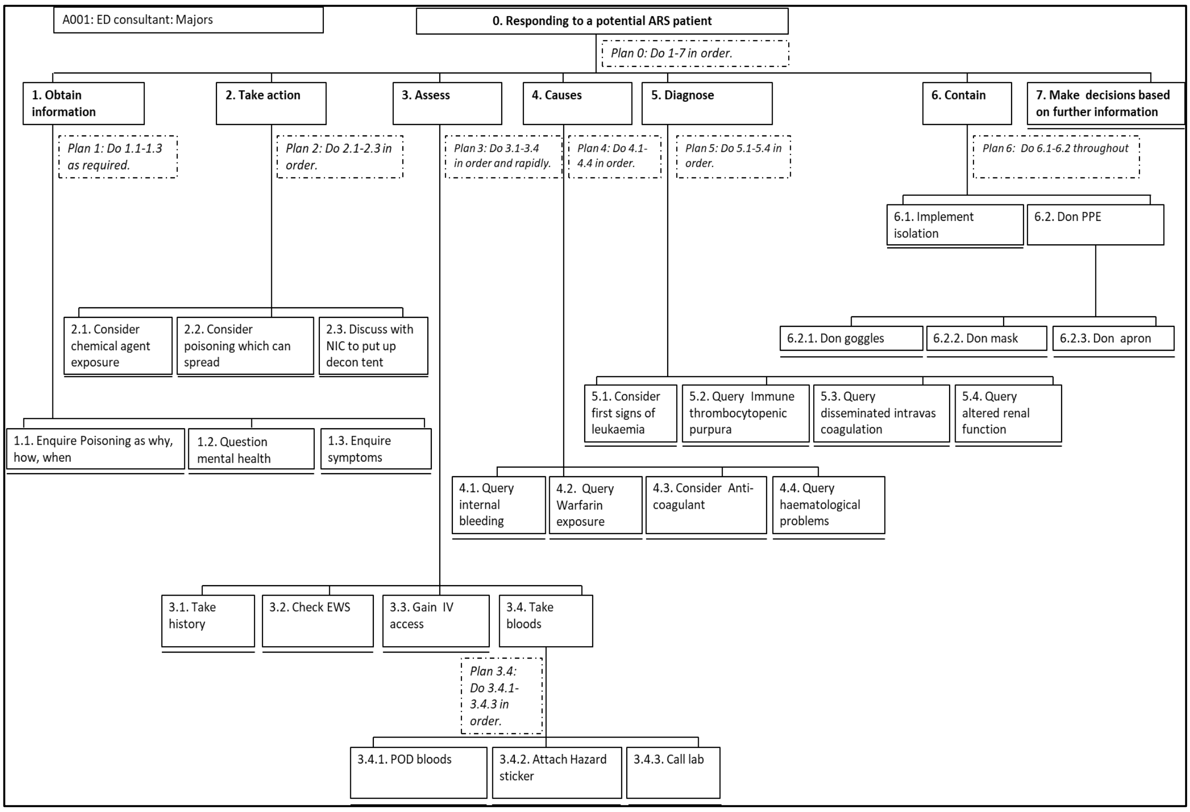


Figure 40: First receiver (ED consultant) response to ARS scenario card

5.2.2 Part 2: Field data collection

5.2.2.1 Design

An exploratory qualitative design was combined with semi-structured interviews which presented a scenario card.

5.2.2.2 Participant information and sampling

Participants were recruited from two Type 1 EDs in the Midlands region of England (Chapter 3). The participants adhered to the inclusion criteria outlined in Chapter 3 and had been employed in the ED for a minimum of three months on a substantial (permanent) contract. This was to ensure that all participants had the opportunity to be provided with a Trust induction which consists of major incident and CBRN training.

57 participants were recruited (Table 27) (30 females and 27 males). Ages ranged from 21-60 years (mean=39 years, SD=10). Participants were employed by the NHS in a different role or different department for an average of 12 years (SD: 8). The length of employment in the ED ranged from 3 months to 20 years (mean: 8 years, SD: 5).

Table 27: Study population demographics

	Age	NHS Experience	ED experience
Range	21 - 60 years	9 months – 33 years	3 months - 20 years
Mean	39 years	12 years	8 years
Standard Deviation	10	8	5

Purposive sampling was used because this involved the identification and selection of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Creswell & Plano-Clark, 2011). A representative sample was ensured by calculating the percentage distributions of first receivers on a typical shift. This was used to determine the actual number of first receivers required. Initially, a maximum of 50 first receivers was expected to reach saturation point; however, it became clear that greater numbers and types of first receivers were required. This included security officers and medical physicists (Chapter 3).

The number of participants from each Trust differed. This is because whilst the study was developing, differences in the specific roles' individuals played in the event of a CBRN emergency became apparent. For example, according to Trust Bs CBRN plan, porters would be required to organise refreshments thus having a role in the CBRN response.

The results of each Trust are presented individually, with a detailed comparison in chapter 6. The demographics of Trust A are shown in Table 28 (p. 150) and Trust B in Table 29 (p. 151).

Table 28: Demographics of first receivers (Trust A)

Trust A					
Participant	**Gender**	**Age**	**Professional Role**	**NHS experience**	**ED experience**
A001	M	42	Doctor (Consultant)	17 years	13 years
A002	M	48	HCA	8 years	8 years
A003	M	21	Porter (Logistics team leader)	3 years	6 months
A004	M	-	Doctor (Registrar)	1 year	6 years
A005	M	31	Doctor (SHO)	10 years	4.5 months
A006	F	49	Receptionist (Tracker)	17 years	6.5 years
A007	M	24	Nurse	2 years	2 years
A008	F	28	Nurse (Sister)	5.5 years	5.5. years
A009	F	60	Receptionist (Admin assistant)	14 years	14 years
A010	F	49	Nurse in Charge (NIC)	29 years	7 years
A011	M	28	HCA	3 years	2 years
A012	M	39	Porter	8 years	3 years
A013	F	24	Nurse	2 years	10 months
A014	F	32	HCA	9 months	9 months
A015	M	36	Nurse (NIC)	16 years	5 years
A016	F	31	Nurse (Deputy sister)	11 years	11 years
A017	M	51	HCA	4 years 6 months	4 years 6 months
A018	M	38	Doctor (SHO)	3 years	10 months
A019	F	47	Receptionist	14 years	14 years
A020	M	38	Doctor (Registrar)	8 years	3 years
A021	F	39	Nurse (ANP)	16 years	6 years
A022	M	37	Nurse (Deputy charge nurse)	15 years	15 years
A023	F	51	Receptionist (Team leader)	17 years	17 years
A024	F	26	Nurse (Deputy sister)	5 years	5 years
A025	M	48	Doctor (Consultant)	24 years	20 years
A026	F	43	Nurse (NIC)	15 years	5 years
A027	M	31	Security officer	14 years	14 years
A028	M	54	Security officer	5 months	5 months
A029	F	34	Medical Physicist	12 years	12 years

Table 29: Demographics of first receivers (Trust B)

Trust B					
Participant	**Gender**	**Age**	**Professional Role**	**NHS experience**	**ED experience**
B001	F	23	Nurse	2 years 9 months	1 year 4 months
B002	F	33	HCA (Assistant practitioner)	14 years	11 years
B003	M	32	Nurse (Trainee ENP)	10 years	1 year
B004	F	53	Nurse (Sister)	35 years	10 years
B005	F	46	HCA	11 years	9 years
B006	F	48	Doctor (Junior clinical fellow)	3 years	6 months
B007	F	50	Receptionist (Co-ordinator)	24 years	9 years
B008	F	44	Receptionist	10 years	8 years
B009	F	39	Nurse (NIC)	14 years	14 years
B010	M	58	Doctor (Consultant)	33 years	20 years
B011	M	42	Nurse (Emergency Nurse Practitioner)	20 years	19 years
B012	F	56	Nurse (NIC)	29 years	11 years
B013	F	37	Nurse (Sister)	16 years	12 years
B014	M	46	Doctor (Consultant)	23 years	12 years
B015	F	34	Receptionist (Co-ordinator)	12 years	12 years
B016	F	37	Nurse	14 years	12 years
B017	M	45	Doctor (Registrar)	7 years	6 years
B018	F	27	Nurse (Sister)	10 years	4 years
B019	F	31	Receptionist	1 year 7 months	1 year 7 months
B020	F	29	Nurse	1 year 8 months	11 months
B021	M	31	HCA	7.5 years	7.5 years
B022	M	26	Doctor (FY2)	1 year 11 months	3 months
B023	M	50	EDA – (Emergency Department Assistant)	6 years	3 years
B024	F	54	HCA	4 years	4 years
B025	F	32	Nurse (Sister)	13 years	5 years
B026	M	38	Doctor (Registrar)	7 years	7 years
B027	M	34	Security officer	16 years	13 years (not ED – security)
B028	M	44	Security officer	13 years	13 years (not ED – security)

Verification interviews were carried out to ensure credibility (Chapter 3) of the data collection method, a means of member checking, and a natural output of participatory design. Member checking, in particular, has been suggested to be an effective validation technique to make sure that the participants agree that the findings constructed by the researcher represent what the participants have reported (Thomas, 2017).

Stratified purposive sampling provides the ability to compare, contrast, and identify similarities and differences in the phenomenon of interest (Palinkas et al., 2015), this was combined with the percentage distribution for the verification process (see Table 30). The percentage distribution was used to keep consistency as well as provide representative verifiers for the HTAs. This was the optimal sampling method because it allowed a comparison to be made between types of first receivers as well as a comparison defined by the length of experience in the ED.

Table 30: Sample required based on percentage distribution and purposive stratified sampling for HTA verification phase

Participant	Role	Scenario card
A022	Nurse – Deputy charge nurse	ARS
A023	Receptionist – Team leader	Sarin
A012	porter	SARS
A013	Nurse	ARS
A004	Registrar	ARS
A002	HCA	Sarin
A021	Nurse - ANP	SARS
A025	Doctor - Consultant	ARS
A010	Nurse - NIC	ARS
A028	Security officer	Sarin
A029	Medical Physicist	ARS
B010	Doctor - Consultant	ARS
B022	Doctor – FY2	Sarin
B012	Nurse - NIC	SARS
B007	Receptionist	ARS
B011	Nurse – ENP	Sarin
B028	Security manager	SARS
B018	Nurse – Sister	SARS
B005	HCA	Sarin
B016	Nurse-Band 5	ARS

5.2.2.3 Data collection

There were two phases of data collection. The first phase was the semi-structured interview. The second part of the study was verifying that the HTAs were a just representation of the actions of first receivers during a CBRN event.

During the first phase, data were collected to obtain a representation of WAD, on varying ED shifts. These were week-day day shifts, weekend day shifts, week-day night shifts, and weekend night shifts. Scenario cards were presented at a convenient time when the identified first receiver was available. The participant was presented with the scenario card, given time to read it, and then asked to talk the researcher through their actions when faced with the scenario. Probes were used to expand on responses with *"What, why, and who"* questions. Field notes were made which were transcribed (for record keeping and analysis) and converted to HTAs.

The second (verification) stage, followed the guidance from Stanton (2006) (Appendix 5, p. 298) to confirm the reliability of the HTA to represent the data correctly. The verification process was carried out on a separate occasion and began by providing the first receiver the scenario card as a memory aid. The functions of HTA were then explained and then the participants were given some time (approx. 3 minutes) to review the HTA. The first receiver was then asked, *"Do you think this diagram is a true representation of what you would do in a CBRN event?"* They were then given the opportunity to discuss and amend the HTA.

5.2.2.4 Analysis

The field notes were transcribed for both record keeping purposes and analyses. Each transcript was read and re-read for familiarisation and to ensure complete immersion with the data. The field notes were converted into HTAs, the scenario set out by the card was the main operation of the HTA. Most of the HTAs were formed on PowerPoint; larger HTAs were produced on Microsoft Visio. The HTAs were then printed for task by task manual analysis, in which key comments and keywords were coded onto the HTA. Applied thematic analysis (Chapter 3) was applied to the field notes to systematically identify, organise, and provide insight into patterns of meaning (themes) across the data set (field notes) (Braun & Clarke, 2012) and applied to the HTAs.

The HTA results were 1) Thematically represented by colour, 2) Tabulated by first receiver group, and 3) First receiver specific HTAs were formed (Figure 41, p. 155). First receiver specific HTAs were then combined to form Trust specific standardised WAD top level HTAs to represent the ED response to CBRN events (Figure 48, p. 164 and Figure 52, p. 168).

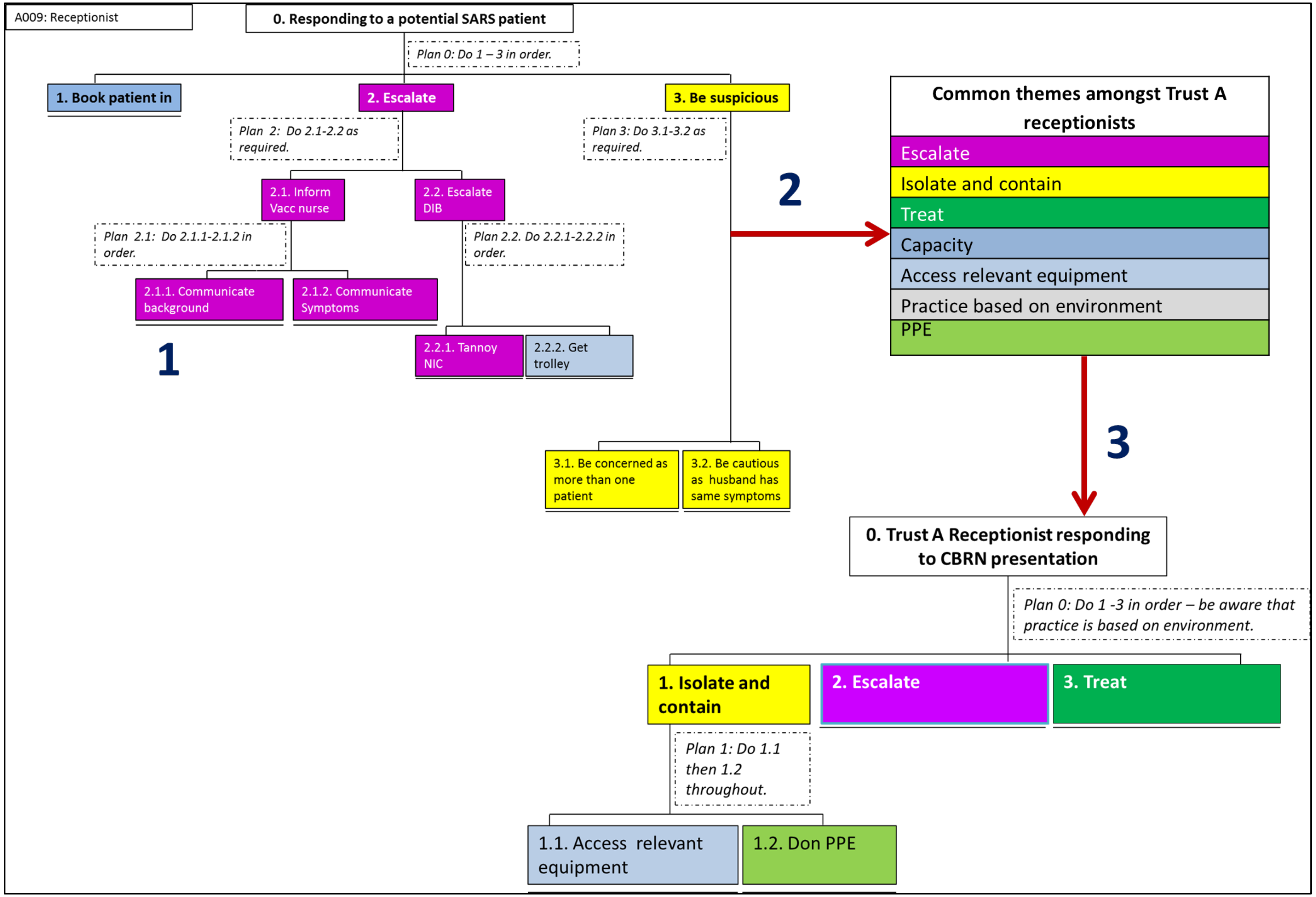


Figure 41: Trust A receptionist process of analyses and example of results

5.3 Results:

The field notes were used to develop the themes. A total of 19 common themes existed between both Trusts (Table 31, p. 157). There were 8 Trust specific themes for Trust A, and 3 for Trust B.

For Trust A, nurse HTAs will be used as an example, for Trust B Doctor HTAs will be used; this is because nurses and doctors make the largest group of first receivers, and their roles include managerial and practical CBRN tasks. The remaining (receptionists, doctors, HCAs, porters, security officers, and medical physicists) results are provided in appendix (Vol 2: Appendix 43, p. 170) and Vol 2: Appendix 51 (p. 198).

The results for each Trust are presented in three parts:

- **Part A: HTA representations of WAD and synthesis of professional groups.**

Examples of nurse and doctor HTAs are represented through a colour coded HTA based on Table 31 (p. 157). A synthesis of professional groups was collated based on the most common themes which are based on two sources of evidence: 1) Field notes and 2) First receiver HTA.

The remaining HTAs are provided as appendices (Vol 2: Appendix 35, p. 143 - Vol 2: Appendix 50, p. 196). HTAs of first receivers with the most ED and NHS experience are used as examples as they exhibit the greatest amount of information.

- **Part B: Verification of scenario cards.**

The changes made to the HTA representations by 3 first receivers at Trust A, and 4 first receivers at Trust B are presented.

- **Part C: Synthesis of WAD**

The most common themes discussed by first receivers at both Trusts were tabulated and formed top level HTAs.

Table 31: Colour coded WAD themes

Common themes	
Trust A	**Trust B**
Isolate and contain	Isolate and contain
Treat/Provide patient care	Treat/Provide patient care
Capacity/patient flow	Capacity/patient flow
Escalate – clinical	Escalate - clinical
Escalate - organisational	Escalate - organisational
Decontaminate	Decontaminate
Liaise and communicate	Liaise and communicate
Assist/assist ED	Assist/assist ED
Implement PPE	Implement PPE
Take lead/manage incident	Take lead/manage incident
Protect (self/patient/ staff/environment)	Protect (self/patient/ staff/environment)
Take notification of casualties	Take notification of casualties
Clinically assess/triage	Clinically assess/triage
Investigate/•	Investigate/•
Guidance	Guidance
Cross contamination	Cross contamination
Detect/identify agent	Detect/identify agent
Secure	Secure
Recognise event occurring	Recognise event occurring
Trust specific themes	
Trust A	**Trust B**
Diagnose	Document
Practice based on environment	Make decisions
Provide/access equipment/stock	Teams
Patient awareness/ sensitivity	-
Provide access	-
Monitoring	-
Manage casualties/influx of patients	-
Manage staff	-

Key

Investigate - Investigate presentation

Investigate• - Investigate symptoms

5.3.1 Results: Trust A

5.3.1.1 Trust A: Part A – HTA representations of WAD

Scenario card responses were made into field notes, and then converted into HTA representations for nurses at Trust A.

Nurse in Charge

NICs at Trust A (see Vol 2: Appendix 36, p. 146) **recognised** a CBRN threat by questioning and **investigating** the situation and the **presentation** and **symptoms**. For example, A010 (Figure 42) would *"Gather information"* and question the presentation as well as the *patient history*. A010 would further attempt to **detect** the agent by using the Geiger counter. A010 stated that they would *"See how they've presented and what information"*. **Recognising** the threat through investigation is echoed in the response of A015 (Vol 2: Appendix 36, A36 3, p. 148) in which they would *"Assess the situation"* then implement actions which were discussed within the field notes such as *"Restricting people going in"* .

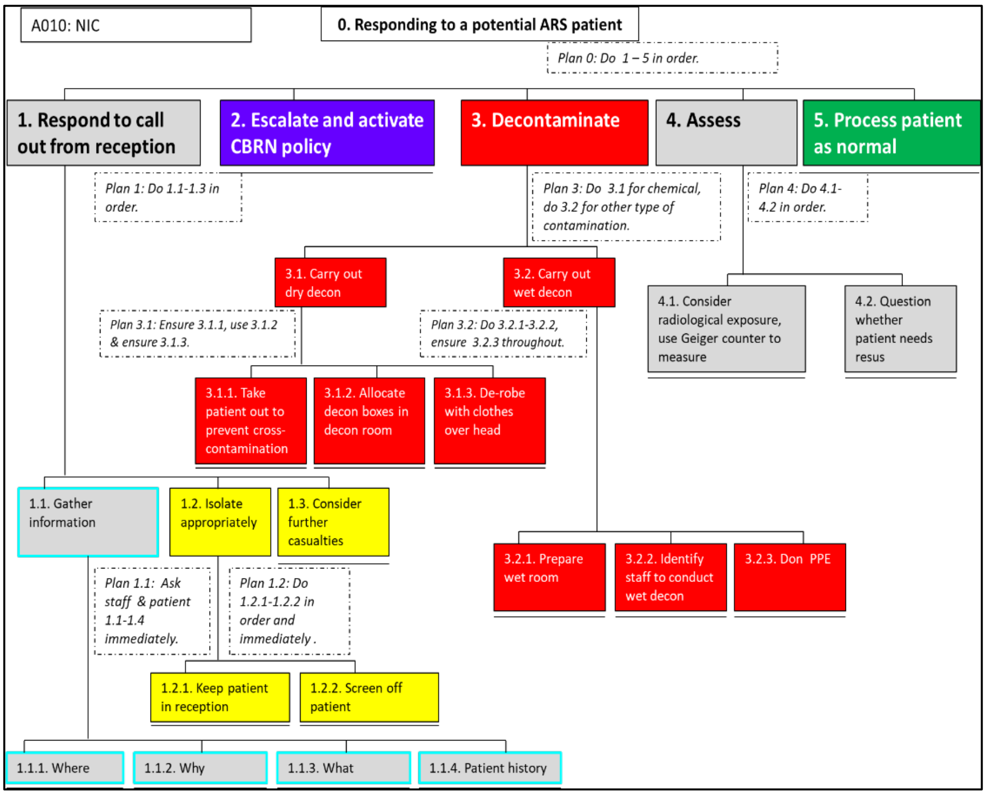


Figure 42: HTA representation of Trust A NIC responding to ARS presentation

The NICs at Trust A took **lead** of the CBRN response by implementing actions such as **containing** the contaminant, **escalating** both on an **organisational** and **clinical** level.

NICs **protected staff** and the environment by organising the **donning of PPE** as well as **decontamination**. **Liaising** with other organisations was also crucial to taking lead as a NIC. All NICs at Trust A found it vital to **isolate and contain** the contaminant (Figure 43); this was achieved by implementing actions such as:

"Restricting people going in, limit to the assessment nurse and doctor going into the patient, seal off, and evacuate the department"

Most (two out of the three NICs) found it important to **liaise** with other organisations for example, A015 found it vital to liaise with "*Fire services*" and the "*Poisons unit*" with A026 prioritising liaising with emergency services (see Vol 2: Appendix 36, A36 4, p. 149). Liaising in relation to the Trust A NICs' response to CBRN event coincided with **organisational escalation**.

Analysis of the field notes revealed phrases such as *"Escalate and activate policy"* (A010) *"Implement CBRN protocol"* and *"Set up command centre"* (A015) as well as *"Major incident due to influx"* (A026). Clinical escalation consisted of actions such as *"Liaising with the consultant"* (A015) and *"Take patient to resus due to risk of airway compromise resulting from excessive salivation"* (A026).

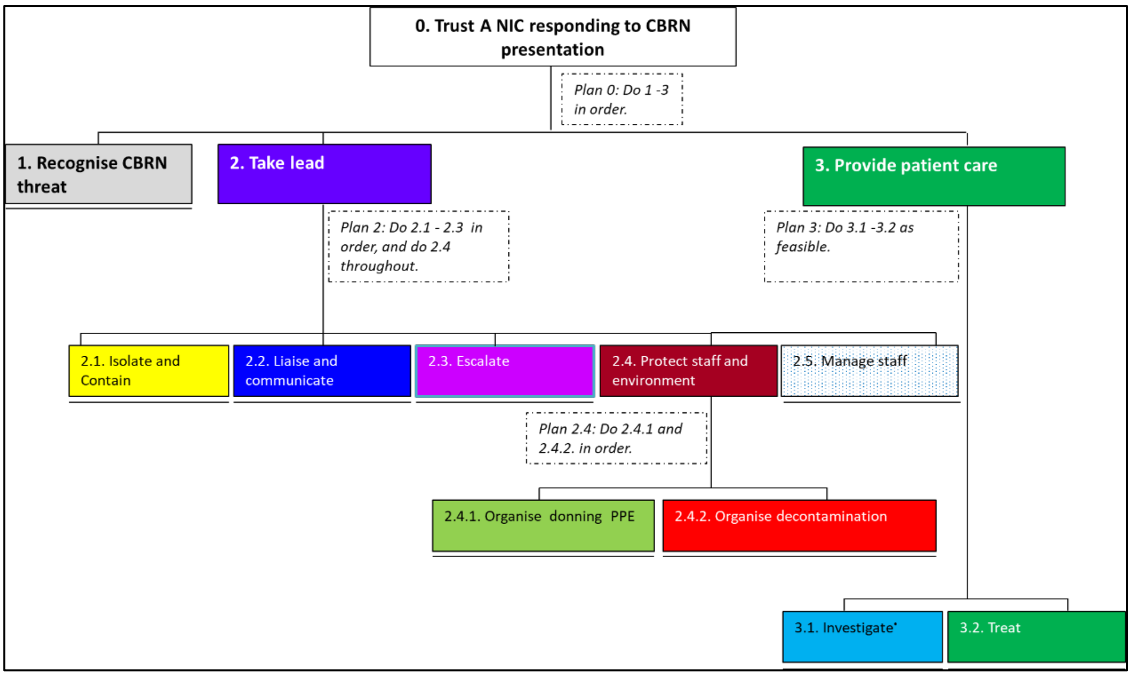


Figure 43: Trust A NIC group synthesis

To **protect staff** and **environment** was a result of organising the donning of PPE as well as effective decontamination. Beginning with the donning of PPE, NIC A026 stated that they *"Would be in PPE throughout"* the incident; with NIC A010 stating that they would *"Ensure they (first receivers) are in PPE"* in response to Sarin and ARS exposure respectively.

All NICs at Trust A discussed decontamination in their response to a CBRN emergency. A010 went into detail about the type of decontamination needed to be implemented whether it was dry or wet decontamination and the actions involved in each (A010, Figure 42, p. 158).

NICs at Trust A managed staff by *"Allocating staff"* (A015) for the decontamination procedure as well as through subordinate tasks such as "*Identify staff to conduct wet decon"* (A015, subordinate task 3.2.2.).

Provide patient care showed differences in the actions amongst NICs at Trust A, for example, NIC A010 showed both clinical and presentation **investigation**. Investigation was a part of treating the patient as evidenced by A010, who stated *"Why does she think she has been poisoned?"* in their response to an ARS presentation.

Nurses

Isolating and containing the contaminant was core to all nurse first receivers at Trust A (Vol 2: Appendix 38, p. 158) apart from A008 (Vol 2: Appendix 38, A38 2, p. 159). Nursing staff implemented **isolate and contain** (Figure 46, p. 162) by carrying out actions such as "*Don PPE"* and **protect staff** by implementing measures such as *"Barrier nursing"* (A007, Vol 2: Appendix 38, p. 158) based on the *risk of contamination* (A016).

Additionally, a means to **protect staff** was by *"Sending the patient to majors or resus in an isolated bay"* (A024). Further, **PPE** was always to be implemented:

> *"Get doctor to come in and review the patient and ensure that he is in PPE, remain with the patient in PPE and patient contact is to be limited to me and doctor reviewing the patient. Try not to keep the patient in the ED for too long and get the patient to infectious diseases ward ASAP because they have proper isolation rooms and equipment, ensure when doing bloods designate one nurse who will be in full PPE which is apron, gloves, and mask"* (A024).

Further, exposure of the patient was limited to prevent cross contamination. Some of the nurses (A007 (Figure 44), A016, and A022) stated that they would implement both PPE and isolate the patient simultaneously. For example, A007 stated:

"See the patient in isolation, separately, and implement PPE including a mask, apron, and gloves as a precaution".

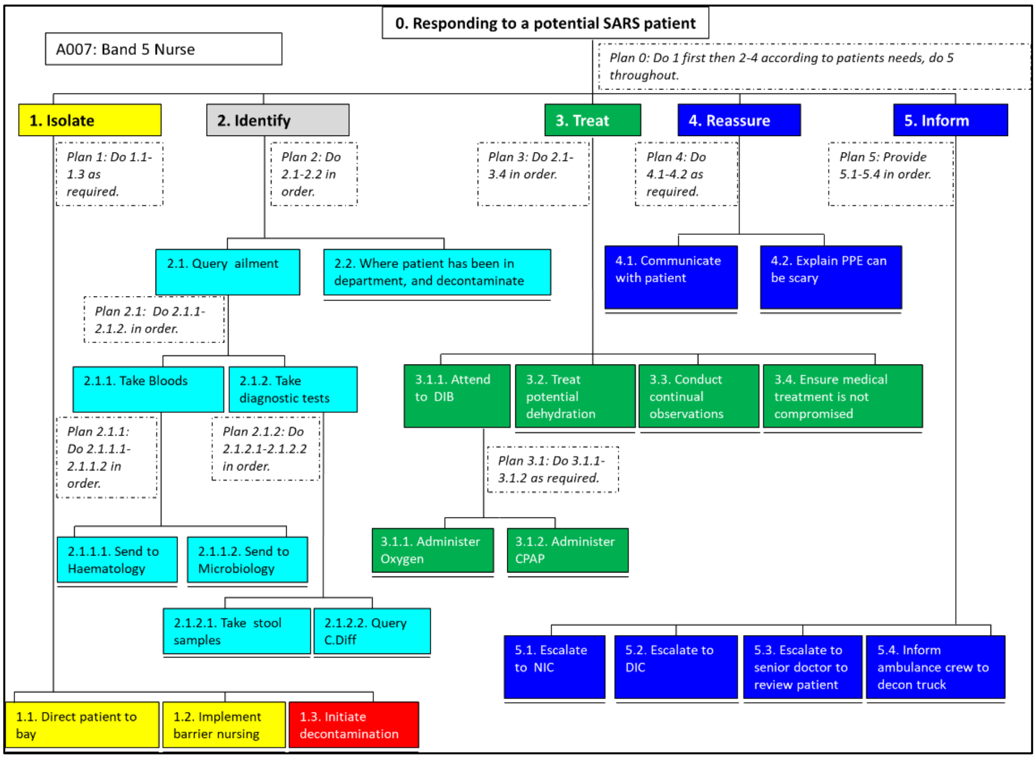


Figure 44: HTA representation of Trust A band 5 nurse responding to SARS presentation

All nurses at Trust A implemented some form of **escalation** (see Figure 46, p. 162) either clinical or organisational. **Organisational escalation** was a characteristic of senior nurses (Band 6 sisters Figure 45, p. 162), for example, when responding to a SARS patient, A016 would *"Contact PHE to find out which part of the far east have SARS and let PHE know – inform them of the patient".*

Other band 6 nurses would implement both clinical and organisational escalation as exemplified by A022 when responding to an ARS presentation they would:

"Escalate to the NIC, and the NIC might want to gain information from other sources such as EMS or the police".

Clinical escalation was a characteristic of Band 5 nurses at Trust A, for example A008 would escalate the ARS presentation to *"The mental health team"*. Similarly, A007 would, *"Ensure that they are assessed by a senior doctor, because something like this needs senior input, for clarification"*.

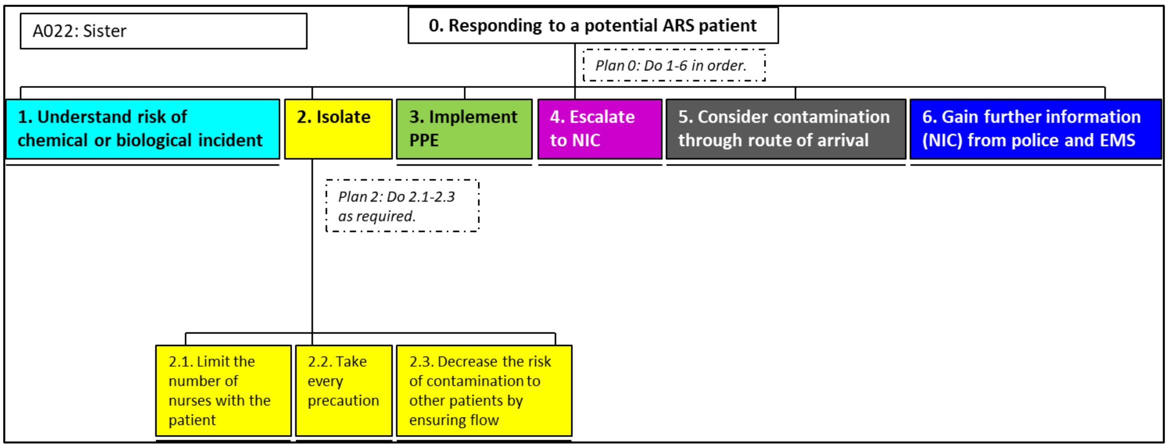


Figure 45: HTA representation of Trust A band 6 nurse responding to ARS presentation

Liaise and communicate was related to the superordinate task escalate (clinical and organisational). Trust A nurses *"Liaised"* with external organisations and *"Communicated"* with individuals. On deeper analysis, four of the six nurses at Trust A would liaise and communicate. For example, A022 would escalate to the NIC by communicating and is expecting that the NIC would *"Want to gain information from other sources such as EMS or the Police"* in which case the NIC is liaising with external organisations.

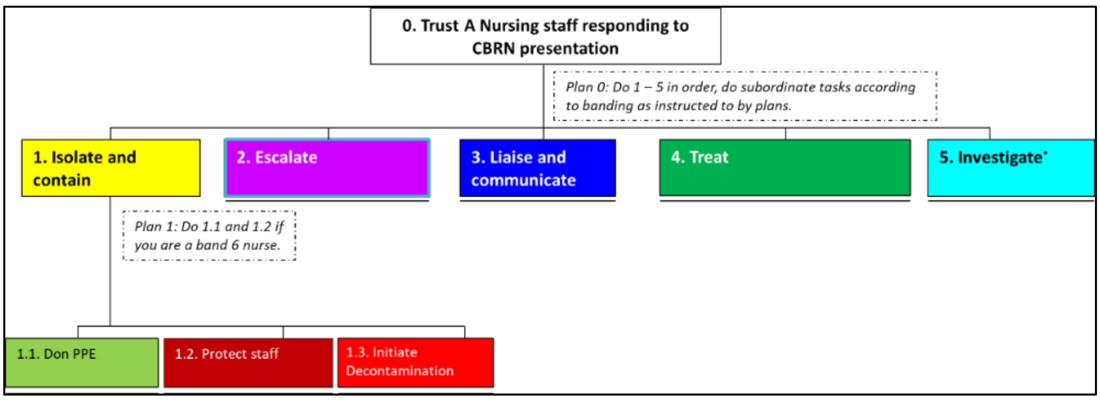


Figure 46: Trust A band 5 nurses group synthesis

Most nurses apart from A022 (Vol 2: Appendix 38, A38 5, p. 162) at Trust A would **treat** the patient. Nurse first receivers at Trust A treated the symptoms presented on the scenario card explicitly; for example, A007 when responding to Sarin exposure questioned that there is: *"Difficulty in breathing, do they need oxygen do they need Continuous Positive Airway Pressure (CPAP), are they dehydrated?"*

Treatment was based on the symptomology of the presentation as well as the outcome of a clinical assessment. This was exemplified by A008 who stated, *"Take to an assessment bay, does not need resus, if the patient is unstable, treat".* Two nurses exhibited uncertainty on how to treat CBRN patients, for example A016 asked *"Is this a chest infection? Sometimes symptoms mimic same things"* when responding to a SARS patient.

Nurses at Trust A showed both **clinical investigation** and **presentation investigation**. Clinical investigation was associated with carrying out invasive investigations to see the underlying causes of the symptoms, A007, exemplified clinical investigation when they stated, *"Identify what this is, do tests and take stool samples because this could be C.diff (Clostridium difficile)"*.

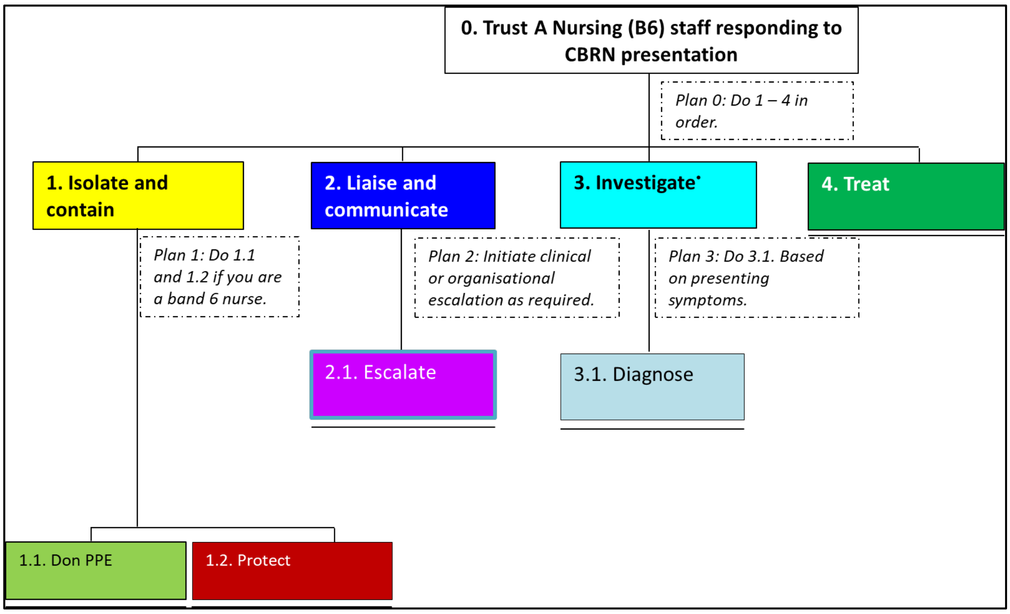


Figure 47: Trust A band 6 group synthesis

Band 6 and band 5 nurses at Trust A responded to CBRN presentations very similarly. However, band 6 nurses did not include decontamination in their responses (Figure 47), whereas band 5 nurses did. Band 6 nurses included **diagnose** in their response; for example, A008 diagnosed ARS exposure as a result of an overdose of "*Substance of some kind, cocaine extensive use, not occasional use*".

5.3.1.2 Trust A: Part B – Verification of scenario cards

Three first receivers made changes to the HTA representation of their response.

1. ED doctor (A004), changes in terms of the actions that the first receiver would carry out.
2. The amendment for the NIC (A010) was a typo error in which the word "not" was put in.
3. The medical physicist's response was the most varied, as the changes were in terms of what order tasks would be carried out in and the content of the tasks. The content of the tasks was based on new knowledge A029 had acquired since the initial scenario card presentation.

5.3.1.3 Trust A: Part C - Synthesis of WAD

After thorough analysis of both the field notes and the resulting HTAs, it was clear that certain tasks were mentioned in response to CBRN events more than others (Vol 2: Appendix 44, p. 175) . The most frequently discussed themes by first receivers at Trust A were organised into a standardised top level HTA (Figure 48):

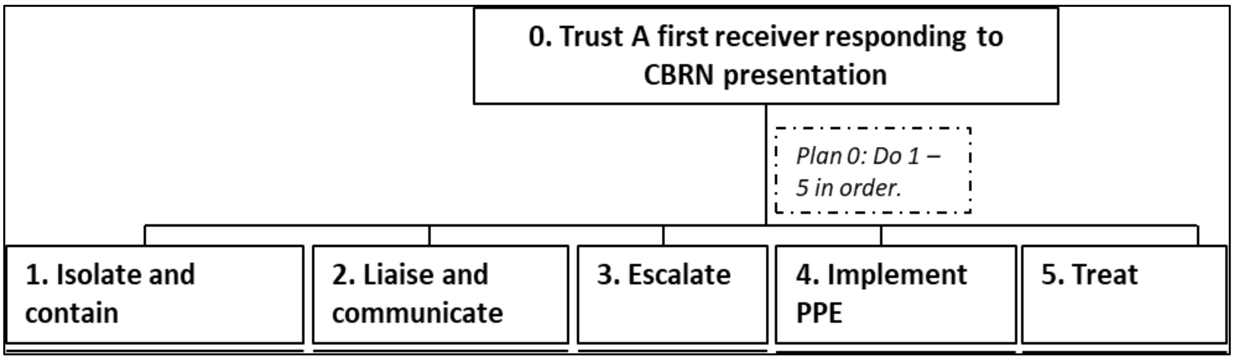


Figure 48: Standardised CBRN response superordinate tasks for Trust A first receivers

5.3.2 Results: Trust B

5.3.2.1 Trust B: Part A – HTA representations of WAD

Doctor HTA representations of CBRN scenario card responses are now presented.

Doctors

Doctors at Trust B (Vol 2: Appendix 47, p. 182) implemented superordinate tasks such as **manage incident** (Figure 50, p. 166) by carrying out tasks such as **isolate and contain**, and **make decisions**. Senior doctors managed the incident, by carrying out tasks such as declare a major incident when responding to a Sarin presentation by:

> *"Adopting the 1-2-3 principle, there are more than 3 patients showing symptoms, think of calling a major incident. This has not come to us through EMS. Call major incident and evacuate the department. Take power of the department and decontamination, call security for lockdown. Designate roles and designate people without exposing us, this is a PHE incident"* (B014).

Not all senior doctors thought of the presentation to be a CBRN event, but managed the situation, nonetheless. Consequently, questioning the management of the event, by expressing concern about contamination and managing the event by *"Seek advice from the health protection department"* (B010, Figure 49):

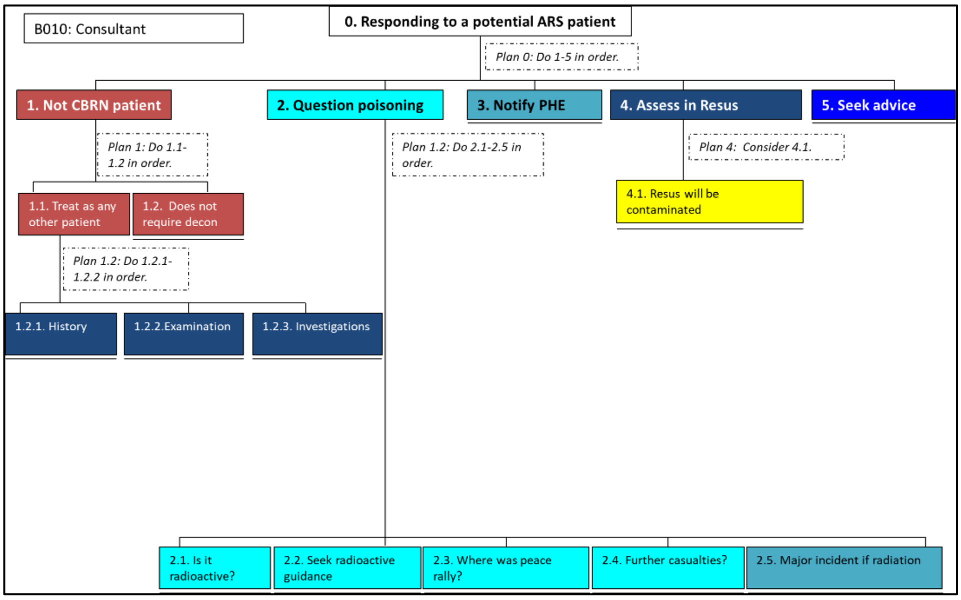


Figure 49: HTA representation of Trust B doctor responding to ARS presentation

All doctors at Trust B apart from B017 (Vol 2: Appendix 47, A47 4, p. 184) discussed **isolate and contain** in their response to CBRN events. For example, when responding to a potential SARS patient, B026 said *"Isolate the patient, this could be SARS virus, which was spread by respiratory droplets, so use mask and use protective barrier nursing".*

Three of the doctors (B014, B022 (Vol 2: Appendix 47, A47 5, p. 185 and B026, A47 6, p. 186) discussed the implementation of **PPE** in their response.

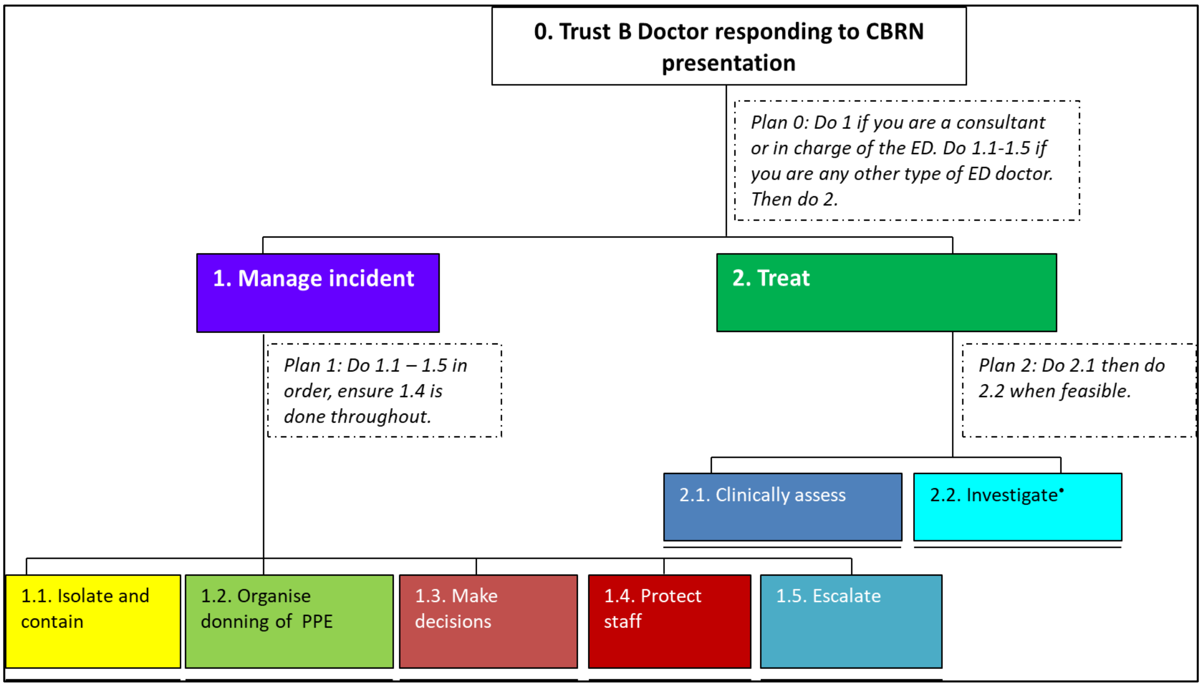


Figure 50: Trust B doctors group synthesis

To **make decisions** (Figure 50) was a task associated with senior doctors at Trust B. Initially, B010 made the decision to *"Treat as any other patient"* and decided that the presentation *"Does not require a tent and is not a decon type patient"*; whereas B014 decided to *"Call a major incident and evacuate the department"* resulting in **organisational escalation**.

Three Trust B doctors discussed **protecting staff** in their CBRN response, for example B022 stated *"Implement staff precautions".*

Organisational escalation was exemplified through actions such as recognising a SARS presentation was a *"PHE issue"* (B006) and:

"Depending on results and suspicion, we will have to call infection control or experts in from Birmingham or wherever the designated area is" (B026).

To **manage** CBRN presentations effectively, Trust B doctors discussed to **investigate presenting condition** (Figure 50, p. 166). Questions such as *"Where exactly were they in the Far East?"* were included in responding to a SARS presentation (B006). Questions were also raised when responding to ARS:

"I'd question where the peace rally was, does anyone else have the same symptoms?" (B010).

Treating the patient was a result of **clinically assessing** and **investigating symptoms** of the presentation. For example, when responding to a SARS presentation B007 would clinically assess the patient by:

"Take an ABCDE approach, assess the patient, looks infectious type. Look for signs and the injury type. Look at the breathing, are there any neuro deficits? Headache? Photophobia? Assess the diarrhoea?".

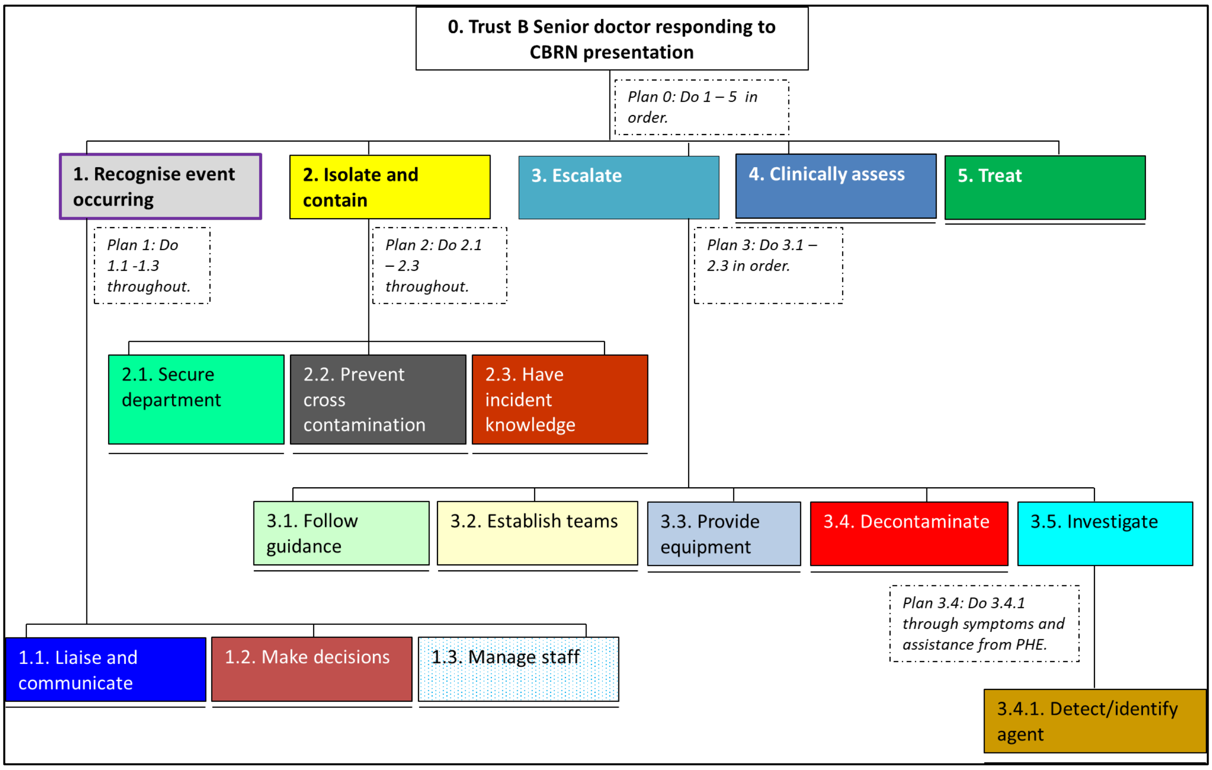


Figure 51: Trust B senior doctor group synthesis

The senior doctor HTA representations of WAD was significantly different to the doctor HTA (Figure 50, p. 166). Although senior actions such as **make decisions** were made by all doctors at Trust B. Senior doctors (Figure 51) carried out additional tasks such as **manage staff**, **secure the department**, and **have incident knowledge.**

5.3.2.2 Trust B: Part B – Verification of scenario cards

Four first receivers at Trust B made changes to the HTA representation of their response.

1. The order of the actions carried out by an HCA (B005) was reorganised.
2. A nurse first receiver (B016) changed a clinical investigation.
3. One of the Band 6 nurses (B018) reorganised the order of the actions carried out when responding to a SARS presentation.
4. The security manager (B028) changed the order of tasks, omitted actions, and added actions.

5.3.2.3 Trust B: Part C - Synthesis of WAD

Cross analysis of the field notes and HTAs resulted in certain tasks being more prevalent than others when Trust B first receivers responded to a CBRN presentation as shown in Vol 2: Appendix 52 (p. 202). The most prevalent themes formed higher level tasks in response to a CBRN event at Trust B (Figure 52):

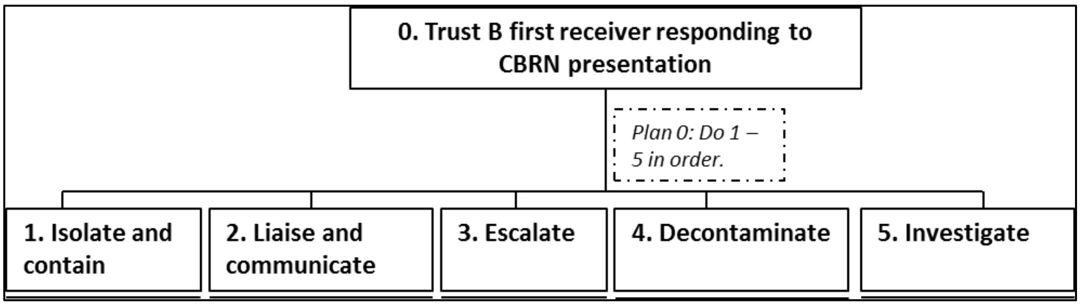


Figure 52: Standardised CBRN response superordinate tasks for Trust B first receivers

5.4 Study summary

The importance of first receivers being able to adapt their skills to respond to varying patient presentations associated with CBRN events was at the forefront of this study. The environment, resources, and professional relationships within the ED potentially influence how first receivers would respond to a CBRN event. As a result, the study was carried out in the ED. This was done to achieve the best possible likeness of WAD.

By using rigorous methods to create and pilot the scenario cards, it is believed that they were a realistic and effective method of representing CBRN events. The application of applied thematic analysis and colour coding to both the field notes and the HTA representations of responses resulted in themes, which consisted of actions crucial to responding to a CBRN event.

NICs at Trust A managed CBRN presentations by taking lead whilst protecting their team and the environment. Band 5 nurses implemented crucial CBRN actions such as isolate and contain. It was found that there was a void in the importance of carrying out decontamination amongst band 6 nurses. All doctors made decisions at Trust B, however senior doctors additionally secured the department and managed staff.

The detailed analysis and synthesis of the themes for individual first receiver groups at each Trust provided the main tasks as a means of bottom up evidence to standardise how first receivers respond to CBRN events as shown in Table 32:

Table 32: Standardised main tasks in response to a CBRN presentation

Standardised CBRN response tasks for first receivers in the ED	
Trust A	**Trust B**
1. Isolate and contain	**1.** Isolate and contain
2. Liaise and communicate	**2.** Liaise and communicate
3. Escalate	**3.** Escalate
4. Implement PPE	**4.** Decontaminate
5. Treat	**5.** Investigate

5.4.1 Conclusion

This study aimed to represent WAD in the ED response to CBRN events amongst two NHS foundation Trusts in the Midlands region of England. HTA effectively illustrated that there is variability in the ED response to CBRN events across the Trusts. Variability was evident in key CBRN tasks such as implementing PPE, Decontamination, Treat, and Investigate.

CBRN events are time critical situations; in which the clinical and organisational skills of first receivers should be prioritised to deliver safe and concise patient care. A means of achieving this could be to standardise the CBRN response in NHS Trusts.

Chapter 6. WAI vs WAD in the ED response to CBRN events: A comparative review

"A key factor in the understanding of safety within organisations relates to the distinction between Work as Imagined and Work as Done"

(Smith & Plunkett, 2019)

6.1 Introduction

This chapter combines the findings from Study 1 in which the blunt end of the Emergency Department (ED) response to Chemical, Biological, Radiological, and Nuclear (CBRN) events was mapped out, and Study 2 which represents the sharp end of the ED response to CBRN events as a means of comparing Work as Imagined (WAI) and Work as Done (WAD) in the ED response to CBRN events.

This chapter presents two comparative summaries (Figure 53, p. 172) for:

1. Work as Imagined (document analysis) for organisational policies and procedures vs Work as Done (first receiver interviews) at each Trust.
2. Work as Imagined vs Work as Done compared between Trusts.

The similarities between WAI and WAD will contribute to the standardised recommendations (Chapter 7). The differences will identify the gaps between WAI and WAD in the ED CBRN response.

6.2 Aim

To extract the main findings from WAI and WAD to propose standardised recommendations for the ED response to CBRN events (Chapter 7).

6.3 Research question

This chapter addresses the following research question:

What are the common and varying factors between WAI and WAD in the ED CBRN response?

6.4 Objective

To combine WAI and WAD findings to propose standardised CBRN recommendations.

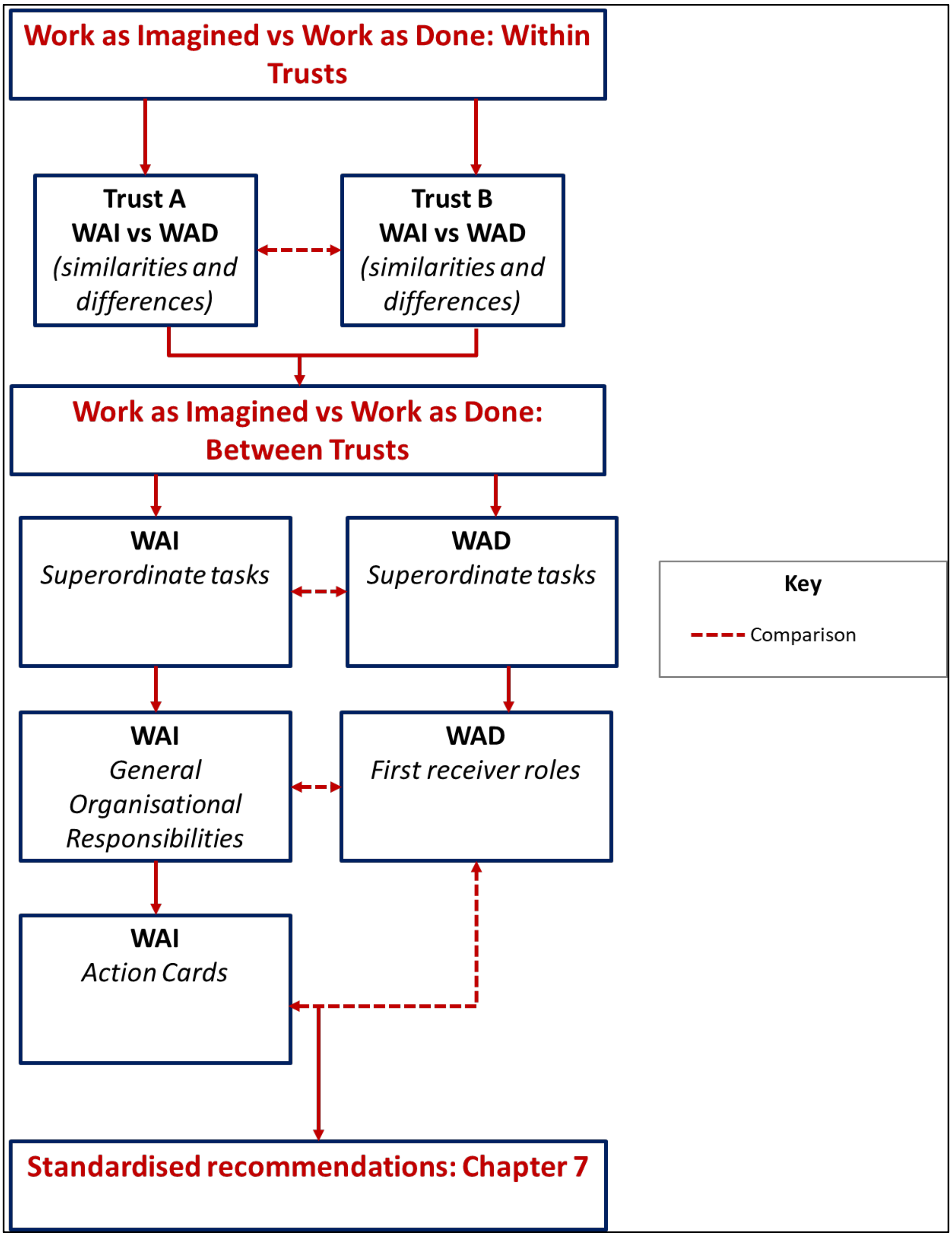


Figure 53: Comparison of WAI and WAD within and between Trust A and Trust B

Work as Imagined vs Work as Done: Within Trusts

Trust A
WAI vs WAD
(similarities and differences)

6.5 WAI vs WAD within Trusts

6.5.1 Trust A: WAI vs WAD similarities

Similarities will be discussed in terms of comparing General Organisational Responsibilities (GOR: The actions and activities expected from the ED as a system within a larger system, e.g. hospital) and action card themes as WAI. Themes formed from the semi-structured interviews will be used as a representation of WAD throughout this chapter.

The similarities between WAI GOR themes and the themes extracted from the semi-structured interviews at Trust A as reported in Chapter 5 were explored. To see whether Trust A first receivers included GOR tasks in their responses to hypothetical CBRN presentations. There were 11 tasks in common which were: PPE, decontamination, clinically assess/triage, isolate and contain, escalate (organisational), guidance, liaise and communicate, detect/identify agent, take notification of casualties, manage incident, and manage staff.

A comparison between Trust A's action card themes and the themes extracted from Study 2 was then made. Out of the twenty-five action card themes, there were 20 themes in common with WAD responses as shown in Table 33 (p. 174). Again, this demonstrates that first receivers at Trust A were familiar with most of the actions expected from them during a CBRN event.

Common themes between WAI action cards and WAD first receiver (group specific) HTAs (Chapter 5) were then compared as shown in Vol 2: Appendix 53 (p. 203) – the summary findings revealed that the most common two themes between the action card themes and responses to hypothetical CBRN situations were:

1. Liaise and communicate
2. PPE

Followed by protect, decontaminate, and escalate.

Table 33: Common action card and WAD themes (Trust A)

Trust A	
Action card themes	**WAD themes**
PPE	PPE
Decontamination	Decontamination
Clinically assess/triage	Clinically assess/triage
Isolate and contain	Isolate and contain
Escalate	Escalate
Document	-
Guidance	Guidance
Take lead/manage incident	Take lead/manage incident
Liaise and communicate	Liaise and communicate
Detect/identify agent	Detect/identify agent
Teams	-
Manage staff	Manage staff
Notification of casualties	Notification of casualties
Recognise event occurring	Recognise event occurring
Manage casualties	Manage casualties
Check	-
Provide access	Provide access
Secure	Secure
Advise	-
Access relevant equipment	Access relevant equipment
Protect (self/patient/ staff/environment)	Protect (self/patient/ staff/environment),
Assist/assist ED	Assist/assist ED
Treatment/patient care	Treatment/patient care
Time	-
Diagnose	Diagnose

6.5.2 Trust A: WAI vs WAD differences

The CBRN plan consisted of the theme **team** which referred to teams that were established to respond to the event, such as Command and Control (C&C) and decontamination teams. Teams were not discussed by any first receivers at Trust A. The only reference to the C&C structure at Trust A was made by a NIC (A015), who suggested that the command centre was to be set up in the sisters' office. Further, to **document**, was a part of the GOR at Trust A (Chapter 4). However, first receivers at Trust A did not discuss documentation in their responses.

There was a total of 16 additional themes discussed by Trust A first receivers for WAD compared to WAI (treat/provide patient care, capacity/patient flow, escalate – clinical, support/assist, protect (self/patient/staff/environment), investigate, cross contamination, secure, recognise event occurring, diagnose, practice based on environment, provide/access equipment/stock, patient awareness/sensitivity, provide access, monitoring, manage casualties/influx of patients). This shows variability between WAI and WAD but also suggests that first receivers at Trust A went beyond the General Organisational Responsibilities expected from the ED as a system.

The action cards had five themes which were not a part of the first receiver responses as explained in Table 34:

Table 34: Action card specific themes (Trust A)

Theme	Example
Document	In this instance, the action cards clearly stated that all actions associated with the CBRN response were to be logged and filed to fulfil a legal requirement.
Advise	The theme of to advise was a part of the role of the medical physicist. The medical physicist was expected to give out radiation advice to both patients, and first receivers during a CBRN event. However, to advise was not a part of the WAD response.
Check	The action card of the PPE buddy donning Powered Respirator Suit (PRPS) stated that the allocated first receiver was required to check that the suit was functioning. Safety checks were not a part of any of the first receivers' responses at Trust A.
Time	Trust A action cards consisted of first receivers allocated to carry out time critical tasks such as the timing board nurse. First receivers such as HCAs were expected to keep track of how long they had been in Chemical Personal Protective Equipment (CPPE) suits.
Teams	Action cards instructed first receivers to form teams to carry out specific tasks, such as decontamination.

The differences between WAI action cards and WAD first receiver (group specific) responses was then made, and the different themes amongst each first receiver tabulated. The key messages from this comparison were that there was a large gap between WAI and WAD for the importance placed on documentation of the event (Vol 2: Appendix 54, p. 204) and actions such as decontamination. Further, first receivers were concerned with treatment and diagnosis, and these actions were minimally included in WAI.

6.5.2.1 Summary

Trust A first receivers exhibited adherence to their role as a part of the ED as a system by including themes of GOR in their responses and discussing most action card themes. **Liaise and communicate** and **PPE** were key in both WAI and WAD at Trust A. There was variability in terms of the actions first receivers would carry out during a CBRN event when compared to GOR, a total of sixteen additional themes were discussed. The biggest variance in WAI and WAD at Trust A was the emphasis placed on **documentation** by WAI, and documentation being nonexistent in WAD. Patient **care and treatment** was a part of one action card (exit nurse), yet the majority of first receivers prioritised patient care and treatment, and **diagnosis** in WAD.

Trust B
WAI vs WAD
(similarities and differences)

6.5.3 Trust B: WAI vs WAD similarities

There were 15 common themes between Trust B GORs and the themes derived from study two: PPE, decontaminate, escalate (organisational), take lead/manage incident, document, liaise and communicate, capacity/patient flow, protect, isolate and contain, guidance, clinically assess/triage, teams, take notification of casualties, detect/identify, and manage staff.

From the 21 action card themes reported in Chapter 4, 17 themes overlapped with first receiver responses in study 2 as shown in Table 35 (p. 177). Similarities between

WAI action cards and WAD (group specific) HTAs were then made (see Vol 2: Appendix 55, p. 205).

The most common tasks between WAI and WAD at Trust B were:

1. Liaise and communicate.
2. Manage/lead event.

Table 35: Common action card and WAD themes (Trust B)

Trust B	
Action card themes	**WAD themes**
PPE	PPE
Decontamination	Decontamination
Escalate	Escalate
Take lead/manage incident	Take lead/manage incident
Document	Document
Liaise and communicate	Liaise and communicate
Capacity/patient flow	Capacity/patient flow
Protect (self/patient/ staff/environment)	Protect (self/patient/ staff/environment)
Isolate and contain	Isolate and contain
Provide/access equipment/stock	-
Guidance	Guidance
Clinically asses/triage	Clinically asses/triage
Manage staff	Manage staff
Teams	Teams
Notification of casualties	Notification of casualties
Time	-
Support/assist	Support/assist
Shadow	-
Clinical escalation	Clinical escalation
Check	-
Make decisions	Make decisions

6.5.4 Trust B: WAI vs WAD differences

There were 6 additional themes in the General Organisational Responsibilities. The action cards had 4 additional themes in comparison to WAD responses as described in Table 36 (p. 178).

Table 36: Action card specific themes (Trust B)

Theme	Example
Provide/access equipment/stock	Providing decontamination equipment was crucial to the role of first receivers, such as the decontamination lead at Trust B.
Time	First receivers such as board control operators at Trust B were expected to manage time for decontamination.
Shadow	The ED loggist was expected to shadow the ED senior team to record any events as they happened. Shadowing or logging was not discussed by any first receivers at Trust B.
Check	The checking of equipment was a task to be carried out by porters at Trust B. However, porters were not a part of the semi-structured interviews (Chapter 3), so a direct comparison could not have been made.

A comparison between WAI (action card HTAs) and group specific HTAs was then made as shown in Vol 2: Appendix 56 (p. 206). Although documentation was mentioned by first receivers at Trust B, it was the most obvious variability between WAI and WAD. An additional difference between WAI and WAD at Trust B, prevalent among most first receivers apart from security officers was the clinical escalation of the presentation.

6.5.4.1 Summary

Trust B had greater variability in GOR themes, as well as having more themes in GOR than in the action cards, suggesting a void between WAI and WAI at Trust B. There was a large overlap between WAI action card themes and scenario card responses, suggesting adherence to WAI by Trust B first receivers. **Liaise and communicate** and **manage/lead** event were the most consistent themes between WAI and WAD. The variability between GOR themes and WAD was not as extended for Trust B as it was for Trust A. Trust B first receivers discussed eight additional themes in comparison to GOR themes (Table 38, p. 182). Key findings from this comparison are that, although documentation was included in three first receiver responses at Trust B, it was still a void between WAI and WAD. Like Trust A, Trust B first receivers focused on patients' needs such as treating the patient, without the focus on diagnosing the presenting condition.

Work as Imagined vs Work as Done: Between Trusts

6.6 WAI vs WAD between Trusts

WAI

Superordinate tasks

WAI is compared between the Trusts using the information from the CBRN plans identifying similarities and differences.

6.6.1 WAI: Superordinate tasks

The superordinate tasks represent the general actions that need to be carried out to fulfil the main operation. When responding to a CBRN event, the superordinate tasks can be divided into three phases 1) Pre-incident, 2) Incident, and 3) Recovery, as illustrated in Figure 54 and Figure 55:

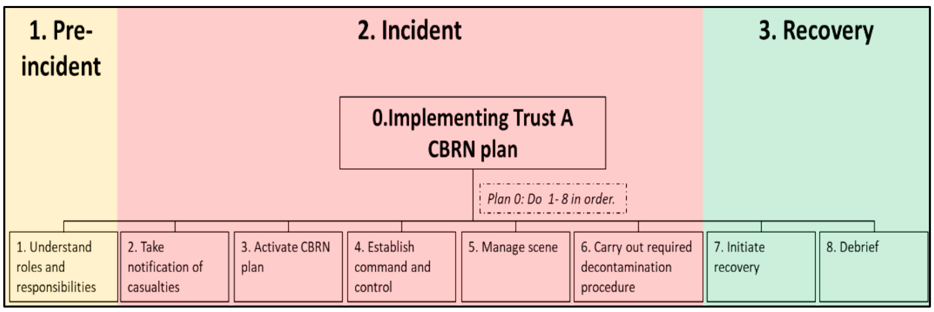


Figure 54: Trust A: GOR phases of the ED CBRN response

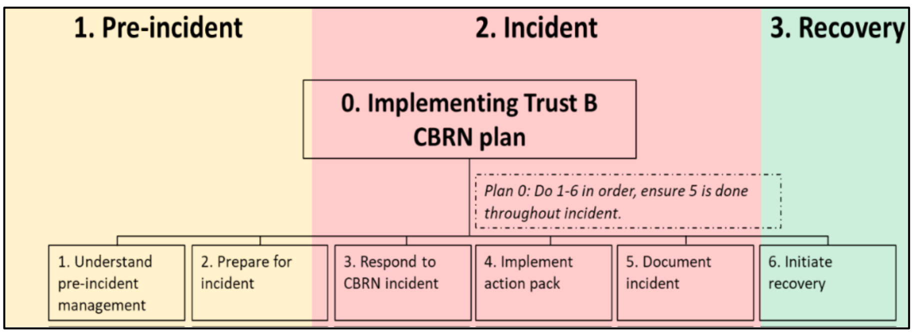


Figure 55: Trust B: GOR phases of the ED CBRN response

Table 37: Phases of CBRN response (WAI)

Phase	Explanation
Pre-incident	The pre-incident phase was to establish an understanding of the potential actions required. This phase outlined the role of the ED in line with other organisations such as Emergency Medical Services (EMS). The preparatory phase at Trust B was longer than that of Trust because there was a prepare for incident phase.
Incident	The activation of the CBRN response amongst both Trusts was identical. The CBRN response was prompted by receiving the notification of casualties. Trust A would respond to a CBRN event by senior first receivers (DIC and NIC) activating the CBRN plan which consisted of escalating the incident throughout the hospital as a means of calling in more staff, establishing response teams such as C&C, and locking down the ED. This response was mirrored by Trust B though the subordinate task of "*Activate CBRN plan in the ED"*. The difference in the response phase between the two Trusts was: Trust A was more categorical in the response steps by having individual superordinate tasks such as "*Establish command and control and carry out required decontamination procedure".* Trust B combined the individual superordinate tasks under *respond to CBRN incident* and discussed specific CBRN procedures such as decontamination under "*Implement action pack"*. A difference between the GOR WAI HTAs between both Trusts was the emphasis placed on documentation. Trust A referred to documentation once through the task of *"6.6.2. Ensure timing nurse records area of high reading"*. Trust B consisted of a superordinate task based on the documentation of patients, samples, and establishing chains of evidence as well as ensuring legible documentation.
Recovery	Both Trusts stepped down from responding to the CBRN event by "*Initiating recovery"*. There was a difference however, in what recovery consisted of. At Trust A, recovery was associated with the decontamination of departmental infrastructure, and the wellbeing of first receivers. Recovery was more of a statement of ending the CBRN response at Trust B, which was evidenced through the C&C team declaring incident stand-down. However, the wellbeing of first receivers was also a part of the recovery phase at Trust B. Trust A was once again more categorical in having an individual debrief superordinate task. Debriefing was a part of the initiate recovery superordinate task at Trust B.

WAD

Superordinate tasks

6.6.2 WAD: Superordinate tasks

The prioritisation of WAD themes across Trust A and Trust B first receivers were grouped together to form superordinate goals specific to each Trust in Chapter 5 (Figure 48, p. 164 and Figure 52, p. 168). Comparing WAI at Trust A (Figure 54, p. 179) and WAD (Figure 48, p. 164) within Trust A, the pre-incident phase consists of actions such as **isolate and contain**. A difference between GOR WAI CBRN response and the WAD response from first receivers is that first receivers did not include a recovery phase in their response.

There was an extended pre-incident phase at Trust B (Figure 55, p. 179), in the WAD representation (Figure 52, p. 168). The incident phase tasks in WAD, were complimentary to WAI superordinate tasks, for example, to **escalate** was crucial to **respond to CBRN incident**.

Inter-Trust WAD similarities amongst first receivers were evident in superordinate tasks such as **isolate and contain**, **liaise and communicate**, and **escalate**. Suggesting these superordinate tasks should contribute to the standardised CBRN recommendations (Chapter 7).

6.6.2.1 Summary

There is a clear difference in the phases of WAI and WAD representations of the ED response to CBRN events, with WAI having three defined phases. WAD across both Trusts consists of two phases, with the crucial action of **isolating and containing** being core to the pre-incident phase. The incident phase actions across both Trusts are a means of achieving the superordinate tasks defined in WAI. There was a difference between both Trusts on the importance placed on **PPE**, **treatment**, **decontamination**, and **investigation of the presenting condition**.

WAI

General Organisational Responsibilities

6.6.3 WAI: General Organisational Responsbilities

This section will provide a comparison between WAI themes derived from GOR HTAs (Table 38):

Table 38: Comparison of GOR themes across Trust A and Trust B

General organisational themes	
Trust A	**Trust B**
Decontaminate	Decontaminate
PPE	PPE
Liaise and communicate	Liaise and communicate
Isolate and contain	Isolate and contain
Clinically assess/triage	Clinically assess/triage
Take lead/manage incident	Take lead/manage incident
Document	Document
Guidance	Guidance
Notification of casualties	Notification of casualties
Escalate	Escalate
Identify/detect agent	Identify/detect agent
Teams	Teams
Manage staff	Manage staff
-	Capacity/patient flow
-	Respond to patient/respond
-	Provide/access equipment/stock
-	Clinical knowledge
-	Incident type (major incident/CBRN)
-	Protect (self/patient/ staff/environment)
-	Incident knowledge

There were 13 overlapping themes across both Trusts. Relating the themes to the three identified phases in section 6.6.1 (p. 179), all of the themes would contribute to the incident phase. The themes of **liaise and communicate**, **take lead/manage staff**, **guidance** and **teams** would be crucial in all three phases. Therefore, actions associated with the themes should contribute to the standardised response to CBRN events (Chapter 7).

Trust B had seven additional themes. Although these themes present a discrepancy between Trusts when responding to a CBRN event, they cannot be considered as a void in the ED CBRN response, as these themes exist in WAI in terms of the action cards (e.g. **capacity/patient flow**) as shown in Table 39 (p. 184), as well as WAD responses (Chapter 5).

WAI

Action cards

6.6.4 WAI: Action cards

An inter-Trust comparison of the action card thematic analyses from Trust A and Trust B will now be provided. There were 16 themes in common as shown in Table 39:

Table 39: Comparison of Trust A and Trust B action card themes

Action card themes	
Trust A	**Trust B**
Decontaminate	Decontaminate
PPE	PPE
Liaise and communicate	Liaise and communicate
Isolate and contain	Isolate and contain
Clinically assess/triage	Clinically assess/triage
Escalate	Escalate
Document	Document
Take lead/manage incident	Take lead/manage incident
Guidance	Guidance
Teams	Teams
Manage staff	Manage staff
Time	Time
Support/ Assist	Support/ Assist
Check	Check
Protect (self/patient/ staff/environment)	Protect (self/patient/ staff/environment)
Provide/access equipment/stock	Provide/access equipment/stock
Identify/detect agent	Shadow
Diagnose	Escalate - clinical
Recognise event occurring	Capacity/patient flow
Manage casualties/influx of patients	-
Provide access	-
Secure	-
Advise	-
Treat/provide patient care	-

The overlapping themes were crucial to all phases of the ED CBRN response. Trust A had 8 additional themes, which were crucial to the pre-incident phase (e.g. recognise event occurring), and the incident phase (e.g. manage casualties/influx of patients). Trust B had three additional themes which, again were core in the pre-incident phase.

WAD

First receiver roles

6.6.5 WAD: First receiver roles

A systematic approach to further compare WAI vs WAD between the Trusts was implemented. A summary of differences is provided by:

- Comparing additional WAD themes.
- Comparing WAI vs WAD based on first receiver roles:
  - Comparing HTA representations of action cards.
  - Adherence to WAI within Trusts.
  - WAD practices across Trusts.

There were 18 overlapping themes between Trust A and Trust B first receivers (Chapter 5). Additional tasks discussed by first receivers are shown in Table 40:

Table 40: Additional WAD themes across Trusts (Extracted from Chapter 5)

Additional WAD themes	
Trust A	**Trust B**
Diagnose	Document
Practice based on environment	Make decisions
Provide/access equipment/stock	Teams
Patient awareness/ sensitivity	-
Provide access	-
Monitoring	-
Manage casualties/influx of patients	-
Manage staff	-

There were 8 additional themes in Trust A WAD response, of which 6 were in line with Trust A action card themes (see Table 40). The theme **of practice based on environment** was unique to Trust receptionists at Trust A who altered their practice based on the renovation of the ED. **Patient awareness and sensitivity** was a theme associated with Trust A porters. The medical physicist monitored the spread of the contaminant, although the medical physicist would be contacted (as stated in Trust B CBRN plan), a medical physicist action card did not exist so a direct comparison could not be made.

To **document** was core in action card HTAs at Trust A and was mentioned once in the GOR HTA. This theme was not discussed by any first receivers at Trust A. Trust B first receivers however did discuss documentation of the CBRN event.

WAI vs WAD was compared based on job roles; 4 examples were used because their actions cover a broad range of first receiver roles. Receptionists were included because they are the first point of contact for self-presenters, DICs to exemplify a senior first receiver WAD response, nurses – because they make up the largest proportion of first receivers, and finally security officers. General comparisons for the remaining first receivers are provided in table Table 41:

Table 41: WAI vs WAD

First receiver	General comparison	Appendix
NICS	**WAI:** Both Trusts had 3 phases of event response. Differing emphasis on documentation. **WAD:** Response began in incident phase at both Trusts. Protecting staff, implementing PPE, and providing patient care were key actions.	Vol 2: Appendix 57, p.207.
Doctors	**WAI:** Variability in the number of action cards for doctors between Trusts (Trust A: 2, Trust B: 5). Assessment doctor and triage clinicians had same number of incident phases. P1 doctor had 2 phases. **WAD:** Overlap in themes such as taking lead and treating the patient. Variability in type of escalation.	Vol 2: Appendix 58, p.210.
HCAs	**WAI:** No action card for HCA at Trust B. Four action cards for Trust A. **WAD:** Both implemented isolate and contain, PPE, and decontamination. HCAs at Trust A would investigate symptoms and presentation, Trust B HCAs would investigate the presentation.	Vol 2: Appendix 59, p.215.
Porters	**WAI:** Three phases of incident response at Trust A, two at Trust B. **WAD:** Trust A porters adhered to WAD through liaise and communicate and assist.	Vol 2: Appendix 60, p.220.
Medical physicist	Trust B did not have a WAI representation for the medical physicist and access to interview one was limited. **WAI:** Three phases, advise, documentation, and protect were core to CBRN response. **WAD:** In line with WAI, incorporated PPE, and liaise and communicate. Further actions consisted of decontaminate and patient monitoring.	Vol 2: Appendix 61, p.223.

Receptionists/admin staff

There was variability in the number of response phases in WAI between Trusts. The Trust A receptionist staff action card had a recovery phase (Appendix 9, p. 308) whereas the Trust B admin card (Appendix 10, p. 309) did not. Both WAI action cards contained actions associated with **liaise and communicate**, suggesting this to be central to how admin staff are expected to respond to CBRN events.

Trust A receptionists (Figure 56) have a pre-incident phase in which they **isolate and contain, access relevant equipment**, and **don PPE**, in accordance with the action card (Appendix 9, p. 308). Trust A receptionists further went on to adhere to the action card by **escalating** both on a clinical and organisational level. Trust A receptionists however did not discuss the documentation of their actions or **liaise and communicate**.

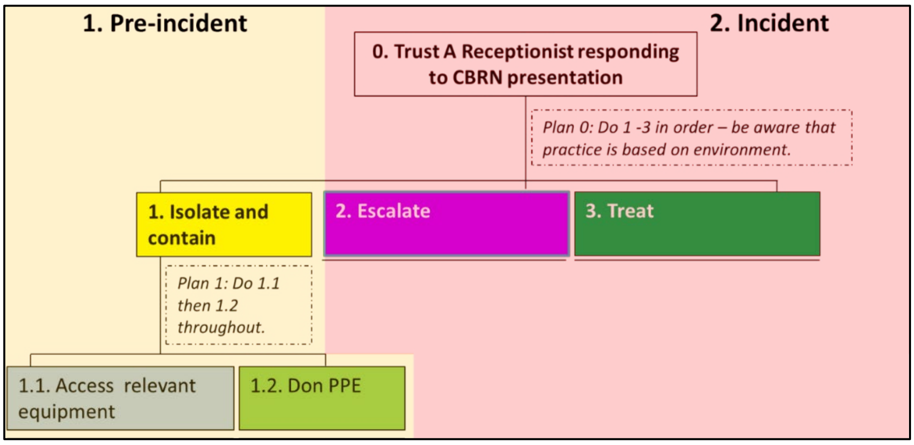


Figure 56: Trust A: Reception staff responding to a CBRN event

Trust B admin staff went directly into the response phase of their CBRN response, they adhered to one theme **(liaise and communicate)**. WAI set out receptionists to provide support during a CBRN event. Trust B admin staff did not specifically discuss support, however, did include assistive themes in their response such as **ensure patient flow**.

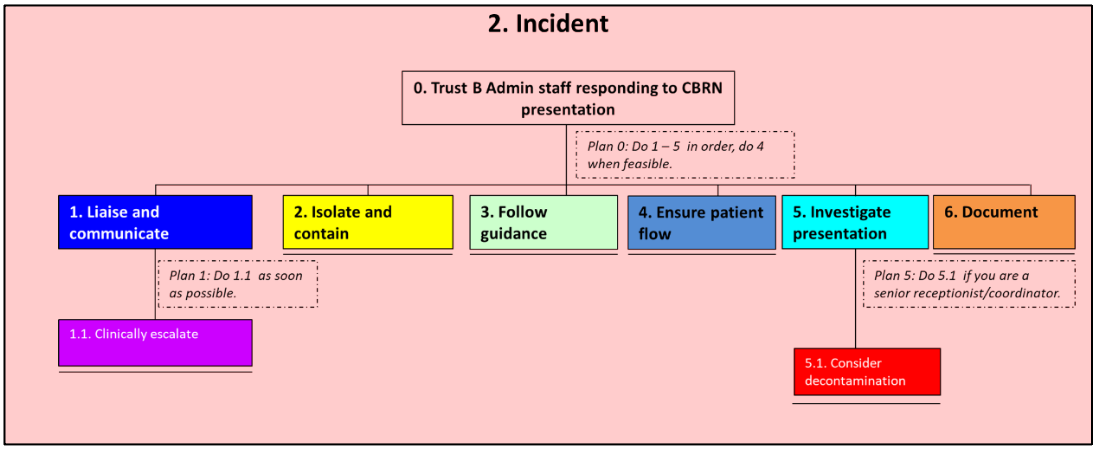


Figure 57: Trust B: Reception staff responding to a CBRN event

Comparing receptionists (Trust A, Figure 56, p. 187) and admin staff (Trust B, Figure 57) both included **isolate and contain** in their response to CBRN exposure as well as **clinical escalation**. These themes are therefore recommendations for actions in the receptionist responding to CBRN events.

Doctors in charge

The action card for the DIC at Trust A (Appendix 11, p. 310) and senior doctor* at Trust B (Appendix 12, p. 311) both consisted of a pre-incident, incident, and recovery phase. There was an overlap of themes between Trust A and Trust B action cards for doctors leading the CBRN event. This overlap was evident through themes such as **lead event, organisational escalation, teams,** and **manage staff.** There were also Trust specific themes in WAD representations identifying variability. For example, to **diagnose** was a part of Trust A action card but not Trust B. DICs at Trust A prioritised **isolate and contain, protect staff,** and **treat the patient** as shown in Figure 58:

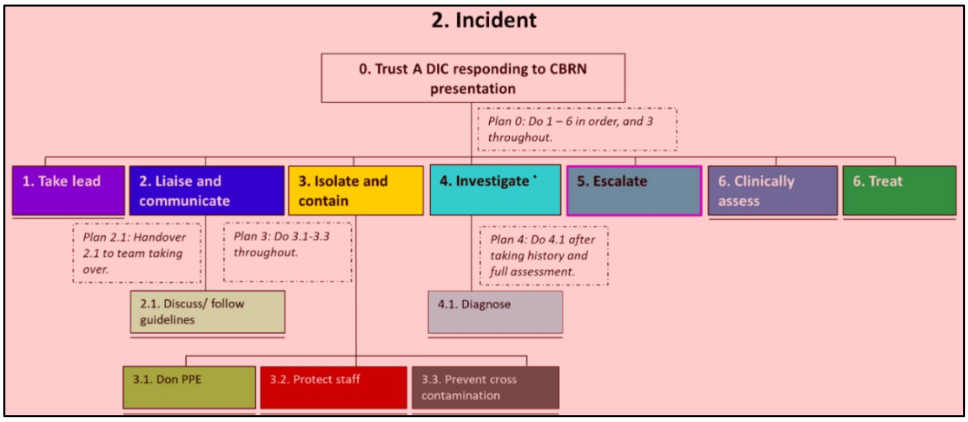


Figure 58: Trust A: Consultant response to CBRN event

When comparing WAI and WAD within Trust B the senior doctors discussed most of the themes set out by the action cards, apart from **PPE.** However, senior doctors at Trust B discussed additional actions that they would implement in response to a CBRN presentation such as **detect/identify agent, treat,** and **have knowledge of the incident** (Figure 51, p. 167).

Standardised recommendations (Chapter 7) from comparing WAI across Trusts would include DICs to implement pre-incident, incident, and recovery phases, as well as actions such as **lead event, escalate (organisational), teams, manage staff,** and **initiate decontamination**. WAD contributions to standardised CBRN process for DICs would include **liaise and communicate** and **treat.** This would result in a different HTA to the ones formed from WAI and WAD yet present a top down and bottom up informed CBRN response.

Nurses

A clear inter-Trust difference in WAI, was in the number of nurses allocated to specific roles within CBRN action cards. Trust A had seven allocated roles for nursing staff, whereas Trust B had three allocated roles. The first allocated nursing role was that of the decontamination nurse team leader which was to be fulfilled by a band 6 nurse at Trust A (Appendix 13, p. 312).

The Trust A decontamination team leader action card was different to that of the decontamination lead at Trust B (Appendix 14, p. 313), based on the existence of a recovery phase which emphasised the importance of **documentation**. Differences existed in Trust A action cards expecting **isolation and containment** and Trust B expecting a focus on adhering to **time** constraints resulting from the decontamination process.

There were two types of decontamination triage nurses at Trust A (Dry and wet, Vol 2: Appendix 26, p. 54-55) and one at Trust B (Vol 2: Appendix 33, p. 129). **Decontamination** was a common theme in both the pre-incident and incident phases for decontamination triage nurses at both Trusts. Although prioritising patients for decontamination was expected from this role, the criteria were either based on the mobility of the patient (Trust A) or on clinical assessments of symptoms (Trust B).

Common themes between the timing board nurse (Trust A, Appendix 15, p. 314) and board control operator (Appendix 16, p. 315) were evident through the emphasis placed on **timing** for efficient decontamination and the importance of **documentation**. Differing actions were associated with themes such as **PPE** (Trust A) and **check, manage,** and **protect** (Trust B).

The decontamination team leader action card at Trust A (Appendix 13, p. 312) was compared with the band 6 WAD HTA output (Figure 47, p. 163). WAD was initiated in the incident phase. There were two overlapping themes, **PPE** and **liaise and communicate**.

Band 6 nurses did not discuss **decontamination** which was crucial to triage/disrobing action cards. Rather they discussed **clinical and organisational escalation, investigation of the presentation and symptoms, diagnosis**, and the **treatment** of patients.

The nurse comparison for adherence amongst Trust B WAI and WAD consisted of the decontamination lead action card (Appendix 16, p. 315) and the collated band 6 WAD representations (Figure 59). There was a difference in the number of phases of the CBRN response. Overlapping themes consisted of actions associated **isolate and contain** and **escalate**.

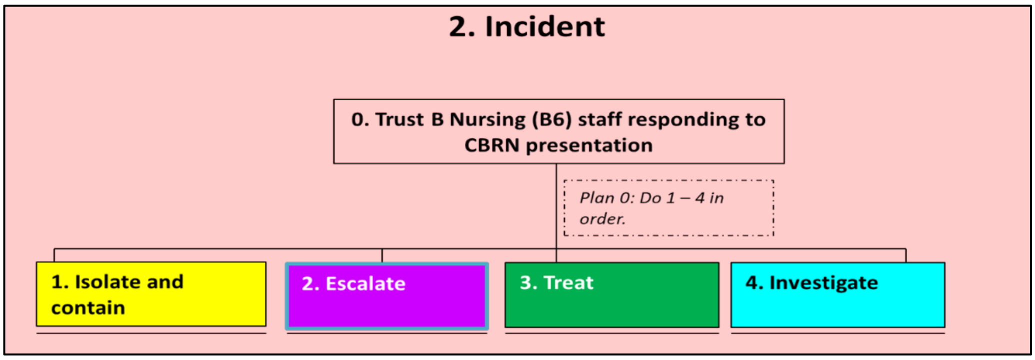


Figure 59: Trust B: Band 6 nurses responding to a CBRN event

When undertaking a comparison for the collated band 5 nurse first receivers (Figure 60, p. 191) and the board control operator (Appendix 16, p. 315) at Trust B. WAI was represented by two phases (pre-incident and incident) whereas WAD consisted only of the incident phase.

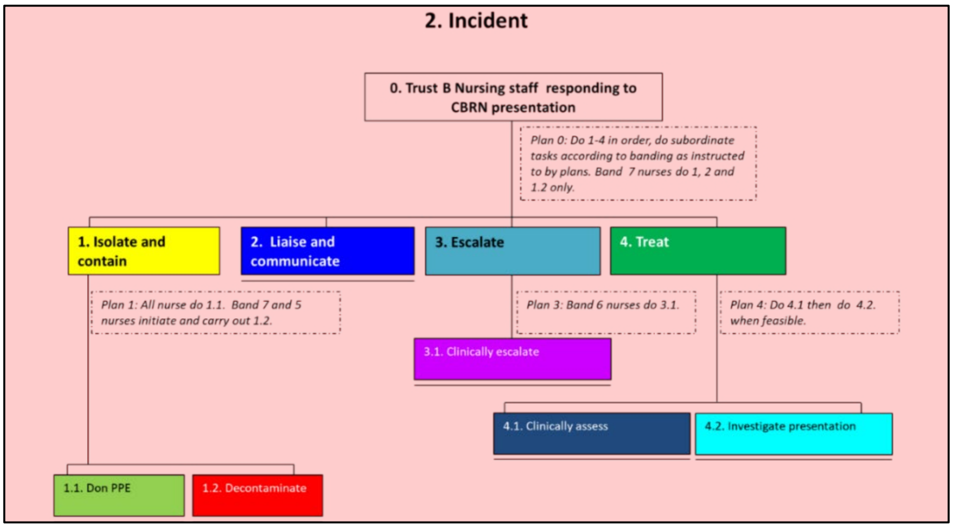


Figure 60: Trust B: Band 5 nurses responding to a CBRN event

Through comparing WAI and WAD across nurses and between Trusts, a differentiation between phases (pre-incident, incident, and recovery) is standardised. Through WAI analyses, **managing/taking lead,** to **liaise and communicate**, **documentation**, and **decontamination** are crucial CBRN response tasks to be standardised. Tasks such as **treat**, **escalation**, and **isolate and contain** are bottom up recommendations for standardising the ED CBRN response for nurse first receivers.

Security officers

Only Trust A had an action card (Appendix 17, p. 316) for the security officer allowing a comparison between WAI and WAD. The WAD security officer response for Trust A (Figure 61, p. 192) consisted of the incident phase, whereas WAI (Appendix 17, p. 316) consisted of three phases. Common actions consisted of themes such as **isolate and contain**.

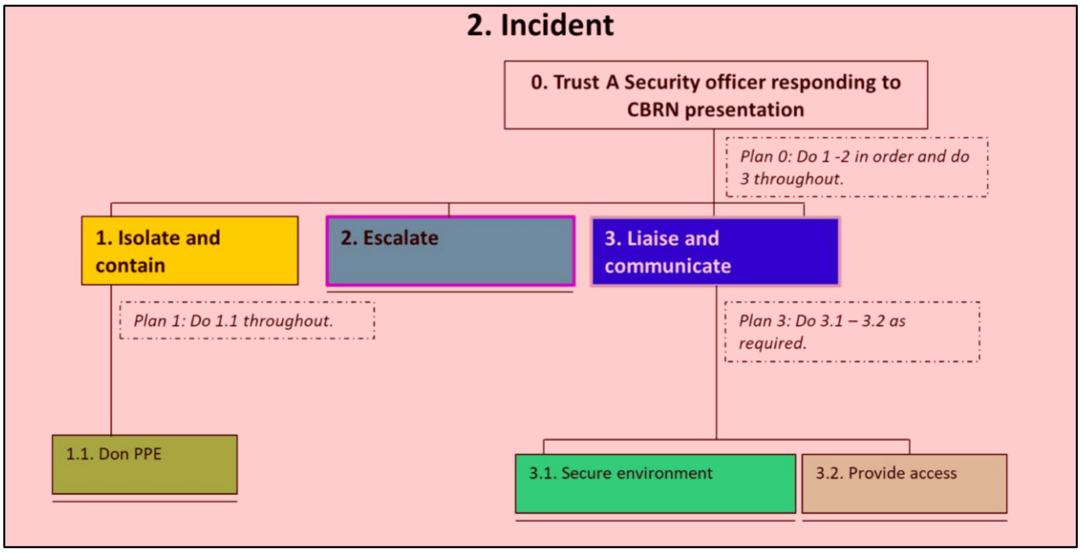


Figure 61: Trust A: Security officer response to CBRN event

Semi-structured interviews were carried out with Trust B security officers to identify their role in a CBRN event. Security officers at Trust A (Figure 61) implemented both **clinical and organisational escalation** in their response, whereas security officers at Trust B (Figure 62) implemented **organisational escalation** only. Additional differences between responses from security officers included Trust A security officers grouping their responses differently to Trust B, for example they would **secure the environment** and **provide access** via **liaise and communicate**.

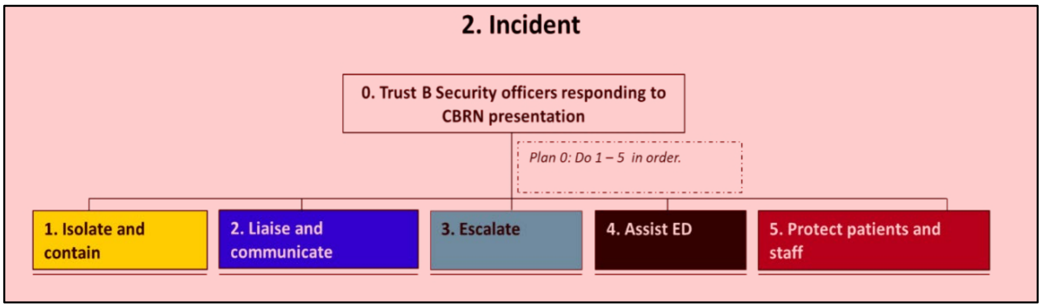


Figure 62: Trust B: Security officer response to CBRN event

Based on the comparison between WAD across Trusts in the security officer response to CBRN events, standardised recommendations would be based on the recognition of the three CBRN response phases (pre-incident, incident, and recovery). Actions such as **isolate and contain** and **liaise and communicate** are standardised recommendations (Chapter 7).

6.6.5.1 Summary

The ED response to CBRN events varied from both a top down perspective (WAI) and bottom up insight (WAD). WAD differed from WAI, more at Trust A than Trust B for two reasons.

1. Trust A had 8 additional WAD themes in comparison to 3 additional WAD themes at Trust B, demonstrating greater variability.
2. The additional themes at Trust A included the themes **patient awareness/sensitivity**, **provide access,** and **monitoring** which were not a part of GORs and action cards at Trust A.

The additional themes discussed by Trust B – **document**, **make decisions**, and **teams** were a part of WAI at Trust B, suggesting greater adherence to WAI by Trust B first receivers.

When comparing WAI and WAD based on job roles there was a difference between the three phases of the ED response to CBRN events in WAI. Most WAD responses across both Trusts consisted of one phase (incident), with a few first receivers proposing **isolate and contain** as a pre-incident phase to prevent cross contamination. A limiting difference was the difference in the number of first receivers allocated to specific CBRN roles as well as the lack of allocation of available first receivers (such as HCAs in the Trust B CBRN plan).

Actions such as **liaise and communicate** were core to first receiver responses across both Trusts; such actions were crucial for the implementation of WAI themes such as **take notification of casualties** and **escalation**, suggesting a systematic synergy between WAI and WAD overall.

6.7 Chapter summary

This chapter has reviewed WAI and WAD in the ED CBRN response and summarised 2 comparisons:

1. **WAI vs WAD within Trusts**

- WAI included actions associated with **documentation**, **advise**, **check**, **time**, and understanding the importance of **teams** at Trust A. These actions were not a part of WAD responses.

2. **WAI vs WAD between Trusts**

   - *Similarities*

- First receivers (WAD) prioritised patients' needs (treatment, diagnosis, and patient care) in comparison to WAI.
- Band 6 nurses (WAD) did not include decontamination in their CBRN response. Even though, leading the decontamination process was core to their role based on WAI.

   - *Differences*

- The majority of WAI action cards consisted of three phases at Trust A and two phases at Trust B.
- Trust B first receivers adhered more to WAI compared with Trust A first receivers.

6.8 Conclusion

WAI focuses on actions such as **documentation**, **checking**, **timing**, and **providing equipment** whereas WAD focuses on patients' needs. There is ambiguity on the allocation of first receivers during a CBRN event. There are voids in crucial practices such as **decontamination** across Trusts. WAD responses present a synergy for the implementation of WAI actions, prompting for the implementation of a standardised ED CBRN response. The aim of this chapter will inform standardised recommendations for the numerous levels of the ED response to CBRN events (Chapter 7).

Chapter 7. Discussion and recommendations

"CBRN events are probably more of a means of disorganisation and major terror than of mass destruction"

(Calamai et al., 2019, p. 2)

7.1 Introduction

This chapter discusses the key findings in the context of relevant literature and practical implications. The chapter begins with a summary of key results. The thesis focuses on a major emergency response - Chemical, Biological, Radiological, and Nuclear (CBRN) events, which allows a detailed review of activities by using the theoretical framework of Work as Imagined vs Work as Done (WAI vs WAD).

WAI vs WAD supports the clinical culture of reflective practice which is described as a way of professionals bridging the theory-practice gap (Schon, 1983). The gap is reduced by recognising the actual theory behind what practitioners do, rather than what they say they do, and is a way of improving practice (Fook, 2015).

The practical implications were explored by unpacking the complexity of the Emergency Department (ED) CBRN response by using a Human Factors and Ergonomics (HF/E) systems approach. The context of the ED, as a complex and unpredictable environment, is in direct contrast to the area of healthcare which has probably received the most HF/E attention, the operating theatre (Al-Hakim, Wang, Xiao, Gyomber, & Sengupta, 2019; Casali, Cullen, & Lock, 2019; O'Connor Papanikolaou, & Keogh, 2010). The use of systems mapping approaches in healthcare will be outlined to locate this research within the wider literature, complex systems, and multi-faceted processes, and discuss why Hierarchical Task Analysis (HTA) offers benefits compared with other HF/E systems mapping methods.

A systems-based approach was embedded throughout this research by combining WAI vs WAD and HTA. Overall, the results demonstrated the applicability, ease, and effectiveness of HTA in this time critical and complex healthcare environment. The comparison of WAI and WAD was an effective framework to identify gaps between policy and practice, for example:

- Top level CBRN response tasks, including differences between the 2 Trusts.
- Priorities for PPE, treatment, decontamination, and clinical investigation.

EDs are at the forefront of ever-changing healthcare systems. This combined with the variability in the ED response to CBRN events identified by this thesis, justifies the applicability and importance of the standardisation of the ED CBRN response process. Accordingly, recommendations for national standardisation in CBRN planning (including a CBRN framework), operational activities (action card), and ED team working (meso-system) are further provided.

7.2 Summary of key results

This thesis found that the ED response to CBRN events differed in Work as Imagined between both Trusts (Study 1). At Trust A, the action cards for first receivers were standardised to consist of: 1) Prepare to respond to CBRN incident, 2) Respond to CBRN incident, 3) Initiate recovery from CBRN incident, and 4) Document CBRN incident. At Trust B most first receiver action cards were standardised into 1) Prepare to respond to CBRN incident and 2) Respond to CBRN incident.

The synthesis of themes from the semi-structured interviews amongst 57 first receivers (Study 2) provided bottom up evidence of Work as Done during a CBRN event. There were differences across Trusts in the importance placed on the type of PPE, treatment, decontamination, and the investigation of the presentation.

This thesis confirmed alignment between WAI and WAD in the ED response to CBRN events. WAI and WAD consisted of actions such as isolation, escalation to senior first receivers, and activating the CBRN plan as being crucial. These actions aim to minimise the risk of secondary contamination; a known phenomenon in acute hospitals when responding to chemical events (Larson et al., 2016).

Misalignment between WAI and WAD was clear through a lack of emphasis on documentation, as shown in Study 2. This can be explained by the busy, interruptive, and multi-tasking nature of the ED, which has been reported to delay or divert from documenting efficiently (Sujan et al., 2014; Werner & Holden, 2015) as well as deviation from Standardised Operating Procedures (SOPs) (Jones et al., 2018).

WAI focussed on actions such as documentation, checking, timing, and providing equipment whereas WAD focuses on the patients' needs. A possible explanation in the difference in WAI and WAD in the ED response to CBRN events is through the Prioritisation of Tasks vs Prioritisation of Patients Needs dichotomy, which includes assessment, treatment, and diagnosis. Although priority is given to minimise the number of deaths, it is advised to prioritise decontamination procedures to reduce the casualties exposure to CBRN materials prior to clinical treatment (NATO Civil Emergency Planning Civil Protection Group, 2014).

CBRN guidance protects responders from contamination, however, by nature responders are known to help; as evidenced by the police officer contaminated in the Salisbury novichok incident (Clarke & Weir, 2019). This explains why first receivers in Study 2 prioritised the needs of patients rather than following guidance, such as keeping a paper trail of actions taken and prioritising isolation and decontamination to minimise contamination.

Study 1 confirmed that there is ambiguity on the allocation of first receivers during a CBRN event. Study 2 confirmed practices such as decontamination across Trusts were vital. The findings of this research lead to three key messages:

1. WAI vs WAD is a useful theoretical framework to unpack a complex socio-technical system.
2. HTA is an effective systems mapping tool in healthcare.
3. Standardisation is required to enhance the ED response to CBRN events.

7.3 Contributions of WAI vs WAD as a theoretical framework

WAI vs WAD was the theoretical framework used to compare how Work is Imagined as set out by CBRN plans to how Work is Done in response to the presentation of scenario cards. The WAI vs WAD framework is suggested to be effective to explain where and why contrasting views about how safety should be managed in healthcare organisations (Smith & Plunkett, 2019). This is because quite often, those who write plans are not involved in carrying out the plans in the environment they are written for, resulting in the differing management of safety.

The visual representations of work (HTAs) enabled an in-depth engagement by the participants, similar to a study carried out by Carvalho et al. (2018) who involved participants at all stages of the research, confirming the applicability and feeding back of WAI vs WAD as a means of reflective practice and improvement. For example, at Trust A, the CBRN lead amended the CBRN plan to include the Initial Operational Response (IOR) as a result of the verification of the HTA representation of the CBRN plan (Chapter 4). One participant at Trust A requested a copy of the HTA representation of her response:

> *"I quite like this (.) could we have it to put in our emergency plan cause it's a nice way of showing it"* (A029).

WAI vs WAD was used as an overarching framework for the thematic analysis implemented in both studies. Thematic analysis optimally contributed to incorporating the cultures of reflective practice, participatory design, as well as identifying and explaining gaps between policy and practice because it is *"A way of systematically observing a person, interaction, a group, a situation, an organisation, or a culture"* (Boyatzis, 1998, p. 5).

WAI vs WAD has been used as a framework to show how operational procedures (WAI) and clinical practice (WAD) were at odds by examining the extent and nature of adaptations during the blood transfusion process (Watt, Jun, & Waterson, 2019). WAI was formed with an intention to achieve alignment between demand and the capacity, whereas WAD faces misalignments between demand and capacity with adjustments to bridge the gap.

In this thesis, WAI as represented by General Organisational Responsibilities (GOR) and illustrated how the ED as a system worked, and when combined with HTA mapped out demand and capacity during a CBRN event. WAD (HTAs) illustrated adjustments to usual clinical practice by first receivers through incorporating CBRN actions such as isolate and contain and decontamination.

The WAI vs WAD paradigm was advantageous because it provided insight into multilevel processes (e.g. decontamination and IOR) as well as clinical decision making (e.g. triage and diagnoses). Chapter 6 identified that WAI was focused on actions, and WAD was focused on patients' needs. This finding confirms that current empirical approaches to decision making reflect clinical reasoning as Imagined whereas the application of naturalistic decision making reveals clinical reasoning as done, because complex contexts are accounted for (Catchpole & Alfred, 2018).

In the initial stages of the research, WAI vs WAD as proposed by Chuang and Hollnagel (2017) set the lens through which the research problem and research questions were to be addressed. The theoretical framework allowed a smooth comparison, synthesis, and a physical framework for the thesis. Simultaneous to the completion of this thesis, the WAI vs WAD domain evolved further to include a more detailed model of WAI vs WAD through *"The varieties of human work"* (Shorrock, 2016) Figure 63:

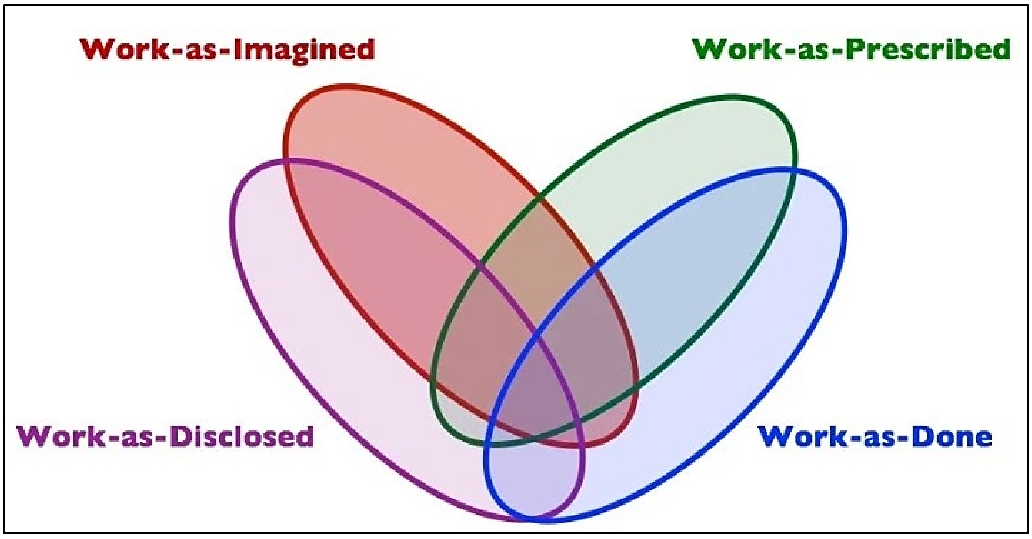


Figure 63: The varieties of human work (image courtesy of Shorrock, 2016)

The development of the framework was evident through:

- **Work as Imagined:** What workers believe that they might do in a scenario, which is usually different to what they would really do.
- **Work as Prescribed:** The specification of Work as Imagined, or Work as Done, or Work as Disclosed and exists as rules, regulations, checklists, and standards.
- **Work as Disclosed**: What workers say or write about work, or how they talk about work.
- **Work as Done**: Actual activity, to achieve a particular purpose in a particular context.

Future work is recommended in terms of *"Work as Disclosed"* and *"Work as Done"* in Chapter 8. Nonetheless, this thesis confirms that the WAI vs WAD framework remains the most apt to enhance and identify gaps between policy and practice in the ED response to CBRN events in line with Resilience Engineering (RE) (Chapter 1) which aims to devise ways to keep WAI and WAD aligned (Hollnagel, 2015).

7.4 HTA as a systems mapping tool in healthcare

The adaptability and effectiveness of HTA as a systems mapping tool is discussed in the context of healthcare as a complex, dynamic, and interdependent system based on patient variability and multiple care interactions (Vosper, Hignett, & Bowie, 2018). HTA was chosen because it is a flexible technique which can be used to describe any system (Kirwan & Ainsworth, 1992). HTA was used as a single method because the baseline method had to be rigorous yet quick, reflecting the nature of the care processes in the ED.

7.4.1 Systems thinking

Patient safety has been proposed as an emergent property in the systems approach (Chapter 1). Additionally, developing a good systems understanding of the workings of care processes is crucial in improving the quality of the care provided (Jun, Ward, Morris, & Clarkson, 2009). Unfortunately, a systems understanding within healthcare is lacking (Clarkson et al., 2004) and safety is considered a relatively new field in healthcare (Sujan, Embrey, & Huang, 2018).

Patient safety initiatives based on adopting a systems understanding however, are emerging. The patient safety strategy (NHS Improvement, 2019) suggests that the implementation of a patient safety system is fundamental to achieving optimal patient safety within the NHS through understanding the importance of HF/E within healthcare. This thesis is an example of forming a patient safety system by using the ED response to CBRN events as an example.

There is greater demand to adopt a systems approach in national healthcare guidelines, as a means of providing both a systematic and sustainable framework to enhancing patient safety (Pickup, Lang, Sharples, & Atkinson, 2018). Four levels of change have been suggested by Ferlie & Shortell (2001) to implement healthcare organisation improvement:

1. The individual.

2. The group or team.
3. The overall organisation.
4. The larger system or environment in which the individual or organisations are embedded.

Healthcare organisations are described as conglomerates of smaller systems (Mohr, Batalden, & Barach, 2004). A clinical micro-systems approach is associated with healthcare improvement, which effectively provides a conceptual and practical framework for thinking about the organisation and delivery of care (Mohr et al., 2003). By adopting a clinical micro-systems approach staff feel motivated to become involved in service improvement activities (Williams, Dickinson, Robinson, & Allen, 2009), suggesting that a systems understanding is key to achieving bottom up service improvement.

A multi-level approach is beneficial in healthcare improvement (Gerrish, Keen, & Palfreyman, 2018). For example, the tiered huddle system which adopted micro, meso, and macro-level interventions, resulted in improving the efficiency of information sharing among staff, enhancing their sense of accountability as well as empowering staff (Goldenhar, Brady, Sutcliffe, & Muething, 2013). Based on the effectiveness of adopting a multi-level approach, the ED response to CBRN events was broken down into systems as illustrated in Figure 64:

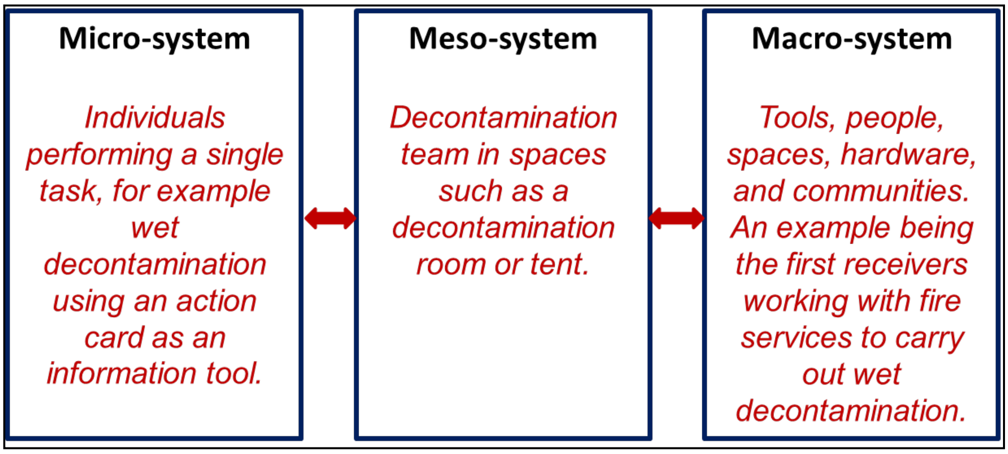


Figure 64: Systems in the ED response to CBRN events

A systems approach was embedded through HTA and WAI vs WAD in three ways (Figure 65):

1. System performance was unpacked.
2. System performance was potentially improved through the synthesis of acquired data to standardise the CBRN response process which are recommended to be implemented in future CBRN policy and practice (Chapter 8).
3. The challenge of variability in healthcare was overcome through the justification of standardisation and adherence through the encouragement of clinical judgment and discretion.

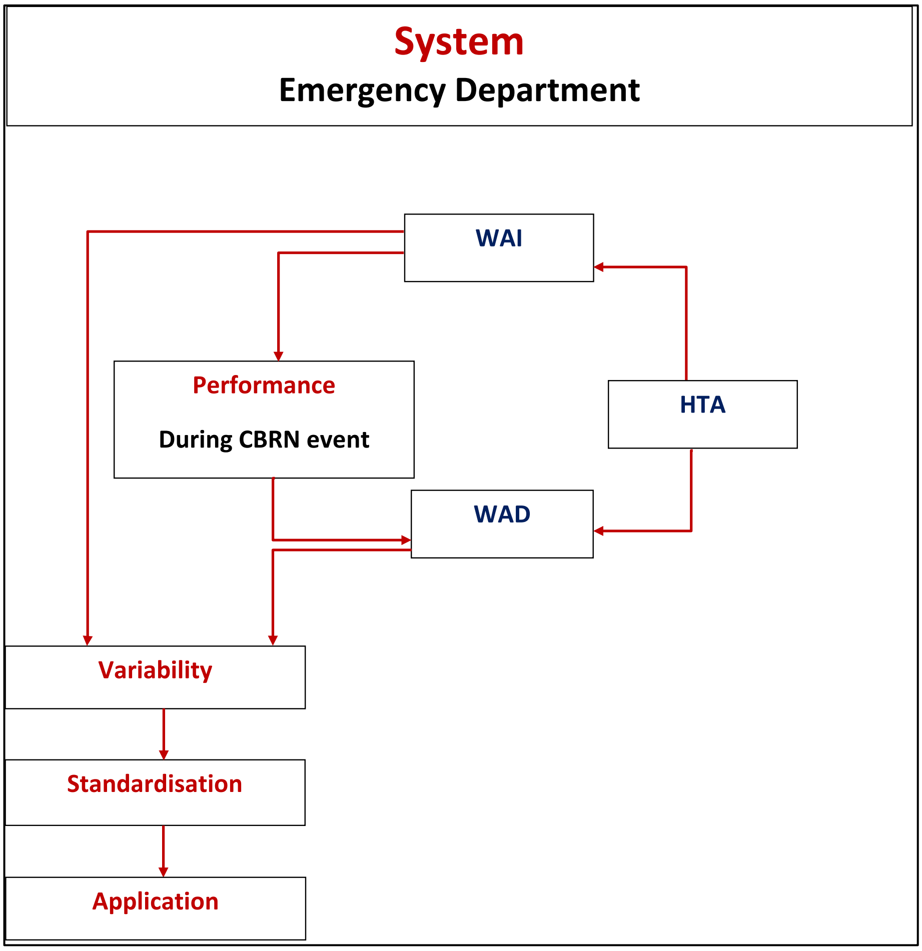


Figure 65: The use of HTA as an effective systems mapping tool in the ED response to CBRN events

HTA was used to address the research questions of the thesis because it:

1. Allowed multiple level comparisons through colour coding.
2. Showed greater usability in comparison to other HF/E methods to unpack a complex system and multifaceted process.

3. Was applied to a large-scale analysis: The ED response to CBRN events.

7.4.2 Multiple level comparisons

HTA allows for many other forms of analyses to be conducted once the sub goal hierarchy is defined (Stanton, 2006). HTA was used on various levels whilst simultaneously combining multiple analyses (Figure 66, p. 204) to provide a comprehensive breakdown of the ED response to CBRN events through:

1. Document analysis to create a visual representation of CBRN WAI (Chapter 4).
2. Semi-structured interviews in which data could be collected from first receivers in the ED to represent WAD (Chapter 5).
3. The conversion of CBRN plans and field notes provided systematic visual representations to allow parallel comparisons between WAI and WAD (Chapter 6).

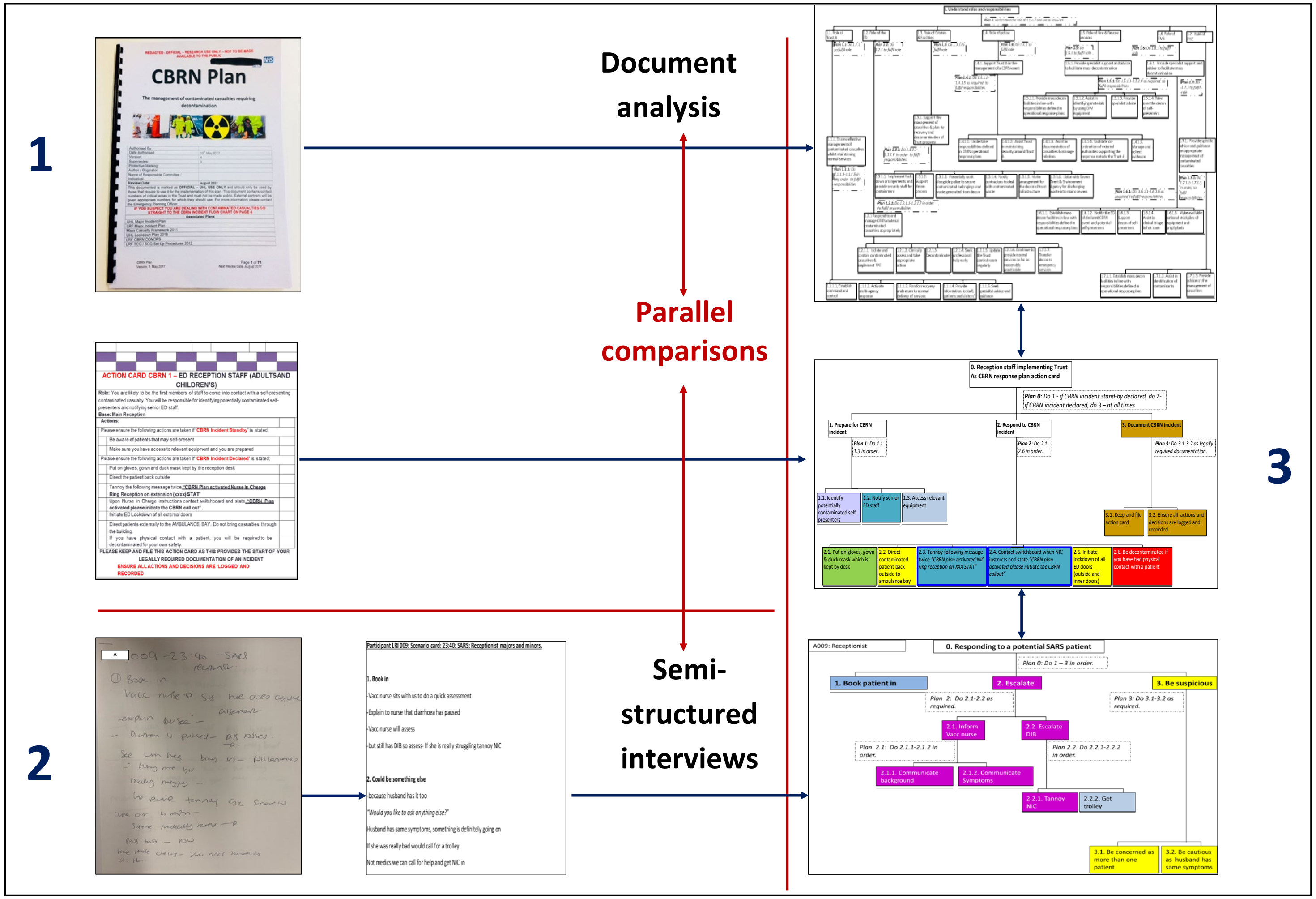


Figure 66: Multi-level use of HTA

Most HF/E methods are not designed specifically for use in healthcare systems and have traditionally been used to examine incidents in high reliability organisations such as aviation and the nuclear industry (Watt, Jun, & Waterson, 2017). This thesis evidences that HTA may provide a consistent methodological framework to make comparisons (Figure 67, p. 207). It also provides an effective structure for complex macro (GOR HTAs) and micro-level (action cards and first receiver HTA) comparisons – representing policy and practice amongst first receivers.

Discrepancies were evident both within and between Trusts. For example, band 6 nurses did not discuss decontamination in their response, yet it was a critical task on the action cards. This finding is likely a result of seniority being associated with certain tasks in the ED in response to clinically urgent presentations. It has been reported that senior nurses are able to recognise acutely ill (septic) patients and provide treatment sooner than juniors (Harley et al., 2019) in line with the finding that band 6 nurses prioritise tasks such as investigate, treat, escalate, and diagnose rather than decontamination.

HTA is a versatile method which allows comparisons on numerous levels, as was demonstrated by Hignett et al. (2019c), in which two HTAs were integrated 1) Macro: complex pre-hospital CBRN field exercise 2) Micro: medical device (Breath analyser). The HTAs were formed to understand the usability and potential integration of the device. This study introduced the concept of *"Plug and play"* in which new medical devices can be *"Plugged"* into a new and complex (macro) system.

Although this thesis has not focused on medical devices, the micro-systems (Figure 67, p. 207) were effectively compared through *"Plugging"* them into already established (and reviewed) macro-system HTAs (Study 1). The process of *"Plugging"* was extended in this research. It was used in:

- **A macro vs micro integration:** GOR HTA vs action cards HTA.
- **A macro vs macro integration:** GOR HTA vs standardised CBRN response superordinate task HTAs.
- **A micro vs micro integration:** Action card HTA vs first receiver response HTA.

Interactions between macro (organisation) and micro (individuals) were crucial to identify discrepancies between WAI and WAD. AcciMaps (Chapter 3) have been suggested to provide a good approach to understanding interactions within multiple socio-technical systems (Salmon, Cornelissen, & Trotter, 2012). Hancox et al. (2016) aimed to develop a socio-technical map of Concept of Operations (ConsOps: a document which describes the characteristics of a system to be developed from the viewpoint of its future user (Korfiatis, Cloutier, & Zigh, 2012)) as a potential platform for technologies used in multi-services emergency responses to CBRN events. They identified essential (harmonised) themes through a modified AcciMap method for key themes of communication, planning, action, and reflection. This thesis similarly found harmonised (common) themes, in Study 1 (Chapter 4) which existed in WAI on a macro (GOR) and micro (action card) level across both Trusts.

Study 2 (Chapter 5) reported key tasks that first receivers would carry out in response to a CBRN event in the ED across Trusts such as isolate and contain, liaise and communicate, and escalate. It is suggested that HTA provided a consistent and coherent framework to give a more detailed level of analysis than AcciMaps, by making a systematic comparison of multiple socio-technical systems (Trust A and Trust B: Chapter 6). Figure 67 (p. 207) shows the multi-level analysis within and across socio-technical systems, supporting this as the method of choice compared to AcciMaps.

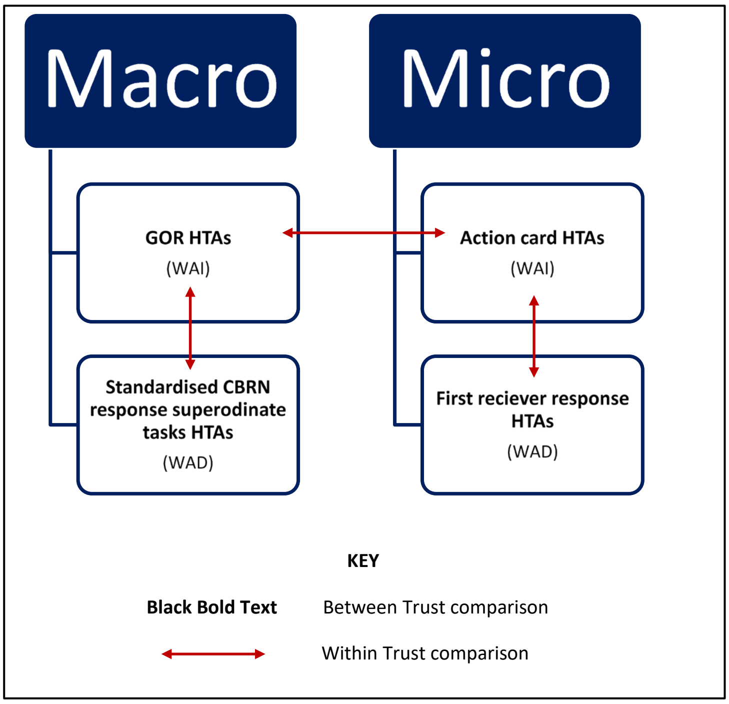


Figure 67: Multiple level analyses, interpretation, and comparison through HTA

The importance of documentation was stressed on both a macro and micro level through GORs and action card HTAs. There was a void between WAI and WAD with regards to documentation. The lack of emphasis on documentation in WAD (Study 2) is a result of the interruptive and multi-tasking nature of the ED which has been reported to delay or divert from documenting efficiently (Werner & Holden, 2015). Comprehensive documentation requires time, which is not conductive to complex and busy work environments (Sujan et al., 2014). In their study using Failure Modes and Effects Analysis (FMEA) to provide a systematic description of risks associated with failures of clinical handover within the emergency care pathway Sujan et al. (2014) found an organisational (WAI) push to document for legal and quality assurance purposes, resulting in unreliable documentation based on its variability due to time restrictions.

This thesis compared operating procedures (CBRN plans) with practice (scenario card response) in the work environment. Similarly, Allitt et al. (2017) used HTA to evaluate and identify causes of errors in medicine management by comparing practice against Standard Operating Procedures (SOPs). Comparisons were made between facilities and against SOPs as well as the HTA representations being reviewed with senior managers, pharmacists, and the Medicines Management Group.

HTA is potentially an effective tool for comparing multilevel processes. This thesis has ensured consistency of comparison by using Type 1 EDs, unlike Allitt et al. (2017) who carried out their study in two different settings - Site 1 was a community hospital which provided in-patient care and had an in-house pharmacy. Site 2 provided in-patient care as intermediate care with medication managed by nurses with the assistance of GPs and an independent pharmacy. Although differences between policy and practice were identified by Allitt et al. (2017), the generalisability of the findings is questionable compared to this thesis.

HTA was used as a framework for standardising care provided during CBRN events by unpacking macro and micro interactions in the ED. Similarly, Hignett et al. (2019a) used WAI and HTA to standardise care provided in labour and childbirth. However, the aim of standardisation was limited to standardising WAI only, limiting the applicability of the findings to actual practice during labour and childbirth. This thesis goes beyond by contributing to policy (WAI) and practice (WAD) with the standardised recommendations intended to enhance practice during CBRN events.

Macro and micro level thinking was adopted to test the usability of CBRN plans (Study 1) by comparing first receiver responses to scenario cards (Study 2). This conformed to research carried out by Gurses et al. (2019) who suggested that HF/E methods could be integrated into guideline development as well as be useful in testing the usability of newly developed guidelines. They assessed the safety risks associated with doffing PPE for Ebola exposure through the triangulation of three methods:

1. HTA of PPE doffing method.
2. Human Factors informed Failure Modes and Effects Analysis.
3. Focus group sessions with infection prevention experts.

The HTAs were used to facilitate discussions in focus groups which consisted of 8 infection prevention experts (doctors and a nurse). Contributing factors related to the individual, task, tools/technology, environment, and organisational aspects of doffing PPE, confirming the findings of the three levels of response planning and preparation reported in the systematic review of this thesis.

7.4.2.1 Colour coding

Multiple analyses were possible by combining HTA representations of WAI and WAD, with colour coding through thematic analysis. Themes were given specific colours to allow a detailed mapping of the CBRN process. Colour coding has previously been combined with HTAs for highlighting various aspects in a HTA.

Embrey et al. (2009) implemented colour coding to highlight initial tasks and plans for predicting and preventing human errors in safety critical plant operations. Whereas Sutherland, Ashcroft, and Phipps (2019) used colour coding to identify actions involved in prescribing drugs in the complex Paediatric Intensive Care Unit (PICU). Colour coding in these studies was combined with HTA for descriptive purposes to show different tasks. The colour coding of HTAs in this thesis was used differently as a means of comparison and rigorous analyses of processes. For Study 1 (Chapter 4), the conversion of the GOR section of the CBRN plans into HTAs resulted in large HTA representations; this was problematic when reporting the results holistically. Colour coding and extracting specific sections of the HTA, resulted in effective reporting of the results. Furthermore, comparative colour coding was an efficient method for highlighting different phases of the ED CBRN response (Chapter 6). Colour coding was used on multiple levels to show macro and micro-level variability, adherence, and potential for standardisation, being a unique contribution to enhance the usability of HTA as a systems mapping tool in healthcare.

7.4.3 Usability of HTA in comparison to alternate HF/E methods

The implementation of methods associated with complex and complicated systems provide a framework to model complex work systems (Chapter 3). The ED is a complex socio-technical system, other HF/E methods have been used (with and without HTA) in operating theatres (Alm & Woltjer, 2010: Functional Resonance Accident Model), neonatal units (Brannon, 2006: Cognitive Task Analysis; Yamada, Catchpole, & Salas, 2019), Intensive Care Units (ICU), and in primary care (Bowie & Jeffcott, 2016; Pickup et al., 2018: Abstraction Hierachy/Work Domain analysis). Although other HF/E methods are appropriate for complex settings, their application may be less suited to the ED due to the unpredictability of patient presentations in the ED.

Like the ED, the ICU is described as a complex socio-technical system which is prone to interruptions (Drews, Markewitz, Stoddard, & Samore, 2019). In this thesis, HTA was advantageous because it provided a quick insight into how first receivers thought tasks should be carried out during a CBRN event. This insight links HTA to Verbal Protocol Analysis (VPA), which was used and showed that experienced nurses provided greater insights into clinical decision making when caring for post-operative patients in the ICU (Hoffman, Aitken, & Duffield, 2009). Although VPA was an ideal method to collect data, it was not a suitable method for the ED because of the controlled environment in ICU in comparison to the ED. In ICU patient presentations are elective and expected, one-to-one patient care is the norm (one nurse is allocated to one patient), giving the researcher access to one nurse for an extended period, allowing the researcher time to record the care process. In the ED, there is a quicker patient turn over, and ED first receivers tend to talk to the patients (in most cases), limiting their ability to think aloud whilst providing care, making VPA an unsuitable method of enquiry for this thesis.

Study 2 identified common themes such as capacity and patient flow between both Trusts. FMEA has been used as a practical tool to identify and evaluate risk factors and propose actions to eliminate risk involved in care processes in the ICU (Askari, Shafii, Rafiei, Abolhassani, & Salarikhah, 2017; Faye et al., 2010). However one of the issues with this method is that it is reported to be time consuming and resource intensive (Bevilacqua, Mazzuto, & Paciarotti, 2015; Wetterneck, Hundt, & Carayon, 2009).

Sutherland et al. (2019) combined HTA with Systemic Human Error Reduction and Prediction Approach (SHERPA) to enhance the care provided to patients in the complex PICU environment whilst highlighting multifactorial and contextual factors associated with prescribing errors. The method implemented by Sutherland et al. (2019) was based on HF/E principles, in which HTAs and interview data were combined with SHERPA - comparative to chapter 6 in terms of the level of analyses carried out. A key difference is that it aimed to identify error, making SHERPA the optimal tool to do this, whereas this thesis aimed to explore whether HTA was a suitable method to unpack complex socio-technical systems (Chapter 1).

CBRN events are multi-faceted emergencies which could result in an influx of casualties to arrive in the ED. Responding to a CBRN event presents major challenges to first receivers. This thesis found that responding to CBRN events was a process, which consists of phases such as prepare, respond, and recovery.

HTA has been used as an effective method to map out complex surgical procedures (Catchpole et al., 2016; Menozzi et al., 2019). Similar to this thesis, a triangulation of methods such as a literature review, observation of Functional Endoscopic Sinus Surgery (FESS) to form HTA representations of the process, and interviews with surgeons to input on the FESS technique HTA was carried out by Corbett et al. (2019); who then applied SHERPA to the HTA representation to identify errors, their frequency, severity, and potential reduction of occurrence. The researchers concluded that the combination of HTA and SHERPA was effective to standardise and optimise clinical practice during the FESS procedure. HTA was not combined with another method (such as SHERPA), in this thesis but was triangulated with thematic analysis to provide rich insights into the numerous simultaneous (multi-faceted) processes which occur during a CBRN event.

HTA was effective in mapping out the interactions between the ED environment whilst responding to a CBRN event. This was evidenced in Study 1 in which the Command and Control centre was established as a part of GOR, and in Study 2 in which the hospital would be locked down. Interrelationships between the unpredictable ED environment as well as external (interagency coordination) and internal (medical specialities/departments) (Chapter 4) were mapped out. Similarly, HTA was used to address interrelationships between (ergonomic) features of the operating environment, as well as internal and external disruptive factors (Al-Hakim et al., 2019). The idea set out by Al-Hakim was that the tasks and skill set of the surgical team could not be changed during surgery, however the environment could. In this thesis the environment was adaptive to a CBRN event, the skill set of first receivers when responding to a CBRN event could not be changed, however, the unpacking of the CBRN response through HTA resulted in identifying discrepancies which informed standardised recommendations.

HTAs of the CBRN response (macro and meso) were represented by superordinate tasks (Study 1 and Study 2). Additionally, comparisons were made by categorising superordinate tasks to prepare, respond, and recover phases in Chapter 6. HTA has similarly been used to apply phases to rotator cuff surgery (Demirel et al., 2016)**.** Rotator cuff surgery was categorised into pre-procedure, start examination, and start repair procedure phases. The HTA provided an effective grading metric for the use in the forthcoming Virtual Reality (VR) simulator; demonstrating that HTA can be used as an effective method to highlight variability. Variability in time was informative of the skill level of the surgeon, whereas variability in this thesis highlighted non-adherence to operational procedures, such as lack of documentation amongst first receivers (Chapter 6) or differences in responding to a CBRN event, for example differences in the importance placed on type of PPE (Study 2).

The use of HTA has provided a complete systems perspective through a top down and bottom up approach to complex processes. Whereas Corbett et al. (2019) used HTA through a bottom up approach only, because the HTA representations were formed through observations and were participant driven. The research in this thesis differs in two ways. Firstly, the outlined research (Al-Hakim et al., 2019; Corbett et al., 2019; Demirel et al., 2016) is carried out in operating theatres; although a highly pressured environment, it differs from the ED environment in terms of predictability, team structure and roles, and patient presentations. Secondly, the research logic of the papers can be questioned, in terms of whether a complete systems representation is being presented.

It is evident that HTA can be applied in different healthcare settings to understand processes and be combined with other methods (e.g. SHERPA). The ED is a uniquely unpredictable complex environment and CBRN events are a rare and real threat, with the potential for detrimental outcomes if not responded to adequately. For clarity in such a complex environment HTA was used as a single HF/E method for simplicity and detail.

7.5 HTA and the CBRN response

It was found that responding to a CBRN event consisted of stages both from a WAI and WAD perspective. This finding is in line with Baber et al. (as cited in Stanton, 2006), who used HTA to analyse emergency services responses to a farm based hazardous chemical incident. Their HTA had four main superordinate tasks, 1) Receive notification of the incident, 2) Gather information about the incident 3) Deal with the incident, and 4) Resolve incident.

The stages are similar to the findings of study 1 in which Trust A action cards consisted of three superordinate tasks 1) Prepare for CBRN incident, 2) Respond to CBRN incident, and 3) Document CBRN incident. Most of Trust B action cards consisted of 2 superordinate tasks 1) Prepare to respond to CBRN incident, and 2) Respond to CBRN incident. The superordinate tasks reported by Baber et al. (as cited in Stanton, 2006) can be aligned with the phases of the CBRN response (pre-incident, incident, and recovery) as identified in Chapter 6.

Baber et al. (as cited in Stanton, 2006) reported the response as a teamwork task, and the HTA effectively represented the interactions between the hospital, police, and fire services. Such interactions also formed the basis of the GOR macro HTA in study 1 (Chapter 4). Interactions between internal organisations (e.g. Control and Command Centre and medical specialities) and external organisations (e.g. fire, ambulance, and police) were represented. This thesis classified the types of interactions, liaising was with external organisations and communication was with individuals (Study 2) exemplifying a deeper level of analysis in comparison to Baber et al. (as cited in Stanton, 2006).

The superordinate tasks, compatibility of response phases, and interactions outlined by Baber et al. (as cited in Stanton, 2006), were similar to this thesis because such factors are a result of the task being analysed. HTA however, was used differently because it was used as a retrospective analysis of an event by Baber et al. (as cited in Stanton, 2006). In this thesis HTA was used as a multi-level analysis, which went a step further by comparing WAI vs WAD to enhance practice in prospective CBRN events.

7.6 The standardisation of the ED response to CBRN events

The themes from the systematic review of the state of science (Chapter 2) identified four themes: preparedness, response, decontamination, and PPE problems. These were used as the framework for the empirical data collection in Chapters 4 and 5. The findings from the systematic review and studies were synthesised to fulfil the second aim, which was to propose recommendations for the ED response to CBRN events. Four evidenced based recommendations resulted:

1. Standardised CBRN checklist (systematic review).
2. Standardised action card template.
3. Example of a standardised ED response meso-systems.
4. Standardised CBRN Framework.

It is suggested that standardisation can reduce the reliance on team experience to ensure safe and effective practice, particularly in non-routine work situations (Künzle, Zala-Mezö, Kolbe, Wacker, & Grote, 2010). CBRN events are non-routine work situations, accordingly standardised recommendations as illustrated in Figure 68 (p. 214) fulfil the second aim of this thesis (Section 1.4, p. 21).

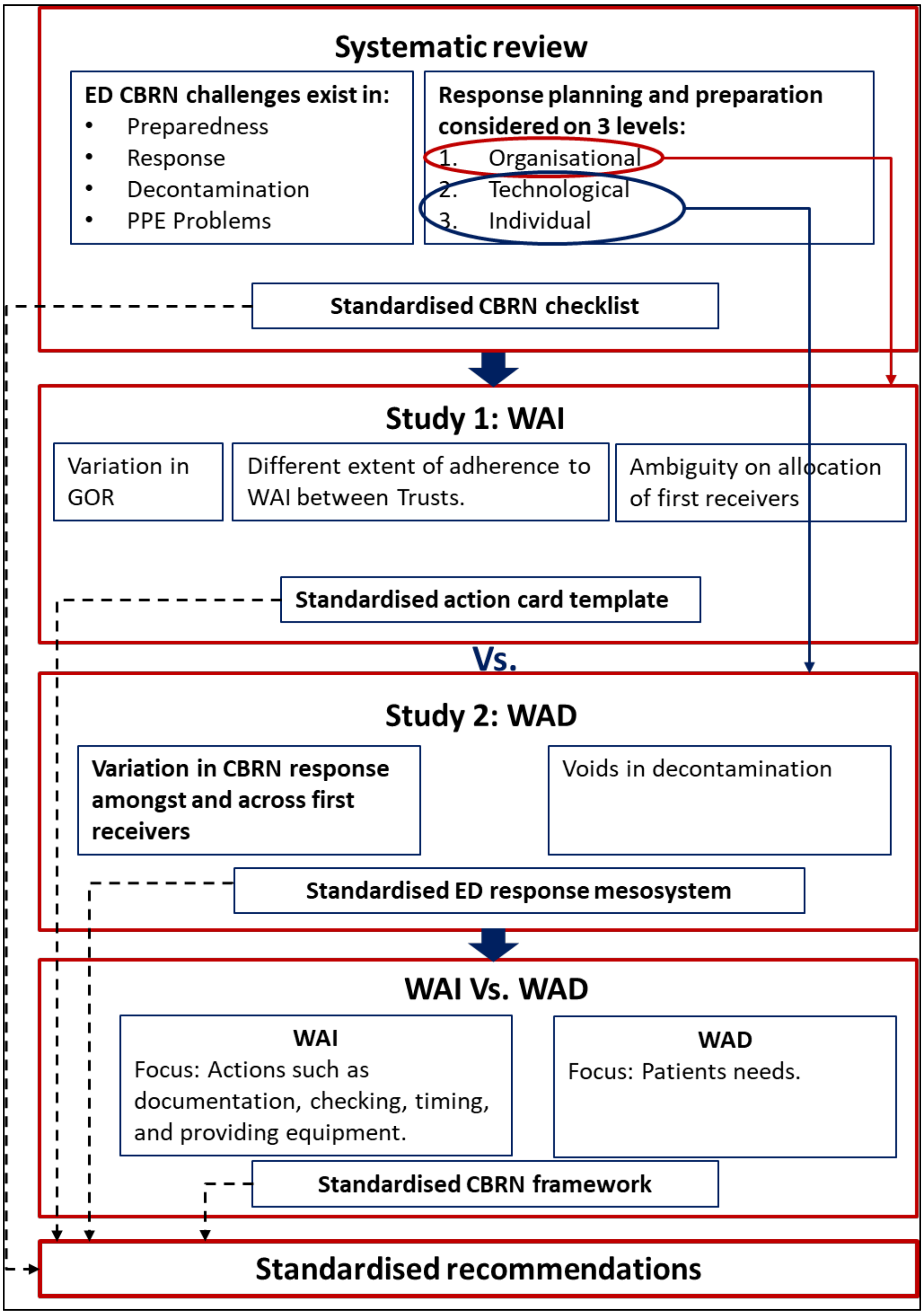


Figure 68: Key findings as evidence for standardised recommendations

Linney et al. (2011) reported that there is a lack of standardisation with regards to NHS emergency planning, and there is an urgent need to standardise national planning, training, and evaluation of NHS staff who are expected to respond to CBRN events.

A challenge to an effective CBRN response, is the existence of a vast number of procedures and guidelines to be followed in healthcare. Guidance is often followed inconsistently resulting in non-compliance. HF/E science should be applied to the development, design, and testing of policies, and guidelines (Carthey et al., 2011). The involvement of healthcare staff who have to follow policy in the development phase is suggested to ensure usability in practice. Accordingly, a top down (plan based) and bottom up (first receiver response) approach was combined to formulate recommendations which can be used to enhance patient safety in the ED CBRN response.

Adopting a multi-level systems approach implements the Care Quality Commission (CQC) recommendation for standardisation. Similar to other safety critical industries which have aspired to involve frontline staff to adapt guidance, participate in discussions, as well as provide feedback on areas of improvement (CQC, 2018b).

Contrary to the reporting of the systematic review, findings from this thesis suggest that both Trusts were prepared to respond to CBRN events. This was confirmed through meetings with the CBRN leads as well as having established CBRN plans which were in adherence to legislative practice (Cabinet Office & The Civil Contingencies Act, 2004).

In line with the findings of the systematic review, preparedness through the CBRN plans was divided into two domains (Mitchell et al., 2012) the departmental General Organisational Responsibilities (GORs) and individual domains (action cards). Preparedness was described as three intertwining levels 1) Organisational (providing high standard care), 2) Technological (decontamination), and 3) Individual (willingness to respond), which form the evidence base for the CBRN planning checklist (Figure 7, p. 53).

Checklists have been suggested to impact and improve patient safety in a variety of healthcare settings by strengthening compliance to guidelines, reducing the incidence of adverse events, as well as decreasing mortality and morbidity (Thomassen et al., 2014). Checklists have been reported to improve performance under pressure, reduce stress before carrying out high risk procedures, improve teamwork, and enhance the provision of patient care in emergency medicine settings (Hearns, 2018).

A prime example of an effective checklist is that of the World Health Organisations (WHO) Safe Surgery Checklist (WHO, 2008) to reduce the number of surgical deaths across the world. The checklist addresses crucial safety issues such as anaesthetic safety practices. Haynes et al. (2009) reported improvements in surgical outcomes across 8 diverse hospitals. Postoperative complication rates reduced by 36% on average, as well as the death rates during surgery being reduced from 1.5% to 0.8%; in this international study the impact on the reduction in death rates was predominantly seen in developing countries. A reason for this is that developed countries might already have a lower perioperative mortality rate as reported by Vats et al. (2010). However, more recently developed countries also report a reduction in peri-operative mortality associated with the implementation of the WHO safe surgery checklist (Ramsay et al., 2019) exemplifying the positive impacts of the Safe Surgery Checklist on patient safety.

Although there is evidence of the use of checklists in healthcare, in order to work effectively attention must be paid to the design, understanding of team culture, the environment, and basic skills needed to carry out the task. Bosk et al. (2009) suggest that even when checklists are embedded in rigorous evidence, their impact can be questioned on social and cultural grounds. Clinicians may feel that checklists undermine their claim to expertise and present an unnecessary obstacles to swift decision making and action required for effective care – emphasising the assumption that checklists are a technical solution to solve an adaptive sociocultural problem. Although embedded in rigorous evidence, the CBRN planning checklist (Figure 7, p. 53) overcomes socio-cultural and technical criticisms. Technical underpinnings are included in the checklist. Social criticisms in terms of undermining clinicians are accounted for by being an evaluative tool in planning response for CBRN events.

The formation of checklists has a profound influence on checklist effectiveness because checklists have been described as complex socio-technical intervention (Catchpole & Russ, 2015; Gordon, Mendenhall, & O’Connor, 2013). Barriers such as the timing of when checks were carried out presented in the effective implementation of the WHO Surgical Safety (Vats et al., 2010), for example checking patients wristbands after the patient is draped for surgery. Such barriers can be overcome by implementing a participatory design approach when designing checklists. Participatory design involves front-line groups with the greatest subject matter expertise in a codesign process. In this way they can inform design issues so the outcome meets their needs and usability concerns are addressed iteratively prior to implementation as exemplified by Bowie et al. (2015) when designing a safety checklist for General Practice.

Criticisms associated with the effectiveness of checklists in healthcare exist. On a contextual level, healthcare seeks to embed the relevance of HF/E safety improvement as realised and implemented by the aviation industry through Human Factors Training (Reason, 1997). Safety is crucial in both industries; however, it could be considered overly enthusiastic to think that healthcare systems reflect the amount of planning, order, and level of certainty experienced by aviation systems. Although healthcare shares a safety improvement enthusiasm with aviation, the achievement of safety improvement in aviation is a result of a systematic approach to safety, which is embedded on a top level organisational basis as well on operational and individual levels (Toff, 2010); this is gradually being matched by initiatives such as NHS The Patient Safety strategy (NHS Improvement, 2019).

Although both healthcare and aviation are safety critical industries, it is suggested that when ideas are translated from one industry to another, the original underlying concepts may be lost or diluted (Catchpole & Russ, 2015). Although safety remains the underlying principle, it must be emphasised that checklists are suited to specific tasks, are not a *"one size fits all"* and must be customised to local contexts and practices to avoid diluting their effectiveness (Oppikofer & Schwappach, 2017). For example, in aviation checklists are effective in the take-off and landing of aircraft; but are not as effective in baggage handling, which consists of complex transfers, is unexpected, and is often in poor conditions presenting a realistic analogy for achieving patient safety in healthcare (Bosk et al, 2009).

The success of safety checklists in aviation dates back to 1935 (Lee et al., 2012), giving aviation a time advantage. Comparing the effectiveness of safety checklists in aviation to healthcare presents a challenge based on qualitative differences. Differences include, a greater number of tasks, signatures and tick-box requirements, and discussions, which form a large part of healthcare checklists (Catchpole & Russ, 2015). Additionally, the functions checklists perform in each industry are different. Aviation checklists are designed for modern aircraft that are complicated and not complex like healthcare. In healthcare, checklists have been recommended to be used when aiming to standardise performance, when time is not critical, the series of tasks is too long to be memorised, and the environment allows accessing a physical list to be used (Clay-Williams & Colligan, 2015). The CBRN checklist proposed as a recommendation from this thesis over comes qualitative criticisms such as being too wordy, needing a discussion, or a team response.

It is envisaged that the CBRN planning checklist (Figure 7, p. 53) will be implemented by Trusts. Both Trusts in this research embedded standardised recommendations such as the Initial Operational Response (IOR) in their plans (Study 1) confirming the importance placed on standardised measures by Kotora (2015) and Kollek and Cwinn (2011).

There are three opportunities for the CBRN planning checklist to be implemented. The first is as an evaluative tool in CBRN response planning, the second is to be used as a template for CBRN response mandatory training, and thirdly as a reference point when a CBRN event is declared. The checklist encompasses the planning, preparation, and response phases to a CBRN event. Two of the three phases, planning and preparation, echo the actions required during the pre-incident and incident phase of WAI.

The results of neither studies included competencies (Schultz et al., 2002) or standards (Williams et al., 2007) when preparing to respond to CBRN events. Although the emphasis of CBRN competencies was derived from the USA, developments are being made in the UK by identifying core competencies for the NHS response to CBRN events (Linney et al., 2011); which include awareness of local and national hazards in line with the themes that emphasise the importance of equipment capabilities, response which includes the importance of communication, command and control structure, and recovery. This can be embedded through the CBRN planning checklist which considers first receiver competencies as an organisational factor to enhance the ED CBRN response.

The semi-structured interviews confirmed the findings from the systematic review in line with Klima et al. (2012) and Reddy et al. (2009) in which computer-based systems were anticipated to be overwhelmed and first receivers would implement pen and paper methods (Study 2). The CBRN planning checklist (Figure 7, p. 53) emphasises the importance of communication as technological issues in which a backup paper system should be accessible. Contrary to the suggested lack of preparation in terms of decontamination, equipment, security, and antidotes, neither studies in this thesis demonstrated limitations in such CBRN factors.

It was reported that first receivers would be more willing to respond to incidents that did not involve hazardous materials (Cone & Cummings, 2006; Masterson et al., 2009). However, first receivers across both Trusts were willing to respond to the randomly selected presentation. Considine and Mitchell (2009) reported that nurses with post-graduate qualifications displayed greater willingness to respond. However, this would decrease if the substance was unknown while this variability in willingness to respond to a CBRN presentation was not evident amongst the first receivers in Study 2.

Surge capacity through effective triage (Durukan et al., 2009) was evident in WAD (Study 2) in the ED response to CBRN events. First receivers at both Trusts discussed how they would deal with the surge and create capacity through discharging patients earlier and designating victim flow areas, echoing the findings of Kaji, Langford, and Lewis (2008) and Satterthwaite and Atkinson (2012). Contrary to the findings of the systematic review, whereby surge capacity was restricted based on the failure to fully integrate interagency planning and co-ordination (Jasper et al., 2005) both studies reported strong links with interagency planning and co-ordination. First receivers in Study 2 discussed the ambulance services as being a source of knowledge, fire services being crucial to the decontamination process, and police in assisting with security.

A means of bridging gaps between WAI and WAD identified in Chapter 6, is through combining crucial CBRN actions, as an evidenced standardised CBRN action card template for first receivers (Figure 69, p. 221221). Templates have been recommended to allow the implementation of *"The choice approach"* to standardisation (Nissinboim & Naveh, 2018) which allows clinician discretion (Chapter 1) and encourages naturalistic decision making (Catchpole & Alfred, 2018).

To guarantee effective standardisation, the process needs to be well defined, described, and reproducible (Schleef, Cherti, & Guida, 2019). It is recommended that the number of phases in a CBRN event should be defined, and described through superordinate tasks which are broken down into actions that are reproducible as shown in Table 42:

Table 42: Standardised action card recommendations

Phase	Superordinate tasks	Example actions required
Pre-incident To allow first receivers to uptake a CBRN role or prepare equipment.	Prepare for CBRN event.	Access relevant equipment.
Incident To carry out actions required during the CBRN event (e.g. decontaminate).	Respond to incident.	Put on gloves, gown, and duck mask (PPE).
Recovery For documentation and debrief.	Document CBRN event.	Ensure all actions and decisions are logged and recorded.

Research into the CBRNe response and considerations for vulnerable groups categorised the response into three phases 1) Evacuation, 2) Triage and 3) Decontamination (Hignett et al., 2019b), these actions are compatible with the standardised incident phases outlined in Table 42 (p. 219).

Chapter 6 synthesised the findings of both studies and identified phases of the CBRN response, in line with Johnson and Cosgrove (2016) who proposed general phases (initial response, consolidation phase, and recovery phase) for hospitals responding to major incidents (including CBRN events). The initial response consisted of preparing for the arrival of casualties, this phase confirmed findings reported by Jasper et al. (2005) and Waage et al. (2013) in terms of freeing resources to deal with the surge of casualties. The incident phase identified in this thesis reflected the initial response because it consisted of deployment of staff and the allocation of team members in the *"Manage incident"* superordinate task reported in Study 1. The recovery phase consisted of debrief. The findings of this thesis and findings from Johnson and Cosgrove (2016) confirm WAI in the ED response to CBRN events.

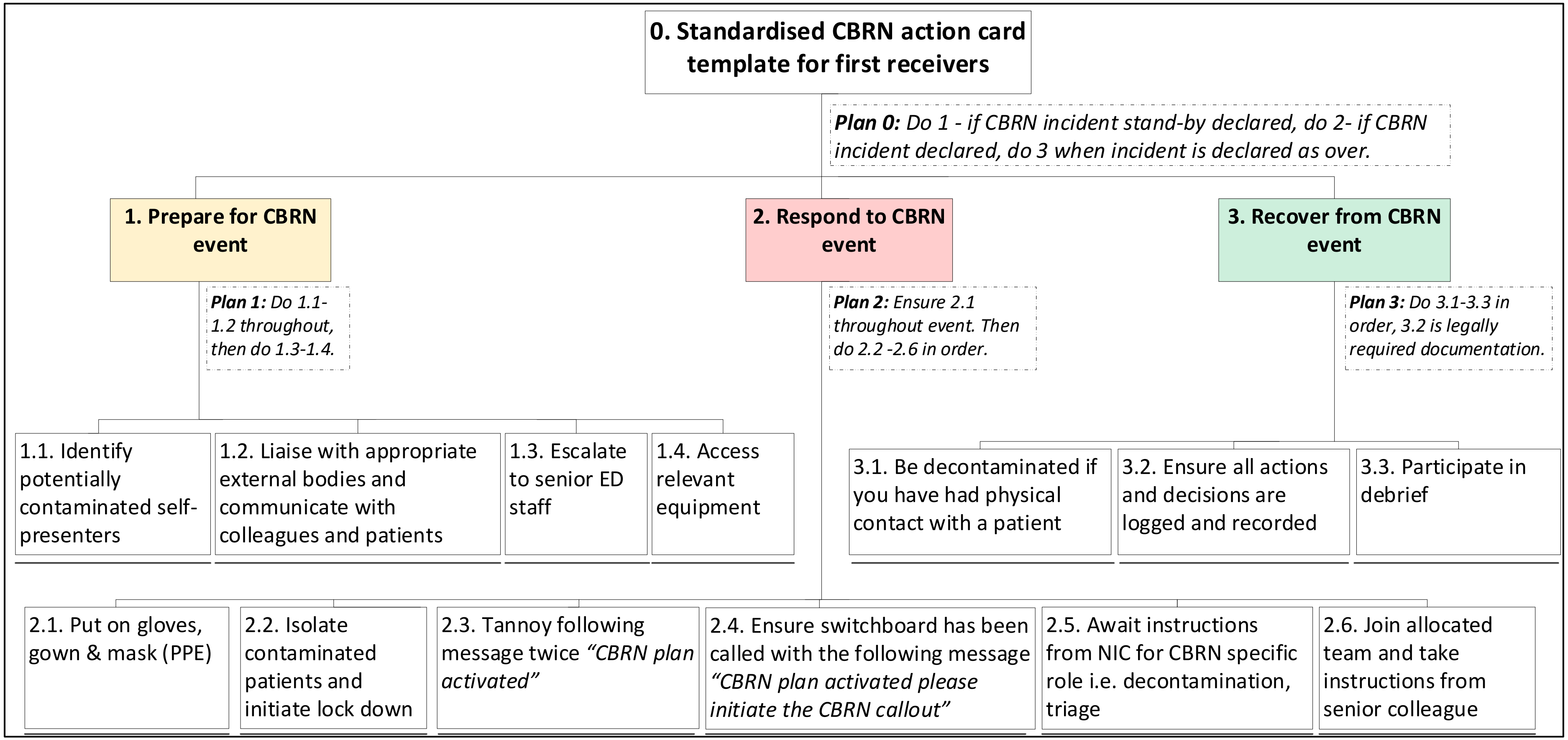


Figure 69: Standardised CBRN action card for first receivers

A systems approach has been adopted to present standardised recommendations in response to a CBRN event. Findings from the micro-systems (HTA representations) from action cards (WAI) and first receivers (WAD), have been explored and exemplified as a meso-system to inform the recommendations. The presentation of WAI and WAD provided an insight into the multi-dimensional variability across the CBRN response for first receivers. Variability is exemplified in 4 ways:

1. Differences in the number of first receivers included in the response.
2. Having different nursing roles across hospitals.
3. Having unspecified banding/experience for CBRN roles.
4. Differences in number of phases in the CBRN response.

To overcome variability in the CBRN response amongst first receivers, it is recommended to have standardised roles during a CBRN event, with banding and experience outlined in the CBRN plan. Alternatives (first receivers) should be provided based on the short staffing of the ED, and unpredictability of CBRN emergencies.

An example of a nursing meso-system is provided in Figure 70 (p. 223). The first receiver flow of communication shows the direction of instructions from seniors (banding) to juniors (banding) as well as juniors reporting back to seniors whilst taking into consideration contamination boundaries. Patient flow shows the movement of patients throughout the CBRN process. The roles are not aligned (physically) based on banding, as meso-systems representing the ED CBRN response are not a hierarchical representation. The spaces are based on where actions will be carried out, for example the decontamination area. Further examples of meso-systems in the ED CBRN response could consist of role specific interactions or processes meso-system. For example, a meso-system illustrating the interactions which occur during the triage process.

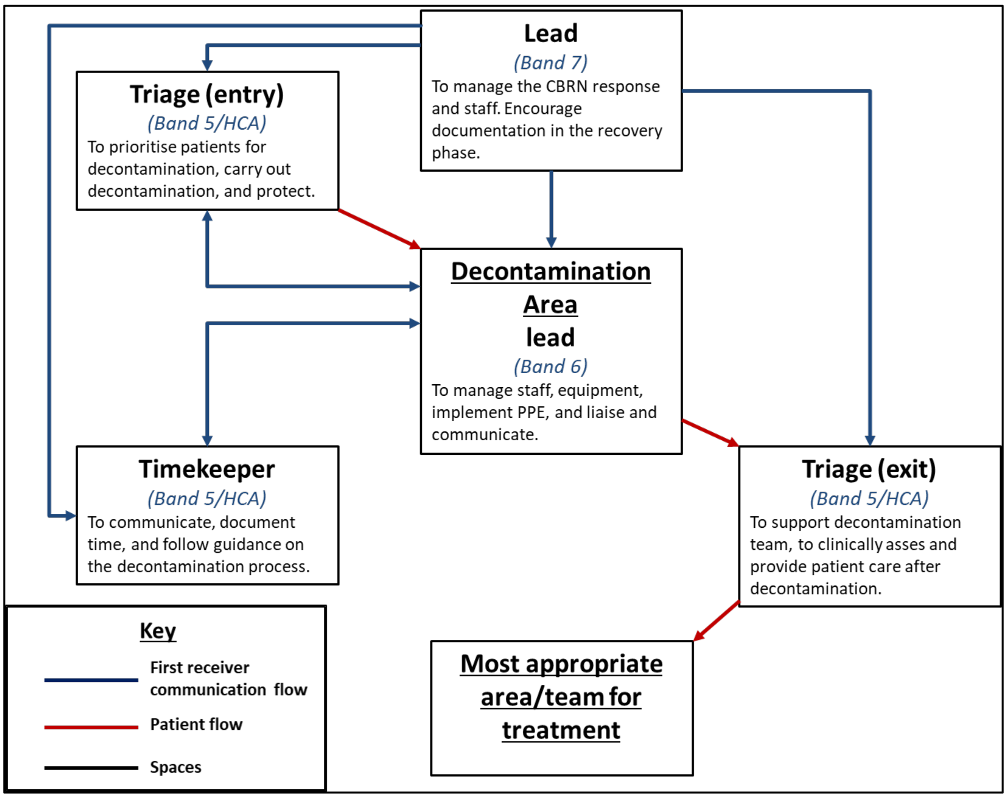


Figure 70: Example of standardised meso-system for the ED CBRN response process

A key component of the systematic review was recognising the challenges of detection, decontamination, and diagnosis when responding to CBRN events in the ED. During CBRN events, there can be a delay in recognising causative agents with the added risk of non-decontaminated casualties walking into or self-presenting at EDs (McGhee, Finnegan, & Angus, 2019). The first receivers at both Trusts emphasised the importance of preventing cross-contamination through isolate and contain being a crucial action in their response to a potential CBRN presentation.

Study 2 found that first receivers were curious to detect and identify the agent. For example, at Trust A, Geiger Counters were used, or specialist detection devices would be used by allocated individuals such as a medical physicist. In line with Becker and Middleton (2008) first receivers could use Geiger counters, however, the first receivers in Study 2 did not discuss their unfamiliarity with such equipment.

In terms of decontamination, Trust A first receivers clearly outlined hot and cold zones in their CBRN plan. Trust B first receivers outlined roles which required the Powered Respirator Protective Suit (PRPS) suits as a means of effectively overcoming the challenge of cross contamination (Larson et al., 2016). First receivers discussed isolation throughout their responses. Challenges in decontamination were evidenced through band 6 nurses not including decontamination in their CBRN response (Study 2).

Diagnosis was evident amongst Trust A first receivers. Diagnosis was made amongst Trust A first receivers through clinical testing. A common response in relation to diagnosis of CBRN exposure was the misdiagnosis of Acute Radiation Syndrome (ARS), with substance abuse or psychiatric issues; confirming the findings of McFee and Leiken (2009) who reported that the physiological symptoms of CBRN exposure mimic other diseases, making diagnosis more challenging.

HTA representations of CBRN plans underwent thorough and objective HF/E review (Chapter 4). The reviews resulted in CBRN General Organisational Responsibilities (GOR) and action card HTAs, which flowed systematically, without repetitions, clear allocations, and standardised phases of response. The updated HTAs were combined with the responses from study 2 (Chapter 5) to give a complete integration of policy (CBRN plans) and practice (first receiver responses), which formed the recommended standardised ED CBRN framework (Figure 71, p. 226).

The standardised CBRN framework implements the findings that overcome the challenges associated with detection, decontamination, and diagnosis as reported in the systematic review. There is no standardised system globally or nationally for key CBRN actions such as triage and decontamination (Ramesh & Kumar, 2010). The standardised CBRN framework implements systems that are flexible, easy to follow to the available medical resources, number of casualties, and severity of injuries, encouraging its usability.

Unique to the outcomes of the studies and the input of the HF/E review (Study 1) the CBRN framework begins in the plan phase, which is aimed at CBRN leads. The prepare phase incorporates WAI from the GORs from both Trust A and Trust B CBRN plans (Chapter 6). Key WAD themes such as PPE are a part of this phase, providing a bottom up contribution to the framework.

The declaration of the CBRN event was an isolated respond phase superordinate task, to emphasise its importance. The CBRN framework recognises the importance of creating surge capacity during the response phase and consists of actions such as calling in staff to respond to the surge effectively. This resonates actions which are included in both CBRN plans as well as WAD actions discussed by Trust A NICs. In agreement with McGhee et al. (2019), who suggest that in response to chemical events, EDs must have enough staff on duty to recognise, assess, and treat exposed patients.

The recovery phase is based on WAI findings (Chapter 4) in particular the concept of *"Debriefing"* which is suggested to take from months to years to identify lessons learned and then be disseminated throughout the medical community to enhance future responses (Johnson & Cosgrove, 2016). Additionally, WAI input from Study 1 is to ensure the psychological wellbeing of staff during the recovery phase. The framework provides an evidence based, simplified template to respond to a multi-faceted CBRN event. The template encompasses findings from literature, both studies, the synthesis, as well as the HF/E review to provide a systems approach to respond to CBRN events.

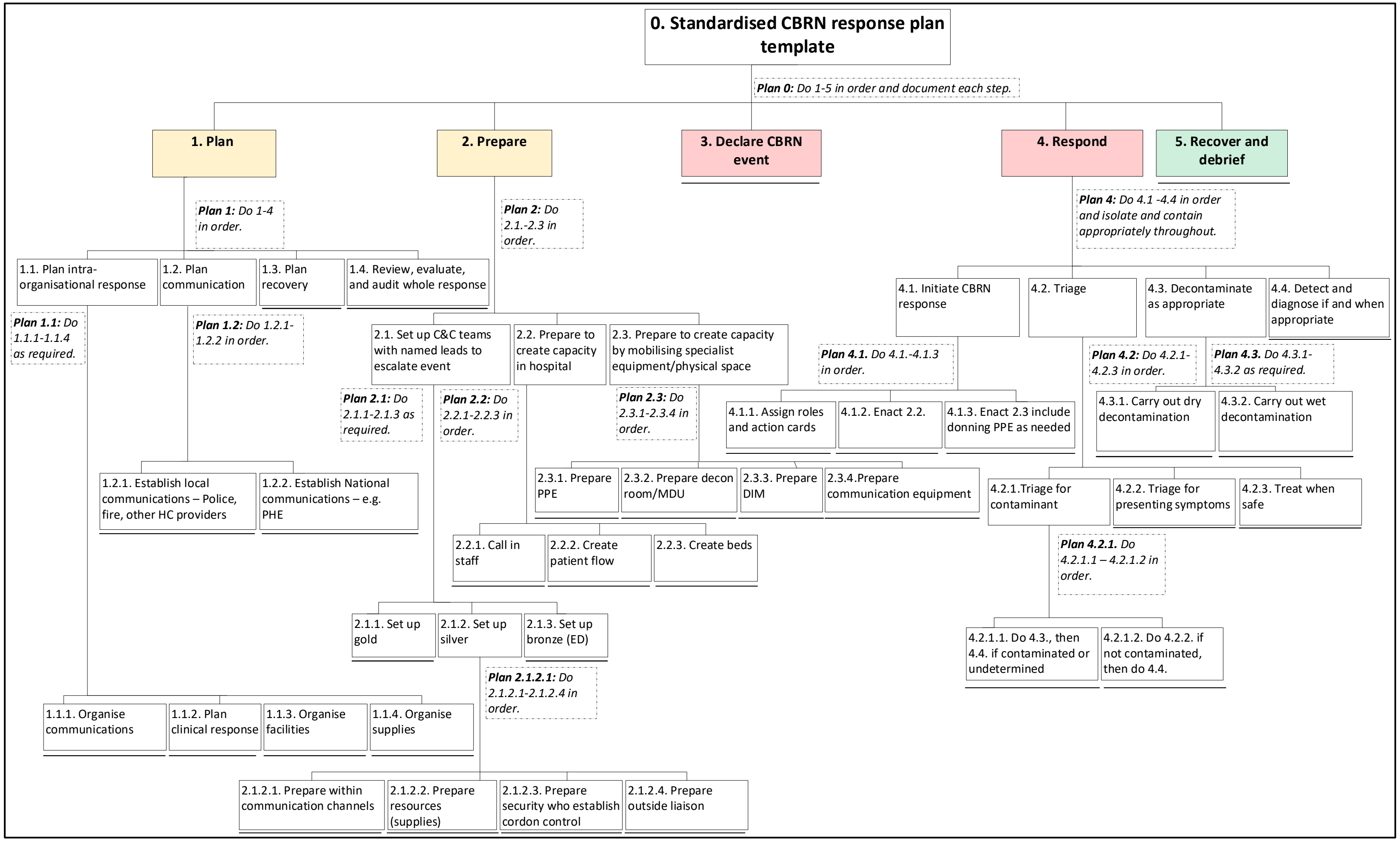


Figure 71: Standardised CBRN framework

Abbreviations: C&C: Command and control, **PPE:** Personal Protective Equipment, **MDU:** Mobile Decontamination Unit, **DIM**: Detection, identification, and monitoring

7.7 Limitations

While this thesis makes unique contributions to existing research and guidance for ED CBRN Emergency, Planning, Preparation, and Response (NHS England, 2015b), it is important to acknowledge the limitations.

Developments to the theoretical framework of WAI vs WAD were made during the research by Shorrock (2016) in terms of further categorisations in the realm of work. However, these were not implemented because a simple framework (WAI vs WAD) was deemed crucial in unpacking a complex process (CBRN event).

A limitation of HTA as a systems mapping tool existed in the consistency in data verification processes between both Trusts. HTA was used to represent CBRN plans (Chapter 4) and required a varying number of revisions for WAI representations for each Trust. Trust A required three meetings with the CBRN lead, Trust B required one meeting. However, the greater number of meetings with Trust A served as reflective practice for the CBRN lead at Trust A, because the HTA representation highlighted limitations in the Trust CBRN plan, resulting in amendments to the plan.

On its own, HTA describes the CBRN process rather than explaining it. Nonetheless, HTA was the most apt method for the research questions posed (Chapter 1) for the following reasons:

- The ED is a complex and unpredictable environment in which *"quick"* data collection methods must be implemented.
- CBRN events are multifaceted situations which require a simple method of effectively unpacking to enhance understanding.
- HTA has provided a consistent method encompassing a top down and bottom up approach to the ED response to CBRN events.

The transferability of the findings from the research can be questioned on numerous levels:

- The studies were carried out across two NHS Trusts in the Midlands region of the UK, which limit the generalisability of the findings on an organisational and regional level.
- Study data were generated from a purposive sample at a single point in time.

- Document analysis was carried out on CBRN plans, which are reviewed and revised bi-yearly.
- Clinical guidance which formed the scenario cards had been updated.

As a means of ensuring rigour throughout the design, data collection, and analysis process (Chapter 3), key factors such as credibility, transferability, dependability, and confirmability were addressed. These factors have been suggested to provide a *"Solid piece of evidence"* in which qualitative research in emergency medicine is improved (Forero et al., 2018, p. 8).

Transferability in qualitative research, is the equivalent to external validity in quantitative research – which is the potential for a study's findings to be generalised from one sample or setting to others (Ferguson, 2004). Transferability is crucial because it allows healthcare practitioners to resonate with the empirical work presented (Hayre & Muller, 2019).

The studies were carried out across two Type 1 NHS EDs in the Midlands, potentially questioning the transferability of the findings. However, a means of ensuring transferability as suggested by Hayre and Muller (2019), is by providing thorough descriptions of the research context and research environments. This was ensured through ethically approved protocols (Chapter 3) as well as descriptions of the EDs in Chapter 5.

Hayre and Muller (2019) further suggest transferability through undertaking multi-site research as a means of providing a complete perspective of behaviours and actions of practitioners; this was addressed in a multi-site approach to overcome issues such as ED specific team culture. Harley et al. (2019) investigated ED nurses understandings of their role in the recognition of sepsis, they suggested that if the study had been carried out in multiple sites, a more comprehensive understanding of the phenomenon of interest would be provided, resulting in findings which were more transferable and generalisable to other settings.

A potential limiting factor is that neither of the EDs were Major Trauma Centres (MTCs). The scenario cards were based on P3 (Chapter 3) patients matching the clinical capabilities of the EDs involved in the studies. Further, Type 1 EDs were chosen to ensure consistency in terms of first receivers' knowledge of CBRN events.

Despite the limitations in terms of transferability, carrying the studies out across two Trusts addressed the research questions effectively, and the objectives were achieved (Chapter 1). There was clear variability across two Trusts, for example the differences in the importance placed on decontamination in WAD (Chapter 5), it is predicted that greater differences would exist amongst a larger number/sample of Trusts.

Data were generated from a purposeful sample at a single point of time, which resulted in rich data. However, this is considered a limitation which is common in critical care services research as encountered by Fealy et al. (2019) when examining clinical handover practices in acute care services. Collecting the data at a single point was planned for two reasons. Firstly, CBRN events cannot be anticipated, and a real life, real-time response was aimed to be achieved. Secondly, EDs are under extreme pressures with demand constantly exceeding capacity, challenges associated with overcrowding in the ED, lead to stress in staff and have been associated with the high turnaround of staff (Royal College of Emergency Medicine, 2015). Further, staff worked varying shifts thus a single point of data collection was the most apt, with a quick turnaround time for verification interviews.

Clinical guidelines should be updated to maintain their validity (García et al., 2014), two types of updates contributed to a limitation of the studies. The first is to Study 1, (Chapter 4) the CBRN plans used to carry out document analyses and converted to HTA representations were reviewed (based on governmental guidance) and revised annually at both Trusts. Therefore, the analysis could be considered *"Out of date"* once the plans were updated.

Secondly, guidance which informed the scenario cards was updated from the first edition (Gov UK, 2008) to the second edition (Public Health England (PHE); 2018) which emphasises incident management principles and has updated chemical and biological guidance based on merging threats. Although the guidance is updated, the validation of the scenario cards by a Hazardous Area Response Team (HART) specialist ensured that the symptomology of the presentations remained realistic.

The use of scenario cards to represent WAD can be questioned. The efficiency of scenario cards has been discussed in Chapter 3. The usability was demonstrated through Study 2. However, CBRN events could not ethically be anticipated or created due to their life endangering nature. This was attempted to be overcome by having realistic scenario cards based on Health Protection Agency CBRN clinical guidance (Gov UK, 2008). Although retrospective analyses of CBRN events have been suggested in the future research opportunities of this research (Chapter 8); Chilcott, Mitchell, and Matar (2019) provided realistic conditions of decontamination during a CBRN event through a chemical warfare agent simulant (methyl salicylate).

It is suggested that the hierarchical nature of HTA is cumbersome for larger scale analyses (Stanton, 2006). This thesis proves otherwise, and the hierarchical diagram is optimal for visualising interactions, making comparisons, and thematically coding for standardised recommendations to enhance the ED CBRN response.

Finally, the collection of data and their analyses were rigorous throughout the studies. Reporting the results was challenging based on the large sizes of the GOR HTAs. Although the transparency and reporting of results in HF/E studies has been questioned (Phillips, Wayman, Omnou, & Foulcer, 2019), the use of thematic analysis and colour coding the HTA representations ensured the systematic reporting of the results. Therefore, HTA combined with qualitative thematic analysis is a transparent, effective, and concise method of enhancing the understanding of multifaceted events in complex environments.

7.8 Chapter summary

HTA was effective in making multi-level comparisons, as well as identifying micro, meso, and macro levels of the ED CBRN response. The combination of colour coding, with thematic analysis, and HTA is a unique contribution to enhance the usability of HTA as a systems mapping tool in healthcare.

HTA was efficient in unpacking a complex system and is recommended as the baseline method for unpacking all complex healthcare systems. HTA has proved its usability in surgical situations and is advocated as a method to identify and prevent error in complex processes.

Contrary to the findings of the systematic review, EDs were prepared to respond to CBRN events. First receivers were willing to respond to CBRN presentations and created surge capacity through effective interagency coordination. Decontamination was core to the ED CBRN response, with variation on its importance between the Trusts. Differences placed on the importance and type of PPE were also evident. Challenges in detection were met by first receivers being curious to identify the agent. First receivers at Trust A attempted to diagnose the presenting condition.

HTA can be used as a systems mapping tool to standardise multifaceted processes in complex environments. Standardisation is required to enhance the ED CBRN response. This chapter presented four evidenced based standardised recommendations. The CBRN checklist was based on evidence from the systematic review. The action card template consisted of top down and bottom up data. The integration of the HTA micro-systems provided an example of a CBRN meso-system. Finally, the standardised CBRN framework was a result of the complete immersion of policy (CBRN plans HTAs) and practice (first receiver response HTAs) to form a standardised response to CBRN events in the ED.

Chapter 8. Conclusion

"Standardisation is a cornerstone of organisation – a central element in any analysis of modernity"

(Le Coze, 2017)

8.1 Introduction

This chapter provides the insights, implications, practical applications, and opportunities for future research. The research idea came from clinical experience as an Emergency Department Practitioner in a NHS Foundation Trust. The first-hand insight into the ED confirmed that it was a complex environment. The fast paced, highly pressured, and often short-staffed environment results in the cancellation of training opportunities for rare events and presentations. This motivated research for a system-wide understanding of how the ED would respond to multifaceted emergencies, such as CBRN events.

CBRN threats with the potential to harm a large number of individuals are becoming more frequent (Carter et al., 2019). The literature emphasised that EDs were under prepared to respond to CBRN events and first receivers were unwilling to respond to CBRN events.

The studies confirmed the contrary, first receivers were willing to respond to CBRN events, as well as being prepared to carry out Bronze level operational actions. Based on this willingness and the ED being a complex clinical system, the ED CBRN response process was unpacked systematically with Hierarchical Task Analysis (HTA), highlighting differences between operational procedures and practice using the Human Factors/Ergonomics (HFE) approach for Work as Imagined (WAI; procedures) and Work as Done (WAD; practice), as a means of providing rigorous and evidence based standardised recommendations to enhance the ED CBRN response.

8.2 Restating the aims

HTA was used as a systems mapping tool to unpack the ED response to CBRN events. Two studies were carried out to address the aims. A document analysis was combined with HTA to visually represent operational procedures (CBRN plans). Semi-structured interviews were then carried out to represent practice in response to a CBRN presentation. Responses were represented as HTAs for rigour, consistency, and comparison.

Aim 1: Explore whether Hierarchical Task Analysis could be used to map complex socio-technical systems

- HTA effectively mapped out complex, interrelated, and multi-faceted interactions in General Organisational Responsibilities (GOR) representations. Specific CBRN actions were further represented as first receiver action card HTAs as a means of explaining Work as Imagined in the ED CBRN response (Chapter 4).
- HTA represented first receiver responses to CBRN presentations as Work as Done (Chapter 5).
- HTA representations were thematically analysed for higher level understanding and comparisons of key CBRN factors (Chapter 6).

Aim 2: Make recommendations to improve the Emergency Department response to Chemical, Biological, Radiological, and Nuclear events.

- The systematic review identified the ED as a system and CBRN response planning and preparedness consisting of three inter-twining levels: organisation, technology, and individual which resulted in the formation of a standardised CBRN planning checklist for CBRN leads (Chapter 2).
- Standardisation of superordinate tasks for first receivers introduced clarity and order across tasks, resulting in standardised action card recommendations (Chapter 4).
- There was multi-dimensional variability across the ED CBRN response, requiring standardised meso-systems of CBRN processes (Chapter 5 & 6).
- Differences across operational procedures were highlighted (Chapter 4) and combined with critical CBRN actions identified by first receivers (Chapter 5) to form a standardised CBRN framework (Chapter 7).

8.3 Summary of findings

Study 1 (WAI) took a top down approach for document analysis of Standard Operating Procedures (CBRN plans) at two Type 1 NHS Trust EDs. The plans were analysed thematically to create colour coded HTA representations of the CBRN plans. Differences in GORs were found between the two Trusts; Trust A had 13 GOR themes and Trust B had 20 GOR themes, of which 13 overlapped. The emergency plans include role-specific action cards used to support individual tasks; each card (n=30) was analysed and represented as HTAs. A HF/E review of the HTAs as part of the coding process produced higher level (standardised) themes at both Trusts as:

1. Prepare to respond to CBRN incident (Trust A and B).
2. Respond to CBRN incident (Trust A and B).
3. Initiate recovery from CBRN incident (Trust A).
4. Document CBRN incident (Trust A).

Study 2 (WAD) collected data with semi-structured interviews from 57 first receivers. Scenario cards were used as prompts to explore clinical and operational practice. The field notes were converted to HTAs and thematically analysed. The synthesis of these themes provided a bottom up perspective to consider standardisation based on WAD (how first receivers respond to CBRN events). Similarities between the Trusts were evident in the importance placed on actions for isolate and contain, liaise and communicate, and escalate.

Differences were found in the importance placed on the type of Personal Protective Equipment (PPE), decontamination, treatment, and investigation of the presentation. The results for WAI and WAD were compared. WAI focused on actions such as documentation, checking, and timing; WAD prioritised patient needs through assessment, treatment, and diagnosis.

8.4 Impact of findings

This thesis aimed to produce findings which made an impact on many levels and several contributions to knowledge have been made. The four standardised recommendation outputs are envisaged to make contributions to practice during CBRN events in the ED.

8.4.1 Contributions to knowledge

HTA has been used to represent interactions between police, fire, and hospital services during an accidental chemical spill by Baber et al., (as cited in Stanton, 2006). HTA has also been used to assess CBRN technology usability in field Trial exercises by Hignett et al. (2019c). This thesis has uniquely made a specific contribution to knowledge by using HTA in the context of unpacking how a complex socio-technical work system (the ED) responds to a multifaceted event (CBRN) from a top down (policy) and bottom up (practice) perspective.

Colour coding has been combined with HTA for descriptive purposes in safety critical plant industries as well as in healthcare (Embrey et al., 2009; Sutherland et al., 2009). This thesis has provided a novel detailed analysis and complex systems mapping tool through combining colour coding and applied thematic analysis to allow multiple comparisons and syntheses of findings.

In the surgical context, Corbett et al. (2019) included surgical consultants reviewing HTA representations of a specific surgical procedure which was formed through observations. This thesis implemented participatory design concepts throughout. Macro HTA representations were reviewed by CBRN leads in study 1. Micro HTA representations were reviewed by first receivers in study 2 to ensure a true representation of outputs. Additionally, HF/E specialist input ensured evaluation for flow, simplification, and standardisation of operational CBRN procedures.

The aforementioned literature has carried out useful research in diverse contexts. It is considered that the work presented in this thesis provides an important and original contribution of impact to the field of ED research and the CBRN context by applying a HF/E approach. A complete understanding of the ED CBRN response has been attempted to be unpacked through adopting a systems approach, HF/E method, and theory.

8.4.2 Application to policy

The findings from this thesis provide an evidence base for national and international policy and guidance.

8.4.2.1 National policy

This thesis impacts national legislative responsibilities presented by The Civil Contingencies Act (2004) in terms of emergency preparedness, response, and resilience.

On an organisational level there is both awareness and implementation of preparedness guidance in terms of the General Organisational Responsibilities – hence the existence of CBRN plans. Additionally, the awareness of decontamination procedures, and the importance of isolation and containment by first receivers suggests that preparedness is both a top down and bottom up priority in the ED CBRN response. However, there is ambiguity associated with documentation when responding to a CBRN event. Therefore, it is recommended that national level policy places focus on developing clear guidance on the importance and process of documentation during a CBRN event in the ED.

A key finding when responding to CBRN events is that there is variability in the allocation of first receivers across Trusts which can be overcome by implementing standardised CBRN mesosystems in national guidance. This thesis further proposes findings that oppose concepts such as first receiver unwillingness to respond to CBRN emergencies. The findings from study 2 suggest that first receivers prioritise patient care throughout and escalate areas of uncertainty to ensure the emergence of patient safety during a CBRN emergency. It is encouraged for national policy to employ CBRN specific escalation pathways for first receivers to enhance frontline resilience.

8.4.2.2 International policy

On an international scale, the Sendai Framework for Disaster Risk Reduction 2015-30 (Aitsi-Selmi et al., (2015); UNISDR, 2015), emphasise the importance of health system resilience and infrastructure. This thesis emphasises the importance of positive inter-agency working as a means of enhancing health system resilience during CBRN emergencies. To strengthen CBRN response infrastructure, the CBRN planning checklist is encouraged to be used as an international inter-agency framework, in which the logistics of responding to a CBRN event are categorised into the three (plan, prepare, response) phases.

8.4.3 Application to practice

It is of paramount importance to provide high quality and safe care to CBRN exposed patients whilst protecting first receivers in the process. This thesis made a practical impact by identifying variability in the ED CBRN response which could be overcome by implementing standardised outputs. Four important contributions to practice can be applied on a national and international scale through:

1. Standardised CBRN planning checklist.
2. Standardised action card template.
3. Example of a standardised ED response meso-system.
4. Standardised CBRN framework.

The formation of and usability of the standardised outputs are discussed in Chapter 7.

8.5 Future work

Future research opportunities exist on two levels:

1. Applying HF/E principles to improve the CBRN response.

2. Combination of systems thinking, HF/E methods, and theory to enhance clinical practice in time critical and complex care processes.

8.5.1 CBRN response

The WAI vs WAD paradigm was justified as the most apt theoretical framework. However, developments have been made through the emergence of the *"The varieties of human work"* (Shorrock, 2016). The methods and findings can be used to explore *"Work as Disclosed"* through retrospective explorations of CBRN events. *"Work as Done"* can be exemplified realistically by implementing chemical agent simulants as shown in Table 43 (p. 238).

Table 43: Future research based on the development of the theoretical framework

The ED response to CBRN events: A varities of human work perspective
Work as Imagined
Positive interoperability discussed by first receivers in this thesis can be investigated further and across responder types.
Work as Prescribed
The participatory approach adopted in this thesis revealed that there was a difference between governmental guidance and CBRN plans that needed to be amended in study 1. Therefore, Work as Prescribed (CBRN plans) should be investigated with CBRN planners and Accountable Emergency Officers to ensure national guidance is being implemented on a local level.
Work as Disclosed
Retrospective reporting of responding to a CBRN event such as the novichok incident.
Work as Done
Use chemical agent simulants such as methyl salicylate (Chilcott et al., 2019) and observe the actions taken by first receivers.

This thesis investigated the ED response to CBRN events amongst Type 1 EDs. It would be useful to adopt a systems approach and triangulate theory (WAI vs WAD), methods (HTA), tools (scenario cards), analysis (thematic analysis), and the unique extrapolation of data (colour coding), to compare ED types. An interesting comparison would be between the findings of this thesis and Major Trauma Centres to identify macro and meso actions to be incorporated in a national ED CBRN response.

8.5.2 Complex processes

This thesis has set out guidance on obtaining NHS approval, effective participant recruitment methods, collecting data in complex and overburdened environments with busy staff, converting data to HTA representations, and thoroughly analysing HTAs to extract recommendations.

The adoption of systems thinking, combined with HF/E theory, and method is considered useful to unpack complex processes within time and safety critical care systems. Such as the transfer of critically ill patients across hospitals, to operating theatres, High Dependency Units (HDU), and intensive Care Units (ICU).

Time-critical situations such as cardiac arrests, sepsis, and trauma alerts can benefit from using HTA as a process mapping tool. Pathways can be formed so that policies and guidance (WAI) provide insight and embed what actually happens (WAD).

8.6 Closing statement

The ED is the highest risk area in healthcare (Bleetman et al., 2012). First receivers are required to care for CBRN material exposed patients, with the danger of becoming patients themselves (Jones, 2019), making the CBRN response a high-risk process. This thesis has identified discrepancies in the ED CBRN response and provided solutions in the form of standardised recommendations.

The WAI vs WAD framework provided a robust theoretical framework to identify gaps and improvement opportunities to prioritise a safe work environment for first receivers to provide safe and high-quality care to patients during a CBRN event. This thesis has shown that HTA is an effective systems mapping tool, which can be used to unpack a multifaceted event in a complex environment.

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Appendix 1. Trial and error technique formulating search trial: Search strings

(ED or emergency department) AND (CBRNE or CBRN incidents)

(ED or emergency department) AND (CBRNE or CBRN incidents OR detection technologies)

Emergency department AND (CBRN OR CBRNE OR mass casual*) AND (detection OR decontamination OR diagnosis)

(Emergency department OR self-present*) AND (CBRN OR CBRNE OR mass casualty OR mass casua*) AND (detection OR decontamination OR diagnosis)

(emergency department OR self-present*) AND (CBRN OR CBRNE OR mass casualty OR mass casua*) AND (detection OR decontamination OR diagnosis OR equipment OR technologies)

emergency department OR self present* and CBRN OR CBRNE OR mass casuality OR mass casua* and detection OR decontamination OR diagnosis OR equipment OR technologies) and not (training OR teaching).

emergency department OR ED OR self present * AND CBRN* OR CBRNE OR mass casualty AND detection decontamination diagnosis equipment technologies NOT teaching OR training

hospital OR emergency department OR ED OR accident and emergency OR self present* OR P3 patients AND CBRN* OR CBRNE OR mass casualty OR mass casualty* incident* AND detection OR decontamination OR diagnosis OR equipment OR technologies

(emergency department OR ED OR accident and emergency dep* OR A&E OR self present OR self presen* OR walking wounded) AND (CBRN OR CBRNE OR mass casuality inciden* OR mass casuality event OR mass casua*) AND (detection OR decontamination OR diagnosis OR equipment OR technologies) (hospital OR emergency department OR ED OR accident and emergency dep* OR A&E OR self present OR self presen* OR walking wounded OR p3) AND (CBRN OR CBRNE OR mass casuality inciden* OR mass casuality event OR mass casua*) AND (detection OR decontamination OR diagnosis OR equipment OR technologies) NOT (teaching or training or education)

(hospital OR emergency department OR self present*) AND (CBRN OR CBRNE OR mass casual*) AND (detection OR decontamination OR diagnosis) AND (equipment OR technologies) NOT (training OR teaching OR education)

(hospital OR emergency department OR ED OR accident and emergency dep* OR A&E OR self present OR self presen* OR walking wounded OR p3) AND (CBRN OR CBRNE OR mass casuality inciden* OR mass causality event OR mass casua*) AND (detection OR decontamination OR diagnosis OR equipment OR technologies)

(hospital OR emergency department OR end OR accident and emergency dep* OR A&E OR self present self presen* OR walking wounded OR p3 OR patient*) and (cbrn OR cbrne OR mass casualty inciden* OR mass casualty event OR mass casua* AND detection OR decontamination OR diagnosis AND equipment OR technologies OR tech

hospital OR emergency department OR ED OR accident and emergency dep* OR A&E OR self present OR self presen* OR

walking wounded OR p3 OR patient* AND cbrn OR cbrne OR mass casualty inciden* OR mass casualty event OR mass casua* AND detection OR decontamination OR diagnosis AND equipment OR technologies OR tech* AND NOT teaching

Appendix 2. Mixed Methods Appraisal Tool Table

Study			Low: 25%	Limited 50%	Moderate 75%	Strong 100%	Total score
Preparedness							
1	Al-Damouk & Bleetman, (2004)	Quan	1	1	0	0	2
		Qual	1	1	1	0	3
		MM	1	1	0		2/50%
2	Anathallee et al., (2007)		1	1	1	1	4 (100%)
3	Becker & Middleton,(2008)		1	1	1	0	3 (75%)
4	Braun et al., (2004)		1	1	1	1	4 (100%)
5	Connor, (2003)		1	0	0	0	1 (25%)
6	Considine & Mitchell, (2009)		1	1	1	0	3 (75%)
7	Duong, (2009)		1	1	1	1	4 (100%)
8	Kaji & Lewis (2006)		1	1	0	0	2 (50%)
9	Kollek, (2002)		1	1	1	0	3 (75%)
10	Kollek & Cwinn (2011)		1	1	1	0	3 (75%)
11	Kotora,J. (2015)		1	1	0	0	2 (50%)
12	Mitchell et al., (2012)		1	1	1	1	4 (100%)
13	Niska et al., (2005)		0	1	1	0	2 (50%)
14	O' Sullivan et al., (2008)		1	1	1	0	3 (75%)
15	Rassin et al., (2007)		1	1	1	1	4 (100%)
16	Shiekh et al., (2012)		1	0	0	0	1 (25%)
17	Treat et al., (2001)		1	1	1	1	4 (100%)
18	Whetzel et al., (2011)		1	0	1	0	2 (50%)
19	Williams et al., (2007)		1	1	1	0	3 (75%)
20	Wetter et al., (2001)		1	1	0	1	3

						(75%)
21	Wong et al., (2006)	1	1	0	1	3 (75%)
	Lessons Learned					
22	Allegra et al., (2001)	1	1	0	0	2 (50%)
23	[a]Bloch et al., (2007)	1	1	1	1	4 (100%)
24	[b]Bloch et al., (2007)	1	1	1	1	4 (100%)
25	Dayan et al., (2005)	0	1	0	0	1 (25%)
26	De Ceballos et al., (2005)	1	1	1	1	4 (100%)
27	Durukan et al., (2009)	1	1	1	1	4 (100%)
28	Einav et al., (2006)	1	1	1	1	4 (100%)
29	Malik et al., (2006)	1	1	0	1	3 (75%)
30	Oh et al., (2010)	1	1	1	1	4 (100%)
31	Raiter et al., (2007)	1	1	1	1	4 (100%)
32	Riba et al., (2002)	1	0	1	0	2 (50%)
33	Rodoplu et al., (2005)	1	1	1	1	4 (100%)
34	Shah et al., (2015)	1	1	1	1	4 (100%)
35	Tham (2003)	1	1	0	1	3 (75%)
36	Goh et al.,, (2007)	1	1	0	1	3 (75%)
37	Umer et al., (2009)	1	1	0	1	3 (75%)
38	Waage et al., (2013)	1	1	1	1	4 (100%)
	Training, Exercises & Knowledge					
39	Alexander, A., (2004)	1	1	0	1	3 (75%)
40	Candiotti et al., (2005)	1	1	1	1	4 (100%)
41	Cohen et al., (2012)	0	1	1	1	3 (75%)
42	Djalali et al., (2016)	1	0	1	0	2 (50%)

43	Filoromo et al., (2003)		1	0	0	0	1 (25%)
44	Jasper et al., (2005)		1	1	0	1	3 (75%)
45	Klein & Atas, (2005)		0	1	0	0	1 (25%)
46	Klima et al., (2011)		1	1	0	0	2 (50%)
47	LeRoy Heinrichs et al., (2010)		1	1	0	1	3 (75%)
48	Martz et al., (2011)		1	0	0	1	3 (75%)
49	Schultz et al., (2012)		1	0	1	0	2 (50%)
50	Vinson D.O. (2007)		1	0	0	0	1 (25%)
	Personal Protective Equipment						
51	Brinker et al., (2008)		1	1	1	0	3 (75%)
52	Castle et al., (2010a)	Qual	1	0	1	0	
		Quan	1	1	1	1	
		MM	1	1	0		2 (50%)
53	Castle et al., (2010b)		1	1	1	1	4 (100%)
54	Castle et al., (2010c)		1	1	0	0	2 (50%)
55	Claret et al., (2016)		1	1	1	1	4 (100%)
56	Flaishon et al., (2004)		0	0	1	1	2 (50%)
58	Schumacher et al., (2015)		1	1	1	0	3 (75%)
	Decontamination						
59	George et al., (2002)		1	1	0	1	3 (75%)
60	Hood et al., (2011)		1	0	0	0	1 (25%)
61	Timm & Reeves (2007)		1	0	1	1	3 (75%)
	Triage						
62	Ashkenazi et al., (2006)		1	1	1	1	4 (100%)
63	Lee et al., (2014)		1	1	1	1	4 (100%)
64	Satterthwaite &Atkinson (2010)		1	1	0	0	2 (50%)

	Management					
65	Cone & Cummings (2006)	1	1	1	1	4 (100%)
66	Masterson et al., (2009)	1	1	1	1	4 (100%)
	Technology					
67	Reddy et al.,(2009)	1	1	1	0	3 (75%)
68	Zhu et al., (2007)	1	0	1	0	2 (50%)

Appendix 3. Table of included studies

Study	**Study type and** study design	**Population and setting**	**Aim**	**Summary of main findings**	**Quality Rating (MMAT)**
Al-Damouk & Bleetman, (2005) [UK]	**Mixed method.** Quantitative survey, qualitative observations and debriefing in two simulated chemical and blast incidents.	192 hospitals 32 ambulance trusts for surveys. Two EDs involved in simulations.	To assess the impact of Department of Health initiative on acute hospital and ambulance Trusts to equip and manage chemically contaminated victims.	Practical difficulties exist with PPE suits.	3 (75%)
Alexander et al., (2005) [Canada]	**Quantitative.** Observational Study.	18 emergency doctors	To evaluate interactive web-based disaster planning curriculum with real time disaster exercise.	Scenarios were enjoyable, realistic and relevant.	3 (75%)
Allegra, et al., (2001) [USA]	**Quantitative**. Retrospective analysis of ED visits for Concern for Exposure (CE) of anthrax.	15 EDs over a 4-month period from 1 month before 9-11 to 2 months after October 11	Identify and characterise ED visits by patients concerned with exposure to e anthrax in 2001.	An increase in CE visits occurred during the 1-month period after October 11, 2001.	2 (50%)
Anathallee et al., (2007) [UK]	**Quantitative.** Descriptive telephone survey.	261 hospitals with ED. Duty sister/charge nurse/duty shift leaders.	To assess current facilities and procedures in UK EDs for the management of potential biological incidents.	EDs in the UK are not prepared for emerging biological threats.	4 (100%)

Ashkenazi et al., (2006) [Israel]	**Quantitative.** Descriptive retrospective analysis of patient records.	104 victims from explosive MCIs.	To assess the precision of triage in MCIs.	Primary triage, even when carried out by experienced trauma Doctors, can be unreliable in a MCI.	4 (100%)
Becker & Middleton, (2008) [USA]	**Qualitative.** Exploratory focus group study.	77 ED nurses and doctors	To understand the perceptions, concerns, information needs, preferred information sources, and views of existing guidance and information related to radiological terrorism.	Hospitals and EDs are not sufficiently prepared for a terrorist event involving radioactive materials.	3 (75%)
Bloch et al., (2007) [a] [Israel]	**Quantitative.** Descriptive. Disastrous Incidents Systematic Analysis Through-Components, Interactions, Results. (DISAST-CIR)	131 victims taken to nearby hospitals following an explosion.	Identify lessons learned from the medical response to a terrorist explosion.	Distribution of casualties from the scene plays a vital role in the management of a MCI.	4 (100%)
Bloch et al., (2007) [b] [Israel]	**Quantitative.** Descriptive study.	64 patients presented to ED.	To describe the characteristics and lessons learned from a terrorist explosion.	After an explosion, a large number of mildly injured victims experiencing stress are to be expected, without a direct relation to the attack.	4 (100%)
Braun et al., (2004) [USA]	**Quantitative.** Descriptive survey.	223 hospitals pre and post 9-11. Staff most familiar with the hospital's emergency management plan.	To evaluate the effectiveness of the links between accredited hospitals and other key entities in responding to a bioterrorism event.	Before 9-11 few hospitals addressed bioterrorism in their emergency management plans. By 2002 majority of responding hospitals had a bioterrorism response plan.	4 (100%)

Brinker et al., (2008) [UK]	**Quantitative.** Descriptive survey.	28 emergency medicine registrars. 47 anaesthetic registrars.	Evaluate PPE knowledge amongst emergency doctors and anaesthetists.	Greatest awareness surrounding SARS. Fair knowledge was found about anthrax, plague Ebola and smallpox. Knowledge about PPE was limited. Knowledge about personal protection measures for biological agents was acceptable and limited for chemical agents.	3 (75%)
Candiotti et al., (2005) [USA]	**Qualitative.** Descriptive survey.	90 anaesthetic accreditation programmes.	To determine level of clinical management training provided to doctors for patients exposed to WMDs (Chemical, Biological, and Nuclear events)	Most anaesthetic residency programmes in the USA provided little or no training to management of WMD events.	4 (100%)
Castle et al., (2010a) [UK]	**Quantitative.** Randomised Control Trial.	81 participants: Emergency nurses, nurse lecturers, paramedics, paramedic lecturers, and paramedic students.	To evaluate the impact of the CBRN-PPE on drawing up of drugs from glass ampoules, plastic ampoules, or pre-filled syringes.	NHS CBRN PPE has a negative effect on the drawing up of drugs especially from glass ampoules.	4 (100%)
Castle et al., (2010b) [UK]	**Mixed methods**. Quantitative and qualitative. Clinicians secured ET tube and were then interviewed.	75 clinicians: Anaesthetics consultants, registrars, ED doctors, pre-hospital doctors, paramedics and resuscitation officers.	Assess the impact of CBRN-PPE on the ability to secure an ETT with either the Thomas tube holder or cotton tape tied in a knot.	Thomas tube holder is easier and faster to apply when wearing CBRN-PPE in comparison to cotton tied in a knot.	2 (50%)

Castle et al., (2010c) [c], [UK].	**Qualitative.** Interviews.	25 participants who were anaesthetists and paramedics.	To evaluate which IADs (Intermediate Airway Device) should be used by professionals in PPE during CBRNe events.	Heavy bias towards using Laryngeal Mask Airway and I-gel.	2 (50%)
Claret et al., (2016) [France]	**Quantitative.** Prospective randomised crossover study.	41 ED doctors.	To evaluate the performance of orotracheal intubation with the Miller laryngoscope compared to the Airtraq laryngoscope wearing CBRN-PPE type III, on infant manikins.	Orotracheal intubation success rate with the Airtraq laryngoscope was higher than with the Miller laryngoscope.	4 (100%)
Cohen et al., (2013) [UK]	**Qualitative.** Semi-structured interview using virtual scenarios.	23 Pre- hospital and hospital clinicians.	Determine feasibility of virtual world environments for training.	Content validity of low-cost virtual worlds for incident simulation has been established.	3 (75%)
Cone & Cummings (2006) [USA]	**Quantitative.** Descriptive survey.	1,704 hospital workers who were nurses, physicians, physician assistants/ nurse practitioners and other clinical staff.	To assess hospital employees attitudes and needs regarding work commitments during disasters.	Greater willingness to work after natural disasters than after manmade disasters.	4 (100%)
Considine & Mitchell, (2009) [Australia]	**Quantitative** Disaster preparedness survey.	64 ED nurses.	Explore issues related to disaster preparedness of emergency nurses.	Most nurses were willing to participate in CBR incidents. Willingness decreased with unknown chemical or biological agent.	3 (75%)
De Ceballos et al., (2005) [Spain]	**Mixed methods.** Descriptive case study.	312 victims following 10 commuter train explosions.	Review in hospital triage. Patterns of injuries', and care of the victims.	There was an over-triage to the closest hospital.	4 (100%)

Djalali et al., (2016) [Italy]	**Qualitative.** Modified 3 step Delphi method.	15 experts.	To determine competencies required by hospital staff when responding to CBRN emergencies.	Identified a set of core competencies and specific knowledge and skills required by medical staff to respond to CBRN emergencies.	2 (50%)
Duong, (2009) [Australia]	**Mixed method.** Exploratory survey.	Senior nurses working within 8 EDs.	Examine emergency nurse's knowledge and understanding of disaster response in healthcare settings.	Nurses perceived themselves to have a decreased level of disaster preparedness.	4 (100%)
Durukan et al., (2009) [Turkey]	**Qualitative.** Descriptive case study.	41 patients admitted to the ED with diagnosis of endosulfan poisoning.	Describe characteristics of patients with acute endosulfan mass poisoning	Healthcare professionals should understand the hazards associated with pesticide use. As well as the diagnosis and treatment of such presentations.	4 (100%)
Einav et al., (2006) [Israel]	**Quantitative.** Descriptive study of patient records.	325 victims from 32 events.	To suggest guidelines for hospital organisation during terror related MCIs.	High staffing demands for ED, operating theatres, and Intensive Care Units overlap.	4 (100%)
Flaishon et al., (2004) [Israel]	**Quantitative.** Cross-over study.	15 Anaesthetists.	To ascertain whether surgical attire or anti-chemical protective gear makes a difference in controlling the patient's airway. Compared endotracheal tube with laryngeal mask airway.	Laryngeal mask airway insertion is faster than tracheal intubation when wearing protective gear.	2 (50%)
George et al., (2002) [UK]	**Quantitative.** Descriptive audit.	261 EDs in Scotland, Wales and Northern Ireland.	Audit the facilities for chemical decontamination. Specifically, for cyanide poisoning.	Only a minority of departments were satisfactorily equipped to deal with a serious chemical incident.	3 (75%)

Goh, Tiah & Lim, (2007) [Singapore]	**Qualitative.** Retrospective Descriptive case study	22 patients who were victim to a smoke inhalation incident.	Description of the triage criteria that were modified and adopted for a unique MCI.	Modified triage criteria with selective use of fibre optic examinations, chest radiography and arterial blood gas analysis are useful in smoke inhalation MCIs.	3 (75%)
Jasper et al., (2005) [USA]	**Mixed Methods.** Quantitative descriptive and observation of a multi-hospital large scale exercise.	11 hospitals.	Exercise was deigned to determine the level of preparedness of hospitals to respond to a radiological terrorism event. To additionally promote long term learning for staff at participating hospitals.	Hospitals are well prepared for a terrorism event that involves a radiological dispersion device. However, there is difficulty in maintaining readiness for events that are rare or never encountered.	3 (75%)
Kaji & Lewis (2006) [US]	**Quantitative.** Descriptive. Cross-sectional telephone survey which was followed by an onsite survey.	45 designated 9-1-1 receiving hospitals.	To characterise disaster preparedness among a cohort of hospitals focusing on practice variation, plan characteristics, and surge capacity.	Disaster preparedness and surge capacity are limited by a failure to fully integrate interagency training and planning.	2 (50%)
Klima et al., (2011) [USA]	**Mixed Methods:** Descriptive statistics. Simulation of an MCI involving a chemical spill.	16 hospitals.	To evaluate the results of a multidisciplinary and multi-organisation Full Scale Regional Exercise (FSRE).	Communication remains a significant gap in the mass casualty scenario. FSREs should be routinely performed to prepare for catastrophic events.	2 (50%)
Kollel & Cwinn (2011) [Canada]	**Quantitative.** Survey.	34 ED chiefs or physicians designated to complete the survey.	To use the Hospital Emergency Readiness Overview (HERO) to assess the readiness of the EDs in Canada at organisational and administrative levels.	Gaps in Canadian healthcare facility readiness for disasters, specifically one involving contaminated patients. There is a lack of standardised assessment	3 (75%)

				of healthcare facilities and CBRN readiness is lacking.	
Kollek, (2003) [Canada]	**Quantitative.** Cross sectional online survey.	53 ED chiefs.	To review the risks and characteristics of CBRN events and to assess the preparedness of Canada EDs to respond.	Canadian EDs and by inference Canadian hospitals are unprepared for a CBRN event.	3 (75%)
Kotora, (2015) [USA]	**Quantitative**. Retrospective observational online survey.	191 doctors, mid-level providers and nurses employed in the ED.	Evaluated the CBRNe preparedness of doctors, nurses and midlevel providers in an urban tertiary care ED.	Emergency care providers are inadequately prepared to manage CBRNe incidents. A valid and precise instrument capable of ensuring preparedness needs to be developed.	2 (50%)
Lee & Franc., (2015) [Canada]	**Quantitative.** Prospective observational cohort study. Simulation study.	21 emergency medicine resident physicians and 2 triage nurses. .	To examine the impact of a two-step ED triage model using Simple Triage And Rapid Treatment (START) for pre-triage. Followed by triage with the Canadian Triage and Acuity Scale (CTAS), on patient flow during a virtual MCI simulation exercise.	Experienced triage nurses were able to apply the CTAS effectively during simulation exercise. A 2 step ED triage model using START and the CTAS had similar patient flow and triage accuracy when compared to START alone.	4 (100%)
LeRoy Heinrichs et al., (2010) [USA]	**Mixed method. Quantitative** Descriptive questionnaires, observation on Virtual Emergency Department (VED) ii for chemical and radiological events.	10 Doctors 12 Nurses	Determine whether VED ii, is an effective clinical environment for training ED clinicians.	A virtual environment is an effective method of training for CBRNe events.	3 (75%)

	Followed by focus groups.				
Malik et al., (2006) [Pakistan]	**Quantitative.** Descriptive case study.	161 victims.	To determine the effectiveness of hospital management, triage system, hospital staff response, medical resources availability and surgical management of a mass casualty incident.	Mass Casualty management in a terrorist attack requires prompt hospital response, appropriate triage, efficient surgical approach, and dedicated post-operative care.	3 (75%)
Martz et al., (2011) [USA]	**Qualitative.** Descriptive study based on scenario drills.	-FBI -Army 415th brigade -Wisconsin national guard -Wisconsin department of health services -US coast guard Fire department. -Sheriff's department. -Police department. 3 hospitals.	To review the "Red dragon drill" largest multi-agency Radioactive Dispersal Device scenario.	Communication is not timely or reliable. Staff turnover rates can significantly impact knowledge base. Decontamination conducted by first responders must be verified.	3 (75%)
Masterson et al., (2009) [USA]	**Quantitative.** Descriptive survey.	204 participants from 8 hospitals. ED doctors nurses, and support staff.	To examine willingness to respond to various MCIs.	Staff members were more willing to work additional hours for victims of an aeroplane crash than for a radioactive bomb or a biological agent.	3 (75%)
Mitchell. et al., (2012) [Northern Ireland]	**Quantitative.** Competency questionnaire, cross sectional survey and clinical audit.	50 staff: in 3 EDs consisting of a mixture of skilled nurses.	Identify areas where ED nurses may need training and support to improve their response to a CBRNe incident.	Key areas identified for training: - Waste management - Triage - Chain of command	4 (100%)

				- Awareness of the range of PPE and appropriate use -Decontamination	
Niska & Burt, (2005) [USA]	**Quantitative.** Descriptive survey.	294 Hospitals with 24-hour ED or outpatient department supervised by a doctor.	To provide a descriptive summary of the responses from which national estimates of preparedness can be generated for overall US hospitals.	Almost all hospitals have plans for responding to national disasters (97.3%). Most have plans for responding to chemical (85.5%), biological (84.8%), nuclear or radiological (77.2%) and explosive incidents (76.9%).	2 (50%)
O' Sullivan, et al., (2008) [Canada]	**Quantitative.** Survey.	1,543 ED and ITU nurses.	To test 3 hypotheses: 1. Nurses will have higher preparedness for infectious diseases and natural disasters than CBRN events. 2. Perception of preparedness will vary according to previous outbreak experience. 3. Personal preparedness will be related to institutional preparedness.	Nurses felt least prepared to respond to a CBRN event. Nurses with previous outbreak experience felt more prepared. Nurses felt their institutions were under prepared to respond to a large-scale disaster.	3 (75%)
Oh et al., (2010) [Singapore]	**Descriptive.** Case review.	11 victims exposed to pepper spray.	To describe the ED response to the event, the spectrum of patient presentation, and their respective treatments.	Effects of pepper spray are typically self-limiting. Secondary exposure within a crowded public area can result in multiple casualties.	4 (100%)

Raiter et al., (2007) [Israel]	**Quantitative.** Descriptive. Disastrous Incidents Systematic Analysis Through-Components, Interactions, Results. (DISAST-CIR).	91 victims.	To describe and draw lessons about the management, of victims at hospitals close to an explosion.	The rapid accumulation of Emergency Medical Services vehicles combined with effective primary triage between five hospitals enabled a rapid conclusion of the event.	4 (100%)
Rassin et al., (2007) [Israel]	**Quantitative**. 41-item questionnaire.	104 doctors and nurses working in, or responding to the ED.	To examine the preparedness level of ED staff to deal with Mass Casualty Events (MCEs) involving paediatric victims.	Preparedness levels for MCEs involving children were low.	4 (100%)
Reddy et al., (2009) [USA]	**Qualitative**. Focus groups implementing a crisis scenario.	21 Clinicians (EMS and ED).	Identify challenges in co-ordination.	Challenges identified: Ineffectiveness of current ICTs and breakdowns in information flow.	3 (75%)
Riba et al., (2002) [Israel]	**Qualitative.** Focus groups.	Approximately 45 ED, ITU, operating theatre, and imaging department nurses.	Investigate the perceptions, reactions and feelings of nurses who cared for victims of multi-casualty terrorism in the ED.	Four stages of personal and professional involvement from nurses. 1. Call up for duty. 2. Waiting for causalities to arrive. 3. Treating the victims. 4. Closure of the event.	2 (50%)
Rodoplu et al., (2005) [Turkey]	**Quantitative.** Retrospective descriptive study.	69 victims.	Estimate the impact of open-air mass bombings on a hospital.	Three waves of injured survivors. First wave: primary injured survivors with mostly minor injuries. Second wave: overlapping wave made up of primary injured survivors with more serious	4 (100%)

				injuries. Third wave: secondary injuries transferred to the ED from other hospitals.	
Satterthwaite & Atkinson (2010) [Australia]	**Qualitative.** Descriptive case study.	30 victims.	Analyse the impact of reverse triage, to create surge capacity for disaster victims.	Reverse triage resulted in no increase in clinical risk.	2 (50%)
Schultz et al., (2012) [USA]	**Qualitative.** Modified Delphi technique.	16 doctors, nurses, and emergency medicine technicians.	Determine the knowledge and skills needed to effectively recognise and treat acute injuries and illnesses resulting from disaster events. Additionally, to create comprehensive disaster core competencies.	A framework of 19 content categories and more than 90 performance objectives were developed for clinicians to address the requirements of an all hazards disaster response.	2 (50%)
Schumacher et al., (2015) [UK]	**Quantitative.** Descriptive survey.	98 specialist registrars.	To assess the knowledge of respiratory and skin protection requirements needed during a resuscitation scenario with Advanced Life Support.	Current knowledge regarding PPE for chemical warfare agents is very limited.	3 (75%)
Shah et al., (2015) [Pakistan]	**Quantitative.** Retrospective descriptive review.	200 victims.	To share the experiences of a tertiary care facility in a low middle-income healthcare setting in dealing with trauma victims from an explosion.	In countries with no pre-hospital triage system, implementing a pre-existing disaster plan with pre-defined interdisciplinary responsibilities can streamline in-hospital management of casualties.	4 (100%)
Tham (2004), [Singapore]	**Qualitative.** Descriptive Case study	11,461 patients who were screened for Severe Acute	Describe the interventions adopted by the ED and hospital to contain SARS.	Although SARS was not a bioterrorism event, the ED disaster response was applicable in the outbreaks management.	3 (75%)

		Respiratory Syndrome (SARS).			
Timm & Reeves (2007) [USA]	**Qualitative.** Descriptive case study.	53 paediatric patients and 3 adults.	To summarise hospital's response, lessons learned, and general disaster planning recommendations in a MCI involving contaminated children.	Hospitals should include children in their disaster exercises. Most victims of disasters will not be triaged, decontaminated or brought by EMS to the ED. Decontamination of children involves special considerations.	3 (75%)
Treat, et al., (2001) [USA]	**Qualitative.** Interviews.	40 hospitals 17 ED medical directors and 13 ED nurse Managers	Assess the training needs of emergency personnel for Weapons of Mass Destruction (WMD) preparedness in hospitals.	Hospitals are not prepared for WMD events. Especially in areas such as mass decontamination, mass medical response, awareness, health communications, and security.	4 (100%)
Umer et al., (2009), [Pakistan]	**Quantitative.** Descriptive case study.	36 victims from bus incident 104 victims from explosion.	To describe the management and outcome injuries of the 2 explosions. To further reflect on the process of care in a developing country.	Vital to understand the patterns of injury and logistical problems that result.	3 (75%)
Waage et al., (2013) [Norway]	**Quantitative** Descriptive retrospective case study following shooting incident.	35 victims from a shooting incident.	To describe the hospitals surge capacity and analyse the hospital major incident plan.	Deviation from the major incident plan was needed. Communication systems and the organisation of radiological (scanning) services were most vulnerable.	4 (100%)
Wetter, et al., (2001) [USA]	**Quantitative**. Cross-sectional questionnaire survey.	186 hospitals. Most responses were from registered nurses (87%, n=162).	Examine hospital preparedness for incidents involving chemical or biological weapons.	EDs are generally not prepared to treat victims of chemical or biological terrorism.	3 (75%)

Whetzel et al., (2013) [USA]	**Quantitative.** Descriptive survey. Literature review followed by descriptive survey.	177 emergency nurses.	Assess nurse's perception of their role in a disaster and their perceived susceptibility to a disaster.	Emergency nurses have not taken basic actions to prepare themselves for disasters either personally or professionally.	2 (50%)
Williams, et al., (2007) [UK]	**Qualitative.** Semi-structured interviews.	18 participants consisting of nurse managers, senior nurses, consultants, and emergency planners.	Assess the preparedness of hospitals for the management of a chemical incident.	Deficiencies in planning facilities, equipment, and training.	3 (75%)
Wong et al., (2006) [UK]	**Quantitative.** Questionnaire survey.	179 registrars.	Evaluate the preparedness of middle grade staff and hospitals for major incidents.	Preparedness for major incidents in the UK remains poor.	3 (75%)
Zhu et al., (2007) [USA]	**Qualitative.** Focus groups.	21 EMS and ED teams.	Understand the challenges associated with decision making and examine ways to support and improve them.	A simulation of R-CAST-MED enabled efficient information management.	2 (50%)

Appendix 4. Table of excluded studies

Study	**Study type and** study design	**Population and setting**	**Aim**	**Summary of main findings**	**Quality Rating (MMAT)**
Connor & White (2003) [UK]	**Qualitative**. Telephone survey.	Key medical personnel at 5 hospitals.	To find out whether medical staff knew of their hospitals policy concerning chemical release and their individual role in that policy.	Reported preparedness does not equate with actual preparedness.	1 (25%)
Shiekh et al., (2012) [USA]	**Quantitative.** Cross sectional electronic survey.	309 emergency medicine residents and faculty doctors.	To assess the attitudes of emergency medicine residents and faculty toward a radiological disaster.	Only 37% and 28% of respondents had attended radiological preparedness training in the preceding 5 years or any training in radiation detection. Many respondents were unable to differentiate between contamination with and exposure to radiological material.	1 (25%)
Dayan et al., (2005) [Israel]	**Qualitative.** Descriptive case study.	Patients involved in suicide bombing and 8 victims.	To examine risks and benefits of “scoop and run” triage in a small MCI.	When an MCI occurs most of the severely injured patients should be evacuated to the nearest level A trauma centre to enhance the completion of definitive treatment.	1 (25%)
Filoromo et al., (2003) [USA]	**Qualitative.** Descriptive study.	50 medical students.	Educate clinicians in event detection, diagnosis, treatment options, and appropriate infection control measures.	Successful application of screen savers.	1 (25%)
Klein & Atas, (2005) [USA]	**Mixed methods.** Observation of tabletop exercise.	23 hospitals, 4 health departments, representative from 1 federal agency.	To describe a multiple hospital bioterrorism exercise.	Having an independent observer group at an exercise appears to provide a value-added benefit for capturing subjective information and data.	1 (25%)

Vinson, (2007) [USA]	**Qualitative.** Observation	150 bed hospital.	To test 6 basic concepts developed from the SARS outbreak.	6 concepts identify critical areas in the effective management of bio contaminated victims and could also be used to manage highly virulent viral bacterial outbreaks. 1 lockdown the ED 2 project emergency care personnel 3decontamiante and triage patients 4 isolate patients 5 treat patients with appropriate medications or measures 6 use restrictive admission and transfer guidelines.	1 (25%)
Hood et al., (2011) [USA]	**Quantitative.** Case study of Decontamination	ED staff-roles not specified.	To determine whether current hospital-based emergency decontamination teams can effectively decontaminate victims of chemical, biological, or radioactive agent contamination.	Hospital preparedness for mass casualty decontamination is minimal at best.	1 (25%)

Appendix 5. Guidance to carry out HTA

Annett (2003)	Shepherd (2001) & (2015)	Stanton (2006)
1. Decide on purpose of analysis 2. Determine task goals and performance criteria 3. Identify source of task information 4. Acquire data and draft decomposition table/diagram 5. Recheck validity of decomposition with stakeholders 6. Identify significant operations considering the purpose of the analysis 7. Generate and test hypothetical solutions to the performance problems identified in the analysis	1. Identify the main goal to be analysed 2. Explore its constraints 3. Explore whether the goal will be met to an acceptable standard given prevailing circumstances 4. Cease further analysis at this point 5. Examine the operation and the human-task interaction 6. Estimate the cost-benefits of the hypothesis 7. Record the hypothesis and cease further analysis at this point 8. Attempt to re-describe the goal 9. Seek advice or review constraints 10. Identify the next goal to be examined	1. Define the purpose of analysis 2. Define the boundaries of the system description 3. Access a variety of sources of information about the system to be analysed 4. Describe the system goals and sub goals 5. Try to keep the number of immediate sub goals under any superordinate goal to a small number (between 3 and 10). 6. Link goals to sub goals, and describe the conditions under which sub goals are triggered 7. Stop re-describing the sub goals when you judge the analysis fit for purpose 8. Try to verify the analysis with the subject matter experts. 9. Be prepared to revise the analysis

Appendix 6. Participant information sheet

HFE review of the ED response to CBRN events

Participant Information Sheet

Chief Investigator: Saydia Razak, Doctoral Research Student, Loughborough Design School, LDS 2.22. Loughborough University Leicestershire, LE11 3TU, UK. S.Razak@lboro.ac.uk. 01509223567.

Supervisor: Professor Sue Hignett, Professor of Healthcare Ergonomics and patient safety, Loughborough Design School, LDS 2.10, Loughborough University Leicestershire, LE11 3TU, UK. S.M.Hignett@lboro.ac.uk. 01509223003.

Project Title

Human Factors (Ergonomics) review of the Emergency Department response to Chemical, Biological, Radiological, and Nuclear events.

Invitation

We would like to invite you to participate in a study based on the Emergency Departments (ED) response to Chemical, Biological, Radiological, and Nuclear (CBRN) events. Before you decide if you would like to participate, it is important for you to understand why this study is being done and what it involves. Please take time to read the following information carefully. The study has been discussed with ED Consultants, Matrons and the Hospital Research Department, who are happy for you to participate. If you have any questions or require any further information please contact Saydia Razak on 01509223567 or email S.Razak@lboro.ac.uk.

What is the purpose of this study?

The purpose of the study is to take a Human Factors and Ergonomic approach, which is the study of how people interact with their environment for useful purposes to understand the current ED response to CBRN events.

Why have I been chosen?

You have been chosen because of your professional experience and expertise of working in the Emergency Department.

Are there any exclusion criteria?

- Under 18 years old.
- If you are not happy to sign the consent form.
- ED employee with less than 3 months experience in the ED.
- Agency employees/Locums.
- Student health care professionals.

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Who is doing this study and why?

This study is being conducted by Saydia Razak, a doctoral student to complete her PhD.

What will happen if I decide to take part?

1. Sign a consent form after reading this information carefully.
2. Be given the opportunity to ask any questions regarding the study.

What will I be asked to do?

You will be asked to participate in a study consisting of 2 activities.

Activity 1: Scenario card presentation

At a convenient time on shift, the Nurse in Charge or a Senior Colleague will ask you to see the Researcher in a designated room in your Emergency Department. Here, the Researcher will present a scenario card to you. You will be asked to guide the Researcher through your actions in response to that particular scenario. Your response is not expected to take more than 15-30 minutes.

It is entirely up to you to decide if you wish to respond to a scenario, and you are free to ask the interviewer to move to another scenario or stop the scenario at any point. Your responses will be noted down through field notes. The Researchers will use the anonymised scenario responses to describe the current ED response to CBRN events by applying Human Factors and Ergonomics research methods.

Activity 2: Group interview discussion

At a convenient time on shift, the Nurse in Charge or a Senior Colleague will ask you and up to 4 of your colleagues to see the Researcher in a designated room in your Emergency Department. Here, you will be asked to answer questions based on the findings of activity one. You will also be shown anonymised diagrammatic findings, from activity 1 on a screen or through paper representations, and asked to discuss these. Discussions will be recorded on a password protected audio recording device. After the group based interview discussion, what you have said will be transcribed (typed into a word document) and stored using a unique identification code. The recording will then be deleted after 6 months. The transcriptions will then be analysed and findings interpreted according to your discussions.

Will I benefit from taking part in the study?

Whilst the study is not designed to give direct benefit to participants, your contributions will give a review of current practice and potentially inform future clinical practice to respond to CBRN events.

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Do I have to take part?

No. it is entirely up to you whether you take part and are free to withdraw at any time during the research without giving any reason. Your decision about participating in the study will not affect your job role in the ED in anyway.

Once I take part, can I change my mind?

Yes. After you have read this information and asked any questions you may have, I will ask you to complete the consent form, however if at any time, before, during or after the sessions you wish to withdraw from the study please contact the research team. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing. However, once the results of the study (1 week after participation) are aggregated and entered onto a database for analysis it will not be possible to withdraw your individual data from the research.

Will I be required to attend any sessions and where will these be?

You will be asked to attend the group interview session, which will be conducted in the seminar room of your ED.

How long will it take?

Activity 1: Scenario card presentation: 30 minutes on shift.

Activity 2: Interview discussion: 30 minutes on shift.

Approximately 1 hour of your time is envisaged to be taken.

What personal information will be required from me?

- Age
- Gender
- Name (on eligibility sheet)
- Contact number (on eligibility sheet)
- Profession
- Professional registration body
- Length of employment in the NHS
- Length of employment in the ED

Are there any risks in participating?

There is no risk associated with taking part in the study.

Will my taking part in this study be kept confidential?

HFE review of the ED response to CBRN events

You will be given a unique identification code and any information taken from this study will be stored using this code, to ensure that the information is anonymous. Group interviews and focus groups will be recorded on a password protected device and listened to and transcribed (written up) by the Researcher. The hard copies of these discussions will be kept in a locked room and a locked cupboard for 10 years.

Who is organising and funding the research?

The study is being organised and funded by the Loughborough University Design School.

Who has reviewed the study?

The study has been reviewed and been given an independent peer review which was organised by Loughborough University. The study has received Health Research Authority (HRA) approval and approval from Loughborough Ethics Approvals (Human Participants) Sub-Committee; and your Trust Research and Development department have reviewed the study.

I have some more questions; who should I contact?

You can contact Saydia Razak or Sue Hignett whose details are at the top of this information sheet.

What will happen to the results of the study?

The results will be analysed by the Researcher and will help to map out the ED response to CBRN events. The results may also be published in healthcare journals and presented at conferences, but you will not be identifiable in any of the results including publications or lectures. The results will contribute to Saydia Razak's PhD thesis.

If you would like to be updated about the results of the study you should ask Saydia Razak to add your details to the mailing list for updates.

What if I am not happy with how the study was conducted?

If you are not happy with how the study was conducted, please contact Ms Jackie Green, the Secretary for the University's Ethics Approvals (Human Participants) Sub-Committee:

Ms J Green, Research Office, Hazlerigg Building, Loughborough University, Epinal Way, Loughborough, LE11 3TU. Tel: 01509 222423. Email: J.A.Green@lboro.ac.uk

The University also has a policy relating to Research Misconduct and Whistle Blowing which is available online at http://www.lboro.ac.uk/committees/ethics-approvals-human-participants/additionalinformation/codesofpractice/

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What do I get for participating?

There is no payment for participating in the study. However, your name will be entered into a prize draw with a chance to win £30 in "love2shop" vouchers, as a means of thanking you for input. Once the findings have been collated, you will be given the opportunity to review current practice in CBRN events through a presentation organised by the research team.

Who do I contact for further information?

If you require more information about this study please contact a member of the research team, whose information is provided at the top of this information sheet.

Thank you for taking the time to read this informtion and for considering taking part in this study.

Appendix 7. Informed consent form

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HFE review of the ED response to CBRN events

Informed consent form

Human Factors (Ergonomics) review of the Emergency Department response to Chemical, Biological, Radiological, and Nuclear events.

IRAS ID: 219968 **Centre Number:**

Participant Identification Number:

Name of Chief Investigator: Saydia Razak **Please initial box**

The purpose and details of this study have been explained to me. I understand that this study is designed to explore the current ED response to CBRN events. ☐

All procedures have been approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee. ☐

I have read and understood the information sheet and this consent form. ☐

I have had an opportunity to ask questions about my participation. ☐

I understand that I am under no obligation to take part in the study, have the right to withdraw from this study at any stage for any reason, and will not be required to explain my reasons for withdrawing. ☐

If I wish to withdraw from the study, I will contact the Researchers within 1 week of my participation of the study, as I am aware that the data will begin to be analysed thereafter. ☐

I agree to take part in all components of this study. Taking part in the study will include being presented with scenario cards during a convenient time on shift and being a part of a group interview, which will include being recorded on a password protected audio recording device. ☐

Use of Information

I understand that all the personal information I provide will be treated in strict confidence and will be kept anonymous and confidential to the Researchers unless (under the statutory obligations of the agencies which the Researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others or for audit by regulatory authorities. ☐

I understand that anonymised quotes may be used in publications, reports, web pages, and other research outputs. ☐

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Name of participant [printed]	Signature	Date
______________________	______________________	________
Researcher [printed]	Signature	Date
______________________	______________________	________

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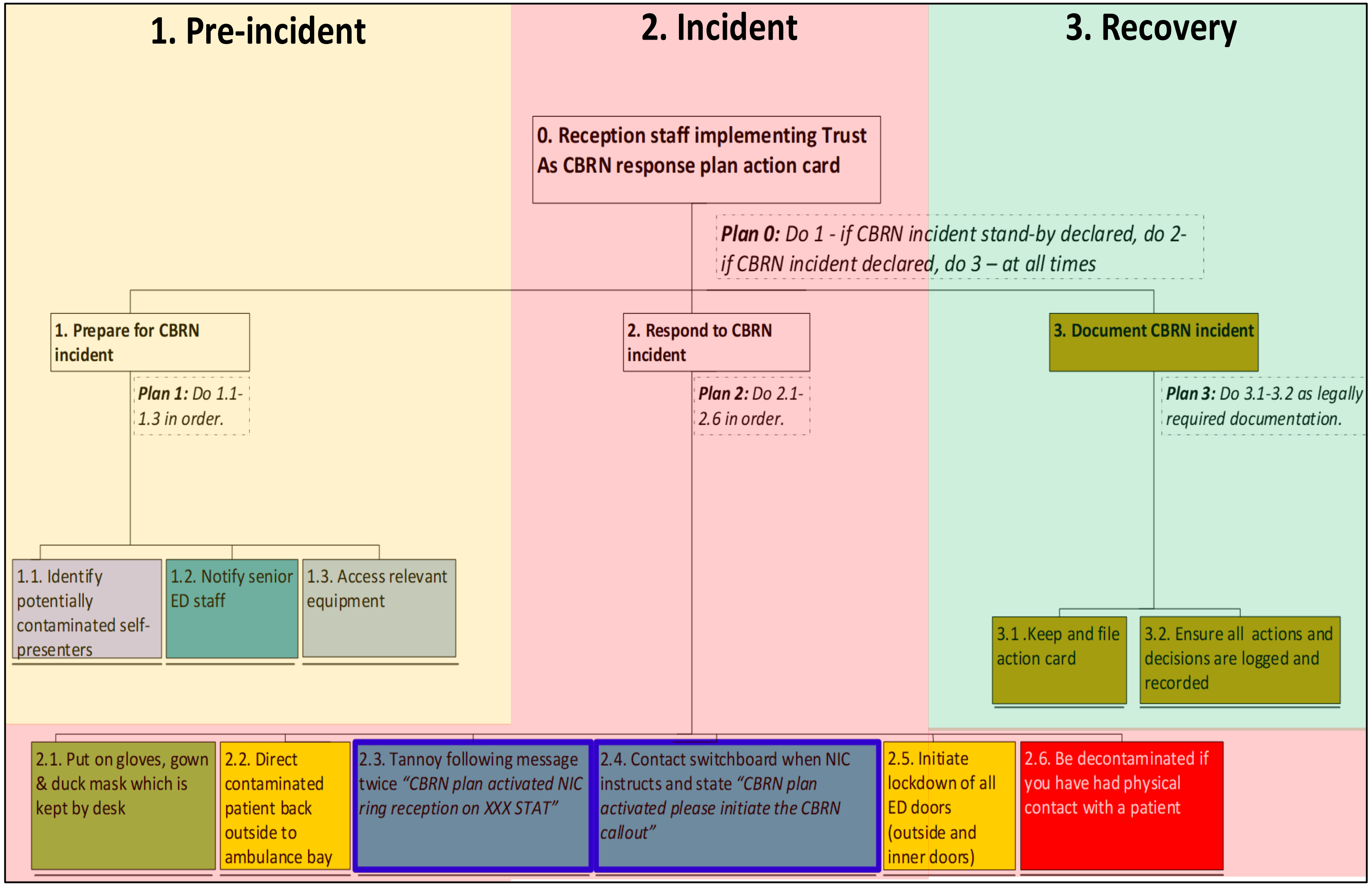
Appendix 8. Approval processes required before beginning data collection

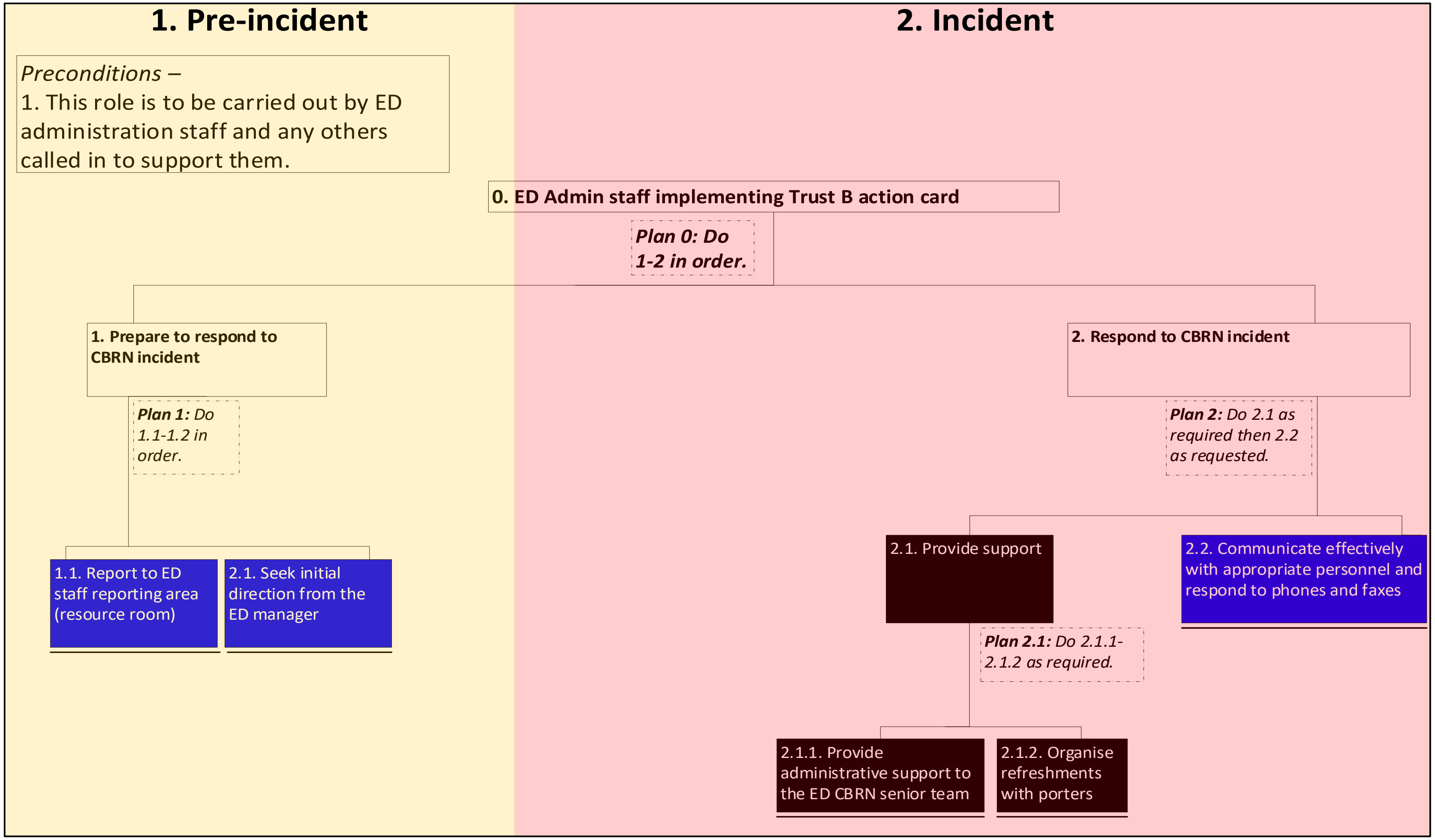
Process	Explanation	Was it required?
Obtaining a sponsor	Studies taking place within the NHS require a study sponsor. The study sponsor is the individual who takes the responsibility for the initiation, management and financing (Or arranging the financing) of the research. The sponsor needs to be satisfied that appropriate checks have been undertaken to ensure that the study meets the relevant standards and that there are arrangements in place for authorisation, management, monitoring and reporting (Altman, 2013).	Yes. The sponsor for this PhD was Loughborough University.
HRA approval	HRA Approval is the process for applying for approvals for all project-based research in the NHS led from England. The HRA approval process brings together the assessment of governance and legal compliance. It replaces the need for local checks of legal compliance and related matters by each participating organisation in England. In order to obtain HRA approval a schedule of events and statement of activities is required to ensure clarity implications for participating NHS organisations and others delivering research within an NHS care setting. Submitting the schedule of events and statement of activities enables participating NHS organisations In England to assess and confirm their capacity and capability to deliver the research (NHS HRA, 2017a).	Yes, because the PhD is project-based research within the NHS in England. Further to this requirement, local collaborators requested HRA approval NHS HRA. (2017b). Yes, these documents were filled and sent as a part of the Local Information Pack (LIP) to both study sites.
Is the project research?	Not all projects are classed as research for example service evaluations, audits and surveillance for which NHS organisations have local clinical governance arrangements(Altman, 2013). The HRA provide a decision tool (NHS HRA, 2017c).	The project was classed as research based on the findings being aimed to be generalisable.
Does the project require Research Ethics	NHS RECs are independent and impartial committees providing advice and approval of proposed research NHS REC approval considers the dignity, rights, safety and well-being of all current or potential participants. The review	NHS REC review was not required as a result of guidance obtained from the decision tool

Committees (REC) approval?	also takes into account the interests, needs and safety of researchers (Altman, 2013; DoH, 2005). Again the HRA provide a decision tool to distinguish whether a project requires REC approval (NHS HRA, 2017a)If projects pose minimal risks, burden, or intrusion to study participants they can be considered for proportionate review. REC review is not normally required for research involving NHS or social care staff recruited as research participants by virtue of their professional role (NHS HRA, 2011).	Proportionate review was not required due to the participants being recruited on virtue of their professional role within the NHS.
R&D approval	The R&D approval process involves an assessment of whether the project can be carried out locally and whether the resources can be made available (Altman, 2013).	R&D approval was required from both sites.
Obtaining access	There are two ways of obtaining access to participants within the NHS: 1. An NHS employee can obtain access to other NHS trusts by their substantive employer completing a "NHS to NHS pro forma confirmation of pre-engagement checks", which is sent to the other NHS trust which then grants the researcher a letter of access (NIHR, 2012). 2. Research passport systems allows higher education institution researchers without a NHS employment access to carry out research in NHS organisation by providing evidence of the pre-engagement checks undertaken on the researcher in line with NHS employment check standards (NIHR, 2017).	Yes. The research passport route was chosen, this is because the researcher was on a career break from her substantive employer.

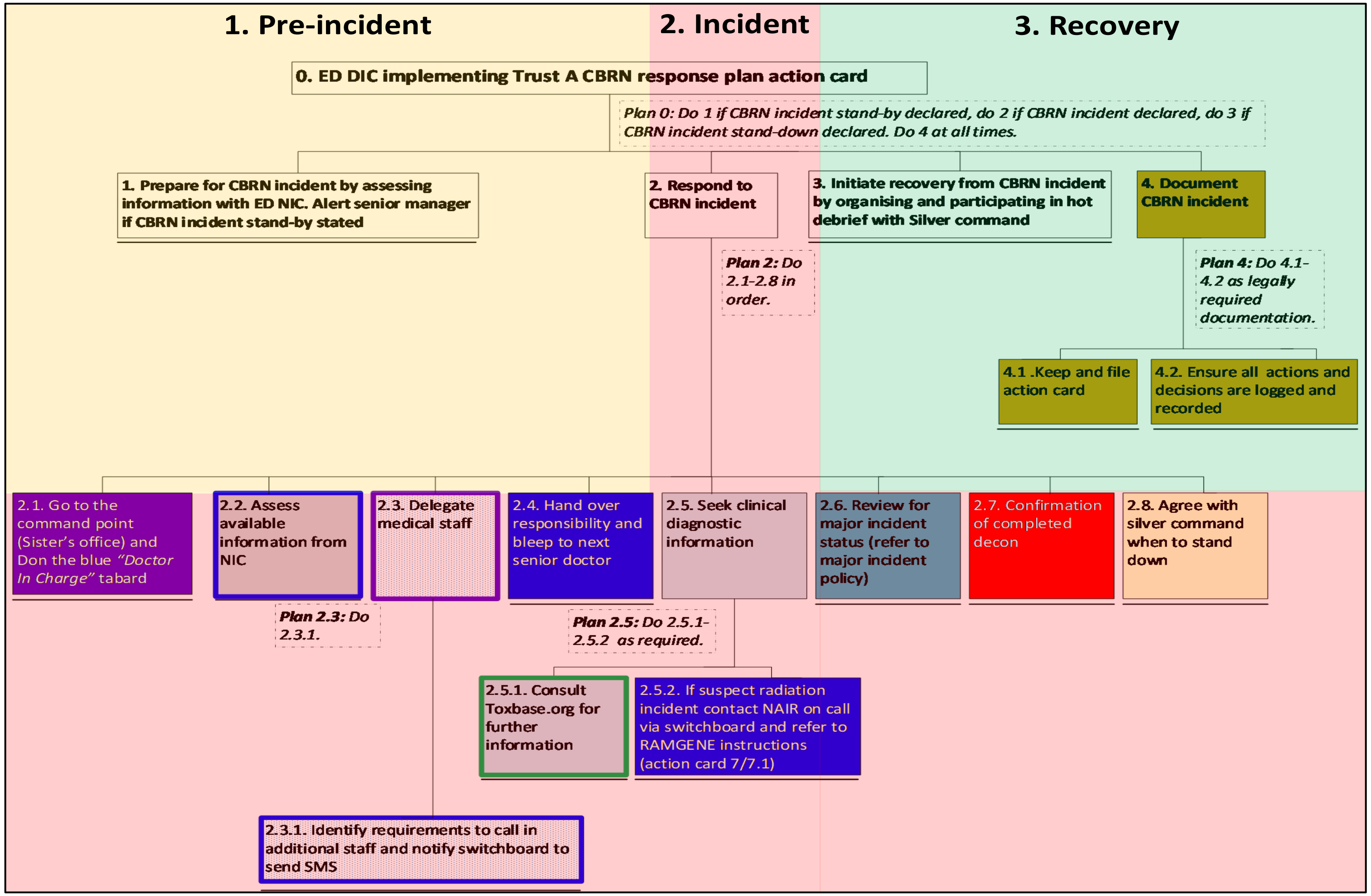
Appendix 9. Trust A: Receptionist action card



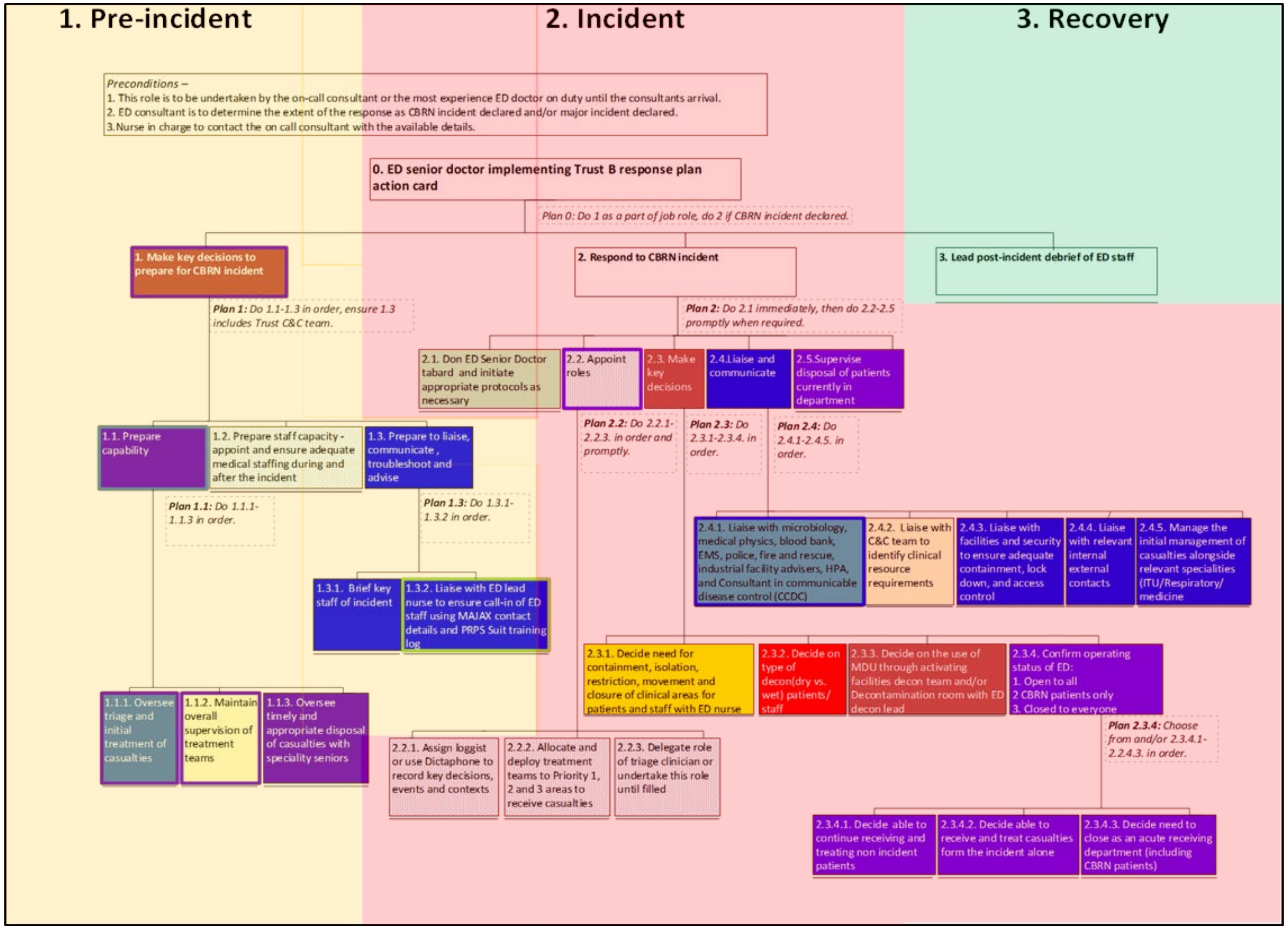
Appendix 10. Trust B: Administration staff



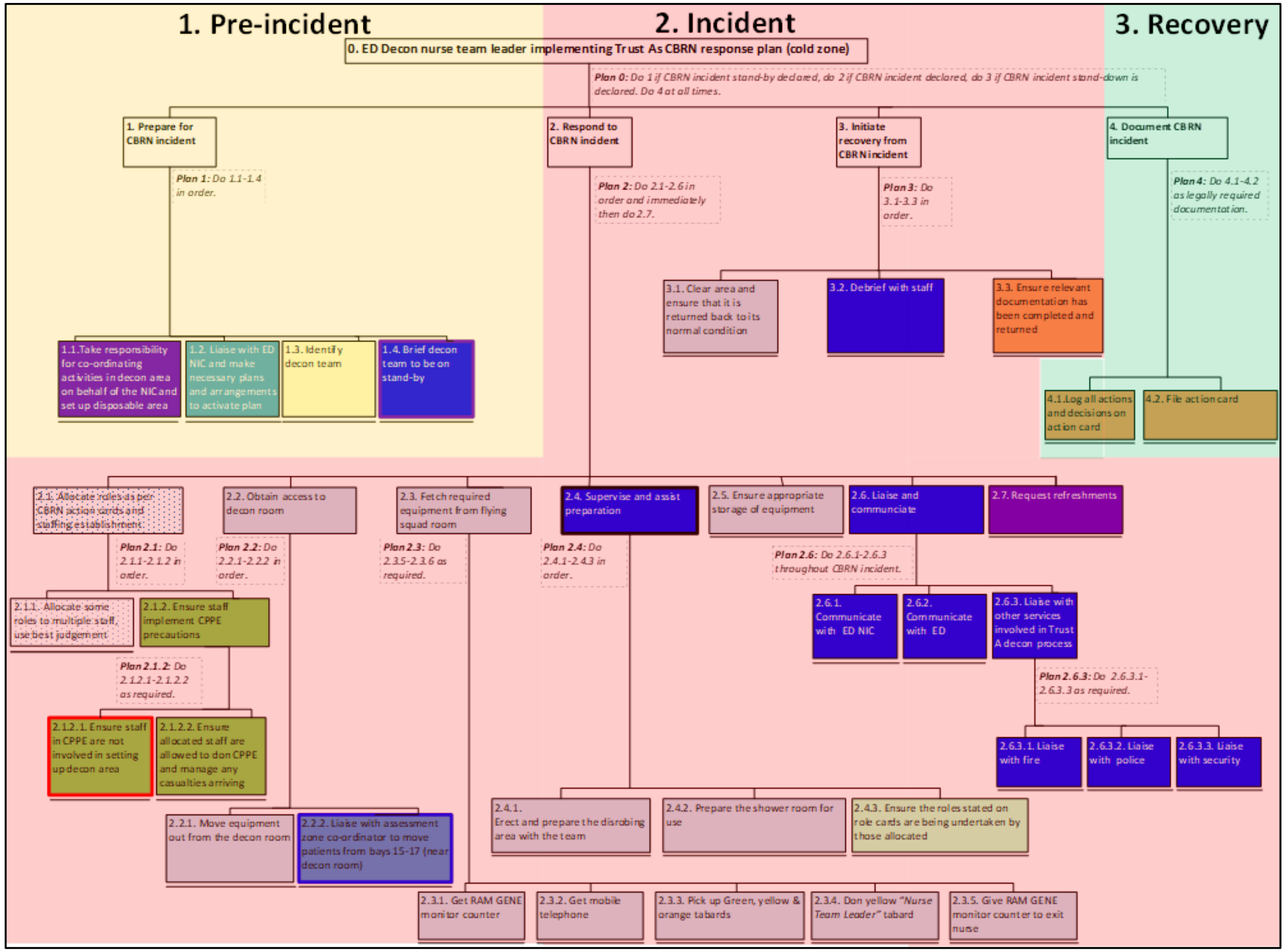
Appendix 11. Trust A: DIC action card



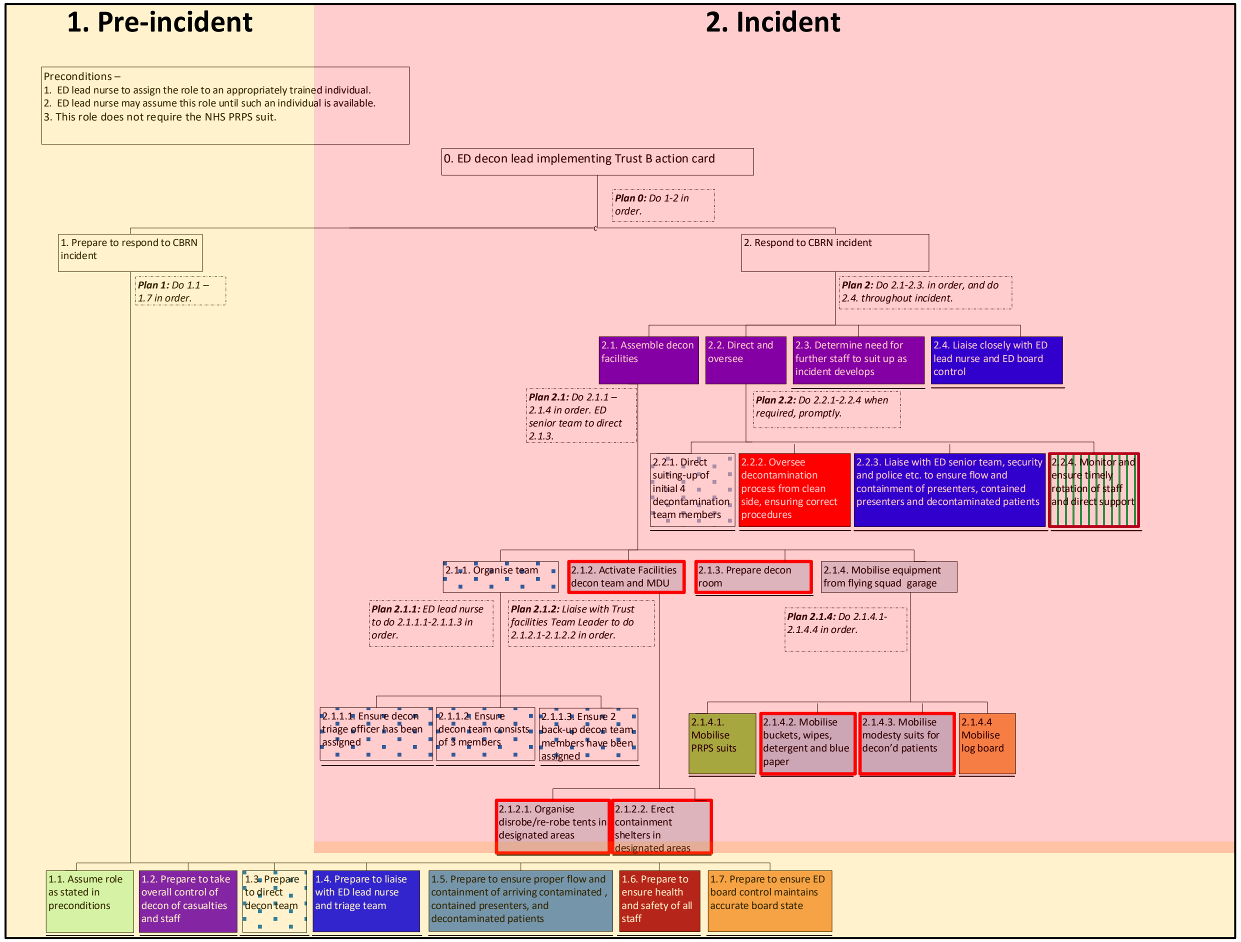
Appendix 12. Trust B: Senior doctor action card



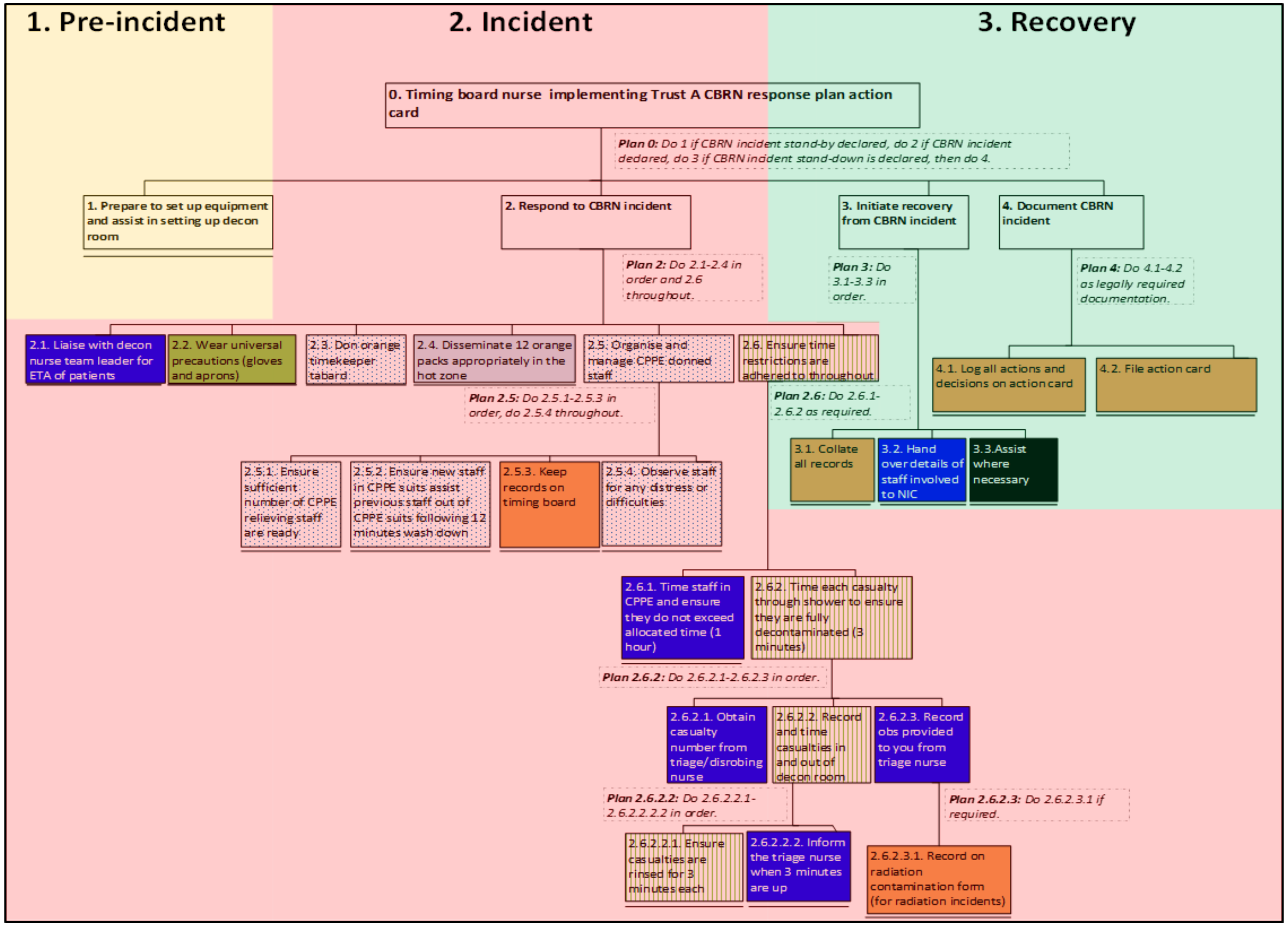
Appendix 13. Trust A: Decontamination lead



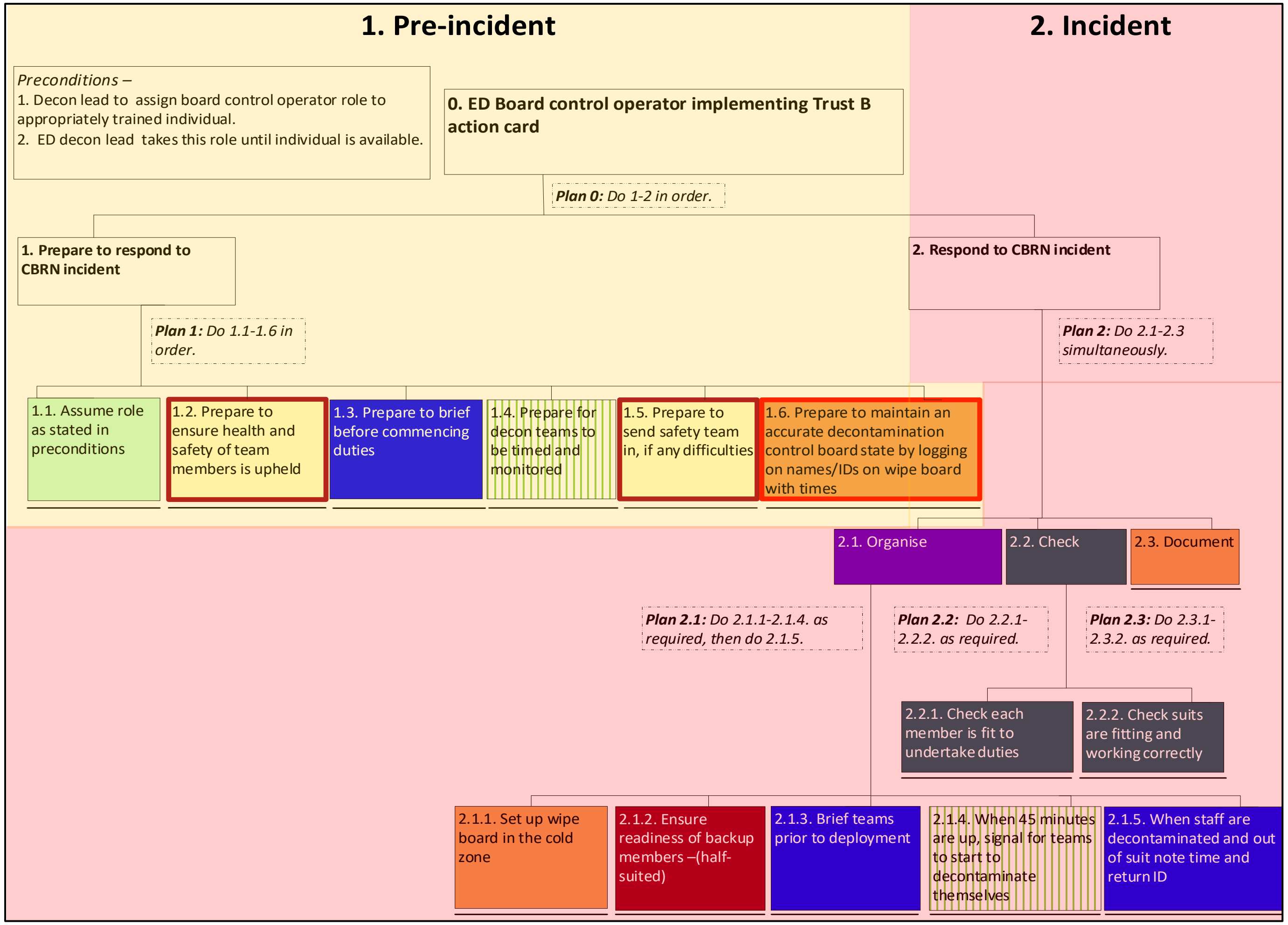
Appendix 14. Trust B: Decontamination lead



Appendix 15. Trust A: Timing board nurse action card



Appendix 16. Trust B: Board control operator



Appendix 17. Trust A: Security officer action card