Development and assessment of the reliability and validity of a proposed Medi-Socio AcciMap Taxonomy approach for analysing IT-related incidents in healthcare

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Abstract

The thesis argues that synthesising a domain-specific classification scheme/taxonomy with Branford's standardised AcciMap approach will improve the reliability and validity of its outcomes. Based on Waterson *et al*. (2017)'s review of the AcciMap methodology, this argument discussed the need for improving the AcciMap approach rather than simply developing novel accident analysis approaches. One recommended way to achieve this includes combining the AcciMap approach with existing error-based classification schemes as part of the "remixing process". Recent studies implementing this process include the UPLOADS classification scheme based on the AcciMap methodology for investigating led outdoor activities (Australia). This example supports the need to develop a health-specific AcciMap approach, as Goode *et al*. (2017) argued for accident analysis, including health IT analysis.

The Medi-Socio AcciMap taxonomy approach built on Branford's standardised AcciMap method was proposed. This novel approach was applied to analysing a significant health-IT related incident (Septra overdose of a patient) as detailed in the Digital Doctor book (Wacther, 2015). Standardised AcciMap and Medi-Socio AcciMap taxonomy approaches were applied to this incident to identify contributing factors, causal relationships (links) and formulate safety recommendations. In assessing the reliability of both AcciMap versions, professionals (Clinical safety/human factors practitioners, NHS) participated in the Septra overdose incident analysis. The validity assessment involved safety experts experienced in using the AcciMap method and applied the two AcciMap approaches to the incident.

Qualitative and quantitative measurements were used to analyse and compare findings between professional users (reliability) and expert results (validity) based on causal/contributing factors, causal relationships and safety recommendations. These studies indicated lower reliability and validity scores for the Medi-Socio AcciMap taxonomy than the standardised AcciMap version, particularly relating to contributing factors and safety recommendations. Outcomes on reliability and validity studies, including usability, were discussed. Also, study limitations, research reflections, and recommendations were presented for future research.

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Declaration

I declare that this dissertation was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

Abbreviations

ACAT	Accident Causation Aviation Taxonomy
AcciMap	Accident Mapping
AHRQ	Agency for Healthcare Research and Quality
ATSB	Australian Transportation Safety Board
CAST	Causal Analysis using System Theory
CCF	Common Contributing Factor
CDSS	Clinical Decision Support System
CPOE	Computerised Order Entry System
DOE	Department of Energy
ECF	Events and Causal Factor
ECFC	Events and Causal Factor Charting
ECRI	Emergency Care Research Institute
EHR	Electronic Health Records
EMR	Electronic Medical Records
FDA	Food and Drug Administration
FRAM	Functional Resonance Accident Model
HFACS	Human Factors and Classification System
HFIT	Human Factors Investigation Tool
HFCF	Human Factors Contributory Framework
HFE	Human Factors and Ergonomics
HIS	Healthcare Improvement Scotland
HIT	Health Information Technology
HSIB	Health Safety Investigation Branch
ICAM	Incident Cause Analysis Method
ICF	Individual Contributing Factor
INR	International Normalised Ratio
IoC	Index of Concordance
IOM	Institute of Medicine
JCAHO	Joint Commission on Accreditation of Healthcare Organisations
MES	Multilinear Events Sequencing
NHS	National Health Service
NPfiT	UK National Programme for Information Technology
NPSA	National Patient Safety Association
NRLS	National Reporting and Learning System

NSS	National Services Scotland
PHIRES	Patient Handling Injuries Review of Systems
RCA	Root Cause Analysis
RMF	Risk Management Framework
SCM	Swiss Cheese Model
SD	Standard Deviation
SEIPS	Systems Engineering Initiative for Patient Safety
SME	Subject Matter Experts
SMS	Safety Management Systems
STAMP	System Theoretic Accident Modelling and Process
STEP	Sequential Timing and Events Process
STPA	Systems Theoretic Process Analysis
TRACEr	Technique for the Retrospective and Predictive Analysis of Cognitive Errors in Air Traffic Control
UCSF	University of California, San Francisco
UPLOADS	Understanding and Preventing Led Outdoor Activity Data System
WBA	Why-Because Analysis
WHO	World Health Organisation

1.0 CHAPTER ONE: Introduction

1.1 Background

Accident investigation and analysis support safety management to improve safety and quality of service (Woloshynowych *et al.*, 2005; Cacciabue and Vella, 2010; Pillay, 2015). Safety-critical systems, including nuclear power, manufacturing, railways, aviation, aerospace, and healthcare, achieve these objectives using different accident analysis approaches underlined by their methodology of application and theories of accident causation on which they were built (Johnson, 2003, 2004). Healthcare systems in the United Kingdom (UK) and the USA have been carrying out these safety management processes to enhance patient safety through the use of Root Cause Analysis (RCA) techniques (Woloshynowych *et al.*, 2005; NHS England, 2015).

These techniques are used in analysing incidents/accidents in uncovering "root causes" and developing preventive and mitigating measures (action plans) to ensure that they do not occur in the future. For example, simple Root Cause Analyses (RCA) tools like Fishbone diagrams and the Five whys technique have been relied upon by clinical safety practitioners in the National Health Service (NHS) for incident analysis (Canham *et al.*, 2018). Other RCA techniques include the Swiss Cheese Model (SCM), bow tie analysis, and the London protocol framework, have also been used for incident analysis in healthcare (Vincent, Taylor-Adams and Stanhope, 1998; Johnson, 2004; Vincent, 2011).

1.2 Evolution of Accident Analysis

In past decades, there has been a progression of accident analysis from the traditional accident analysis (RCA) to Systemic Accident Analysis (SAA) approaches (Canham *et al.*, 2018). SAA approaches were developed to address limitations of RCA techniques for accident analysis (Leveson, 2011), where the author argued that RCA techniques were considered inadequate for analysing complex interactions within socio-technical systems (Qureshi, 2007; Leveson, 2011). It is further argued that accident approaches employing the "systems thinking" paradigm have provided more significant benefits in understanding why

they (adverse outcomes) occurred than linear-based approaches (Underwood and Waterson, 2013, 2014). According to Waldman (2007):

> *"Systems thinking embodies an approach to understanding how things work, and the central thesis is that the effects or outputs of any system are dependent on the interaction of its parts and that studying these parts in insolation will not provide an accurate picture of the system."* (Waldman, 2007)

The concept of systems thinking also *"considers a system in its totality taking relationships among the factors into account from multiple stakeholders at a time"* (Raza and Standing, 2008). Thus, rather than determining root causes, the analysis focuses on establishing underlying contributing factors, particularly systemic factors (Underwood and Waterson, 2013). An example will be comparing the AcciMap approach's application with a linear-based technique like the Events and Causal Factor Charting (ECFC) on a medication error incident regarding a patient's overdose (Igene and Johnson, 2019). The latter technique linearly presents causes until the root cause is identified. However, the application of a systemic accident analysis (SAA) approach (e.g., AcciMap) embodying systems thinking does not focus on identifying the root cause(s) but on existing latent conditions and systemic factors within and outside an organisation that facilitated the events occurring at the "front-end".

However, despite the benefit of systemic accident approaches, there has been a notable "research-practice" gap in applying them practically in healthcare systems (Underwood and Waterson, 2013). One of the reasons for their slow adoption includes usage characteristics relating to their usability, reliability, and validity. These properties are considered very important in determining the usefulness of these approaches for accident investigation and analysis in healthcare (Underwood and Waterson, 2013; Waterson *et al.*, 2015). However, the authors opined that these approaches do not incorporate all three properties, meaning trade-offs are created (Waterson *et al.*, 2017).

1.3 Accident Mapping (AcciMap) Approach

Accident Mapping (AcciMap) is a popular retrospective systemic accident analysis approach that graphically depicts a multi-causal diagram of contributing factors and analyses systemic failures concerning the adverse outcome (Branford, 2007; Branford, Naikar and Hopkins, 2009; Branford, 2011). The prominent feature of this approach is in providing a 'big picture' of the accident regarding decisions and conditions within and between different socio-technical levels (Rasmussen and Svedung, 2000; Svedung and Rasmussen, 2002; Branford, 2007). In addition, causal/contributing factors are linked using "*causal relationships*" depicting "*cause and effect*" within and between six (6) designated levels (Rasmussen and Svedung, 2000; Branford, 2007; Branford, Naikar and Hopkins, 2009) (see figure 1-1).

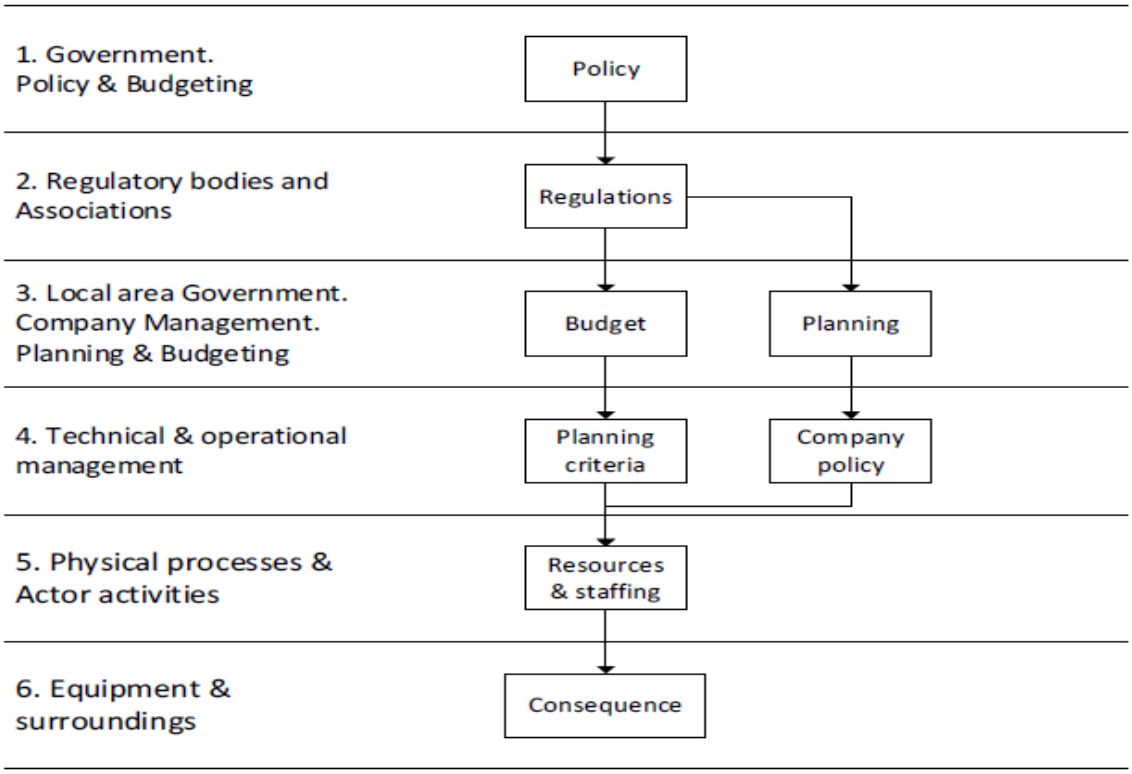


Figure 1-1: Generic AcciMap Model adapted from Rasmussen and Svedung (2000)

The AcciMap approach is one of the most cited and utilised systemic methods for accident analysis (Salmon, Cornelissen and Trotter, 2012; Underwood and Waterson, 2014; Salmon, Hulme, *et al.*, 2020). It is also more closely aligned with state-of-the-art accident causation models in comparison with other approaches, including FRAM and STAMP/STPA approaches (Salmon *et al.*, 2017;

Waterson *et al.*, 2017; Hulme *et al.*, 2019; Salmon, Hulme, *et al.*, 2020). Also, this approach has been applied in analysing major accidents in different safety-critical systems, including outdoor activities (Salmon *et al.*, 2010, 2017; Salmon, Cornelissen and Trotter, 2012), food industry (Nayak and Waterson, 2016), railway accidents (Underwood and Waterson, 2014), aerospace (Johnson and de Almeida, 2008), and public health (Vicente and Christoffersen, 2006).

1.4 Rasmussen's Sociotechnical Framework for Risk Management

The AcciMap approach is also a component of the broader Risk Management Framework (RMF). This framework recognises both past stable conditions and the dynamic society characterised by rapidly changing technology, fast information and communication development, increased scale of industrial installations, and an aggressive environment that influences short term goals of decision-makers (Rasmussen, 1997). Rasmussen also argued that these factors contribute to a scenario where forces and constraints can influence continuously changing work practices and must be considered during accident investigation and analysis (Vicente and Christoffersen, 2006). A system can become unstable at the boundary of safety regulation, thus requiring resilience to maintain control and remain outside the accident region (see figure 1-2).

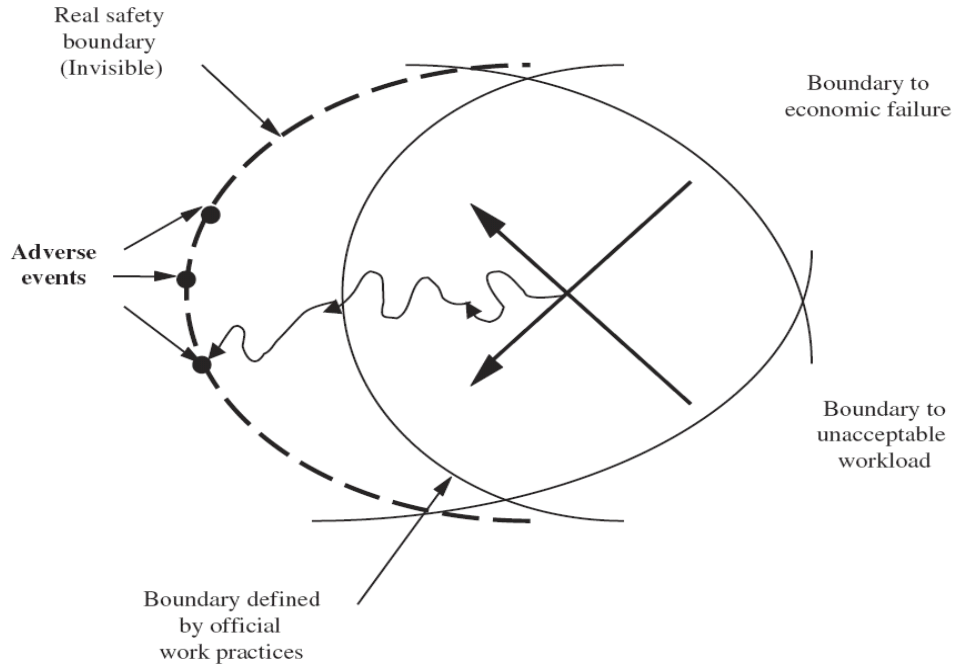


Figure 1-2: Boundaries of Safe Operation

The Risk Management Framework (RMF) underpinned the notion of safety as an emergent characteristic of complex socio-technical systems and is also;

> *"a prominent systems-theory based model for describing work systems composed of various labels, and argues that safety is impacted by the decisions and actions across all levels (e.g., politicians, chief executives, managers, supervisors), not just by those of front line operators alone"* (Donovan, Salmon and Lenné, 2015)

The Risk Management Framework considers two critical factors; Structure Hierarchy and System Dynamics (Rasmussen, 1997; Svedung and Rasmussen, 2002; Qureshi, 2007). *Structure Hierarchy* is associated with different levels ranging from work to government (See figure 1-3). Each level is connected by a flow of information in a top-down approach from the external level to the frontlines (physical level) (Svedung and Rasmussen, 2002). This flow of information from the top denotes decisions taken by different external entities where data regarding the state of the system from the lower level (Waterson *et al.*, 2017) is taken upwards, helping to *"inform decision making and action at higher levels"* (Donovan, Salmon and Lenné, 2015).

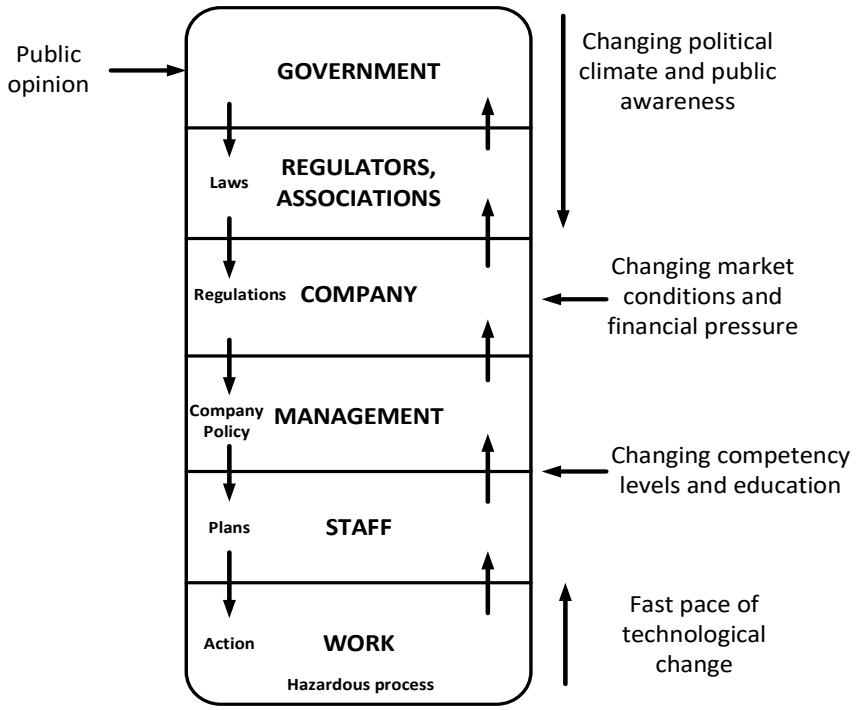


Figure 1-3: Socio-technical model of System Operations (Svedung and Rasmussen, 2002)

System dynamics is associated with conditions in the work environment that can affect the behaviour of operators (Qureshi, 2007). Their decision making and activities are required to remain within the workspace bounds determined by safety, functional and administrative constraints (Rasmussen, 1997; Qureshi, 2007). Systems can also lose control of the processes designed to assert control if there isn't a 'vertical integration' (Cassano-Piche, Vicente and Jamieson, 2006). Interactions within and between these system levels also control the performance and safety of the system (Waterson and Jenkins, 2010; Trotter, Salmon and Lenné, 2014).

While this framework underpins the AcciMap approach, additional tools for further analysis of the socio-technical system include ActorMaps, Conflict Maps, and InfoMaps (Waterson and Jenkins, 2010). Actor Maps graphically depicts a "*layout of decision males, planners and actors who have been involved in the preparation of accidental conditions*" (Svedung and Rasmussen, 2002). InfoMaps graphically presents strong communication lines within a system, and Conflict Maps offers any potential tensions and conflicts between actors that could contribute to adverse outcomes preconditions (Johnson and de Almeida, 2008; Waterson *et al.*, 2017).

1.5 Research Application in Healthcare Systems

The proliferation of computer technology (health IT systems) has seen health organisations transit from paper-based to an electronic-based system to provide more efficient patient care (Koppel *et al.*, 2005; Harrison, Koppel and Bar-Lev, 2007; Wears and Nemeth, 2007; Wears, 2015). Health IT systems include Computer Order Provider Entry (CPOE) systems, Clinical Decision Support Systems (CDSS) (where the CPOE works as a component), Electronic Health Records (EHR), and Bar-Coding systems etc. They help clinicians provide adequate care to patients, prevent financial losses and death (Koppel *et al.*, 2005; Institute for Medicine, 2012). Unfortunately, unintended consequences and new forms of errors can occur due to interactions with clinical users that can adversely compromise patient safety (Ash *et al.*, 2007; Herrick, Gorman and Goodman, 2010; Magrabi *et al.*, 2016). The Institute of Medicine (IOM) report also highlighted the need for improving patient safety by ensuring the safe use of health information technology (HIT) in the delivery of effective healthcare

(Institute for Medicine, 2012). The unintended consequences of using Health IT systems leading to patient harm present a safety-related challenge that fits the purposes of this research with the application of the proposed AcciMap approach in the analysis of a case incident.

1.6 Research Problem

Despite the popularity of the AcciMap approach within the academic research community, its reliability and validity have been a subject of research discussion (Waterson *et al.*, 2017). The term "Reliability" is generally a broad term that focuses on the approach's *consistency* or *repeatability* of results obtained from using an accident analysis method by multiple users (Kirwan, 1992; Branford, 2007). This term has often been used interchangeably with "Consistency" relating to the agreement between various users/raters. "Validity" refers to *"whether a measurement instrument actually measures what it is purported to measure",* and this involves comparing outcomes of users with a "gold standard" of measurement (Long and Johnson, 2000; Branford, 2007). These terms will be elaborated in Chapters Six and Seven, but for this thesis and in addressing the second research question, the term "reliability" is used.

As highlighted earlier, reliability and validity are essential criteria for determining an accident analysis approach' suitability (Underwood, Waterson and Braithwaite, 2016). Based on studies of Baber and Stanton (2002) and Kanis (2014), they argued that accident analysis approaches that do not indicate reasonable levels of reliability and validity could not be considered appropriate for conducting accident analysis (Baber and Stanton, 2002; Kanis, 2014; Waterson *et al.*, 2017). Due to the subjective nature of the AcciMap approach, its reliability and validity have been considered from being "low" to "mixed" compared to some other approaches like HFACS (Human Factors and Classification System) and STAMP (Systems Theoretic Accident Modelling Process) to an extent (Salmon, Cornelissen and Trotter, 2012). Branford (2007) investigated these criteria in developing a standardised AcciMap approach based on the original formats (Rasmussen and Svedung, 2000; Vicente and Christoffersen, 2006). She also created guidelines for conducting AcciMap analysis to improve the reliability and validity of outcomes (contributing factors and safety recommendations).

The concept of a "domain-specific" AcciMap approach has also been explored in other safety-critical domains, particularly in the led outdoor field through the development of the UPLOADS (Understanding and Preventing Led Outdoor Accidents Data Systems) approach (Goode *et al.*, 2017; Salmon *et al.*, 2017). Their studies argued that for the AcciMap approach to be considered valuable and reliable for any safety-critical domain, it must be "domain-specific" (Goode *et al.*, 2017). However, there hasn't been any existing AcciMap approach specific for incident analysis in healthcare. In addition, there hasn't been any study to compare findings between any original AcciMap and proposed AcciMap versions for reliability and validity evaluation. This thesis addresses this by adopting a methodology to develop a taxonomy-based AcciMap approach (Goode *et al.*, 2016, 2017; Salmon *et al.*, 2017). This new AcciMap approach is based on Branford's standardised AcciMap approach.

1.7 Thesis Statement

The purpose of this study is to investigate and evaluate the Medi-Socio AcciMap approach in the context of analysing IT-related incidents in healthcare and determining if outcomes from its application are more reliable and valid. The synthesis and application of a health-specific classification scheme consisting of contributing factors within the AcciMap approach will:

1.) Improve the reliability of results (causal/contributing factors, causal relationships (links), and safety recommendations relating to the adverse event between multiple analysts.
2.) Improve the validity of results (contributing factors, causal links, and safety recommendations) produced by multiple users compared to expert results.

1.8 Research Questions

To achieve the study objectives of the thesis, the following research questions in addressing the thesis statement are as follows:

1.) What is the perception of using the standardised AcciMap approach for accident investigation in the National Health Service (NHS)?
2.) Does applying a contributory factor AcciMap taxonomy improve the reliability of results from health IT analysis compared to Branford's AcciMap approach?

3.) Does applying a contributory factor AcciMap taxonomy improve the validity of results from health IT analysis compared to Branford's AcciMap approach?

1.9 Scope of Research

The research is undertaken in the United Kingdom (UK) involving the National Health Services (NHS) from Scotland and England. While the healthcare system in both countries is under the umbrella of the NHS, they each have their independent safety management system responsible for ensuring patient safety within different trusts (England) and boards (Scotland). The research also involves collaboration with human factors and clinical safety professionals from NHS boards (Scotland) and trusts (England). Other NHS associated entities include the National Services Scotland (NSS) (Glasgow), Healthcare Improvement Scotland (HIS) (Edinburgh), and the NHS Digital (England). The NHS Digital is mainly responsible for providing HIT systems for clinicians, analysts, and commissioners in health and social care (Habli *et al.*, 2018).

Case incidents involving health-IT systems and how they affected patient safety are selected to apply both standardised AcciMap, and Medi-Socio AcciMap approaches. These incidents occurred outside the UK health system and are also selected based on the nature of errors committed that the NHS may not have experienced. They also present opportunities for lessons to be learned and applied in their respective trusts and boards. Practical studies implemented in this thesis include a pilot AcciMap training workshop with Healthcare Improvement Scotland (HIS) and the National Services Scotland (NSS). Subsequent field training and analysis workshop on implementing both standardised and Medi-socio AcciMap approaches was also implemented across different NHS practices, specifically NHS, Nottinghamshire, and Durham. Finally, during an expert analysis workshop, the proposed Medi-Socio AcciMap taxonomy was also presented to the Health Safety and Investigation Branch (HSIB) staff.

1.10 Thesis Outline

Figure 1-4 details the thesis structure, including the introduction and study motivation in addressing the existing gap in knowledge relating to the development and assessment of the proposed AcciMap approach. The grey areas indicated chapters that directly address each research question (see section 1.8). The following summary of the subsequent chapters are outlined below:

- **Chapter Two:** Presents a background study and literature review on existing accident analysis approaches based on theories of accident causation and safety perspectives. In particular, it presents the AcciMap approach, the remixing process, and the need for addressing its reliability and validity. The chapter also provides a background review of the utilisation of health information technology in healthcare systems which serves as a research platform in addressing the research questions.

- **Chapter Three:** Presents a pilot AcciMap training workshop in collaboration with Healthcare Improvement Scotland (HIS). This study involved addressing the first research question in determining the perception of Branford's standardised AcciMap approach by clinical safety practitioners from different NHS boards in Scotland. In addition, training and application of the AcciMap method on the "Wrong Patient" case incident were implemented where outcomes (contributing factors and safety recommendations) were compared and discussed.

- **Chapter Four:** Presents a continuation of the study from the previous chapter in addressing the first research question. It explores the application of Branford's AcciMap approach to a health informatics case incident (CPOE medication dosing error) between a clinical domain expert (e-pharmacy) and an AcciMap expert (creator of the standardised AcciMap version). AcciMap outcomes were produced and qualitatively compared and contrasted for similarities and differences. An interview was conducted with the clinical expert on the experience of applying the AcciMap method.

- **Chapter Five:** Presents the development of the proposed Medi-Socio AcciMap taxonomy. The concept of the new AcciMap approach is based on

existing socio-technical models, human factors/error taxonomies, health IT classification schemes and relevant literature. A taxonomy development approach was applied to determine system categories and corresponding subcategories (contributing factors). The proposed taxonomy was further refined based on review and feedback from patient safety, human factors specialists, and IT specialists within the NHS.

- **Chapter Six:** Presents the reliability assessment (qualitative and quantitative) of applying the standardised AcciMap and Medi-Socio AcciMap approaches by the professional group (NHS clinical safety practitioners). Contributing factors, causal relationships, and safety recommendations based on the analysis of the Septra overdose incident are compared using a qualitative approach (content analysis). In addition, a quantitative assessment (index of concordance) was applied to determine the per cent agreement based on the results of both AcciMap approaches in addressing the second research question.

- **Chapter Seven:** Presents the validity assessment of the Medi-Socio AcciMap approach compared to Branford's AcciMap approach in addressing the third (final) research question. AcciMap results, including contributing factors, causal relationships, and safety recommendations from their applications by the professional group, are compared with findings of experts' application of both approaches. Quantitative assessment was also applied using the Index of Concordance (IoC) measurement for calculating per cent agreement.

- **Chapter Eight:** Presents conclusions and discusses the main findings concerning the research questions. It also highlights contributions to knowledge, recommendations, and the future of research.

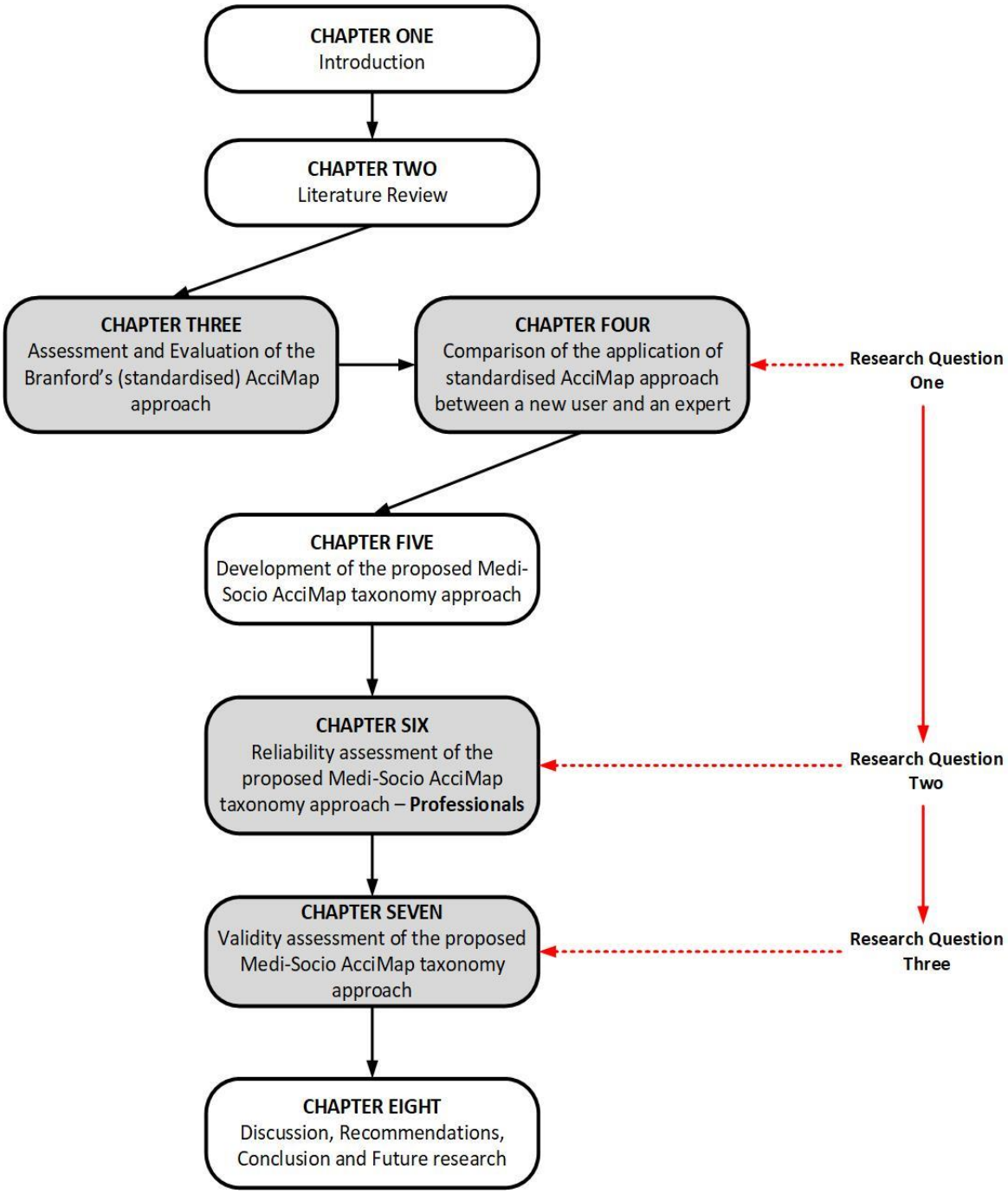


Figure 1-4: Structure of Chapters for the Thesis

2.0 CHAPTER TWO: Application of the AcciMap approach for Health IT analysis: Literature Review

2.1 Introduction

This chapter presents a two-fold literature review; the first aspect broadly reviews accident/incident analysis in practice, different accident analysis approaches and examines Branford's standardised AcciMap approach. The AcciMap method, as introduced in Chapter One, is further elaborated to include its evolution and relevance as a Systemic Accident Analysis (SAA) approach for accident analysis in safety-critical domains and particularly in healthcare. The second aspect reviews the impact of information technology on patient safety in healthcare systems and the risks associated with its use by clinical operators within the socio-technical system. This chapter also discusses the research problem and the domain context for applying Branford's standardised AcciMap approach for health IT analysis. Finally, the research gap is identified and discussed regarding the need to improve the standardised AcciMap method by developing a proposed health-specific AcciMap taxonomy approach and assessing its reliability and validity.

2.2 Background

Different accident analysis approaches, particularly sequential or linear-based models, have been utilised to describe what happened as a cause-and-effect way have been the more popularly used for incident analysis in healthcare (Belmonte *et al.*, 2011; Ferjencik, 2011). However, newer approaches, most notably Systemic Accident Analysis (SAA), have been developed to analyse complex interactions within socio-technical systems that contributed to adverse outcomes or near misses (Qureshi, 2007; Salmon, Cornelissen and Trotter, 2012; Waterson *et al.*, 2017). SAA approaches (e.g., STAMP, FRAM) are argued to be more suitable for accident analysis within the socio-technical context and addresses shortcomings of the more popular RCA techniques (Leveson, 2011). As already highlighted in Chapter One, these SAA approaches incorporate the concept of "systems thinking" in understanding why an adverse event happened, examining the entire socio-technical system, identifying weaknesses and developing safety measures (Leveson, 2011; Underwood and Waterson, 2013). They also provide

the means of implementing a deeper analysis of the broader socio-technical system beyond the actions occurring at the frontline, identifying existing weaknesses and developing appropriate safety recommendations. However, its reliability and validity need to be evaluated to fully realise the benefits of adopting a systemic accident approach, especially transferring research to practice. These characteristics, including usability, are crucial for healthcare organisations to adopt them into live accident investigation and analysis (Underwood and Waterson, 2013).

Healthcare systems are complex socio-technical systems made up of "*a web of dynamic relationships and transactions where in many instances, they drift into failure*" (Waterson and Jenkins, 2010). The term "socio-technical" relates to the interdependency between technologies and the people in the work system (Klein, 2014). However, the author noted that this term is as imprecise as another related term, "system" (Klein, 2014). This tendency for systems drifting into failures can occur due to the combination of technological, environmental, and social systems as they grow in complexity. The healthcare system is also a complex "socio-technological" and an adaptive system with continuous and rapid development resulting from combining user demands, technological advancements, and commercial considerations (Hollnagel and Speziali, 2008). Healthcare systems continuously grow even more complex due to these dynamic interactions, including those between clinicians and health information technology (HIT). The safety approach implemented in healthcare can be "ultra-safe", which focuses on risks being excluded and power is given to regulators and supervisors to ensure front-line practitioners are not exposed to unnecessary risks (Vincent and Amalberti, 2016).

2.3 Definition of Safety-related Terms

In understanding safety-related terms commonly used across different safety-critical domains and within the context of the thesis, it is essential to identify and define them, particularly with accident analysis in healthcare and in general. These terms are defined in the following table 2-1.

Table 2-1: Summary of safety-related terms and their definitions

Safety-related Term	Definition
Cause	This is defined as either a direct cause or contributing factor in a causal chain that eventually leads to an accident or adverse outcome (Woloshynowych *et al.*, 2005).
Root Cause	"*The most basic cause that can be reasonably identified and that management has control to fix"* (Paradies and Busch, 1988). Root causes can sometimes be attributed to deficiencies in management systems (Woloshynowych *et al.*, 2005).
Accident and Incident	These two terms have either been used interchangeably to convey similar meanings or to specific meanings associated with them. Typically, an "**accident**" can be described as an adverse outcome or event where either a patient or patients have experienced severe consequences (e.g., serious injuries or death) because of a chain of decisions and contributing factors. However, an "**incident**", while having a similar definition with "accident", describes an event or outcome that may not necessarily be regarded as adverse or very serious but may still be considered very risky and likely to be repeated (Hollnagel and Speziali, 2008).
Contributing Factor	This consists of influencing and causal factors that are either positive or negative that affect the safety of patients (NPSA, 2009).
Active Error	This is a type of error where either an action or decision results in an adverse (undesired) outcome with consequences (Ives and Hillier, 2015).
Adverse Event	Defined as an event that proceeds to harm a person (patient). They may either be preventable or non-preventable (Ives and Hillier, 2015)
Human Error	This is a type of error leading to an undesired outcome occurring due to multiple contributing factors, including but not limited to workload, time pressure, communication (Ives and Hillier, 2015).
Latent Error (Latent Condition)	A type of error that does not produce an immediate set of consequences but are triggered under certain conditions in the system (Ives and Hillier, 2015).
Near Miss	This is defined as situations "*where an accident could have happened had there been no timely and effective recovery*" (Thomadsen and Lin, 2005).
Safety	This is defined as the prevention of harm to patients in addition to being free from accidental damage and medical errors (Institute for Medicine, 2012; Salahuddin and Ismail, 2015). In addition, a recent definition of patient safety highlighted the prevention of medical errors and improving the condition of patients from adverse outcomes or injuries (Vincent, 2011).
Risk	The term "Risk" has several definitions used by different authors. It is defined as the likelihood of an unwanted or adverse event that results in negative consequences (Kaplan and Garrick, 1981; Ostrom and

Safety-related Term	Definition
	Wilhelmsen, 2012). Risk can also be regarded as "*the chance that someone or something that is valued will be adversely affected in a stipulated way by the hazard*" (Woodruff, 2005).
Hazard	A Hazard constitutes any condition that is deemed "unsafe" or a potential source of an undesirable event with the increased likelihood of harm (Reniers *et al.*, 2005; Marhavilas, Koulouriotis and Gemeni, 2011).
System	A system is formally defined as "*a set of elements or parts that is coherently organised and interconnected in a pattern or structure that produces a characteristic set of behaviours often classified as its function or purpose*" (Meadows, 2009).
System Safety	This term focuses on different aspects, including people, processes, environment, and technology, that affect safety (Ives and Hillier, 2015). Safety can be compromised due to errors induced by system design, poor training, management decisions etc.
Systemic factors	This comprises organisational and managerial causal/contributing factors that created conditions for active errors to occur at the frontline or physical level (Emslie, Knox and Pickstone, 2002; Leveson, 2011).

2.4 Accident Analysis – Current Practice in Healthcare

Investigating and analysing adverse events involves uncovering failures, learning from system weaknesses, and developing actions to prevent them from reoccurring (Salmon, Cornelissen, and Trotter, 2012; Canham *et al.*, 2018). Another purpose is to promote a safety culture (vigilance) in identifying risks and mitigating them (NHS England, 2015). For example, in NHS organisations (England and Wales), healthcare staff report incidents and the data (patient safety incident) are collected by the National Reporting and Learning System (NRLS) (Wheway and Jun, 2021). The national patient safety team then reviews the data collection and analyses to formulate safety recommendations and risk reduction strategies (Wheway, 2020; Wheway and Jun, 2021). Formal investigations implemented in the NHS depends on the nature of the incident, and they consist of a concise internal investigation (Level 1), comprehensive internal investigation (level 2), and independent investigation (level 3) (Canham *et al.*, 2018). Level 1 type of investigation applies to not complex incidents, while level 2 type investigation applies to complex incidents requiring a multidisciplinary team of experts/specialists (NHS England, 2010). Level 3 type

investigation is used where it may be challenging to conduct an objective inquiry due to individuals' organisational capacity or capability (NPSA, 2008).

One of the tools commonly used for incident/accident analysis across safety-critical domains is the Root Cause Analysis (RCA) approach. RCA is a systematic and qualitative management tool used for identifying root causes by asking 'why?' until no additional answer is determined (Walshe and Boaden, 2005). In the healthcare sector, an RCA model was developed by the Joint Commission on Accreditation of Healthcare Organisations (JCAHO) for investigating sentinel events (Walshe and Boaden, 2005). In addition, a comprehensive approach to RCA was developed in the UK by the National Patient Safety Agency (NPSA), including associated training programmes for healthcare providers in England and Wales (Walshe and Boaden, 2005). NPSA's RCA model comprises of ten (10) stages:

1.) Report incident
2.) The decision to investigate and to set up an investigation team
3.) Gathering data
4.) Mapping chronology of events
5.) Identifying care/service delivery problems
6.) Identifying contributory factors and root causes
7.) Developing safety recommendations
8.) Writing a report
9.) Implementing solutions
10.) Evaluating and auditing solutions

These stages can also be broadly categorised into four phases making up the whole investigation and analysis processes comprising of; (1.) Plan, (2.) Investigate and analyse, (3.) Report, and (4.) Act (Woloshynowych *et al.*, 2005). These activities constitute a critical part of a Safety Management System (SMS), which is "*an organised approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures*" (Cacciabue and Vella, 2010). Safety management is also a proactive measure, and its development was made necessary due to past occurrences of significant accidents, including the Chernobyl incident in the late 1970s (Cacciabue and Vella, 2010). In healthcare, implementing activities relating to safety

management is crucial for effectively handling adverse outcomes caused by human error and system malfunctions (Reason, 1995; Cacciabue and Vella, 2010). While the term "human error" is attributed to be the leading cause of accidents (Hollnagel, 2008), it is not considered a well-defined category concerning human performance (Woods *et al.*, 1994). The authors argued that human error associated with actions (individual and organisational) is a social and psychological process rather than a technical or objective term (Woods *et al.*, 1994; Hollnagel and Speziali, 2008). Regarding safety management, for example, the NHS Digital's clinical safety management system, which focuses on reporting incidents on the use of health IT/computer systems, include the following processes (Mawson, 2018):

1.) Reporting incidents relating to health IT systems that may impact (negatively) patient safety,
2.) Enabling the manufacturer's organisation to report on incidents that can impact patient safety,
3.) Providing communication links within the manufacturer's organisation and health organisation using health IT systems,
4.) Provision of sufficient and suitable resources allocated by the manufacturer to resolve any incident reported and,
5.) Enabling manufacturers to send safety alerts to health organisations, advise users regarding potential safety incidents, and provide mitigation measures.

2.5 Review of Accident Approaches

Different accident analysis approaches (Appendix A-1) are developed based on different methodologies (Johnson, 2004; Wienen *et al.*, 2017), theoretical underpinnings and accident causation theories (Fu *et al.*, 2020) (Appendix A-2). Over the past decades, these approaches have evolved from RCA techniques to systemic methods for analysing socio-technical systems (figure 2-1). Accident analysis approaches are broadly composed of three model types: simple linear, complex linear, and complex non-linear models. The following subsections briefly discuss each of them.

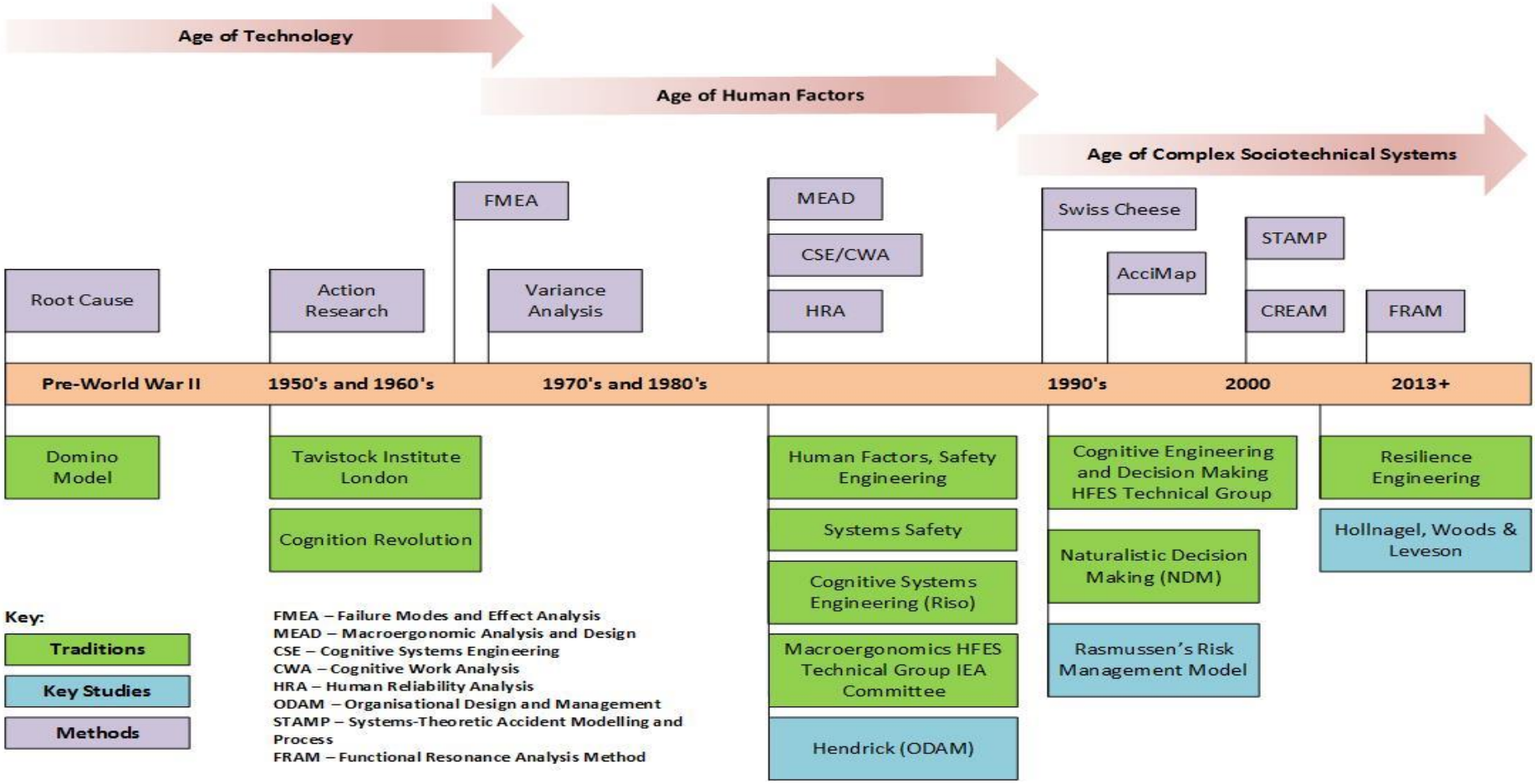


Figure 2-1: Timeline on the development of methods for socio-technical systems and safety (adapted from Waterson *et al.*, 2015)

2.5.1 Simple Linear Models

These models assume that accidents occur due to events linking together sequentially or linearly until the root cause(s) is identified and eliminated (Toft *et al.*, 2012). Simple linear models like sequential (linear-based) approaches, which describe sequences of events (actions) leading to adverse outcomes (Qureshi, 2007; Wienen *et al.*, 2017). They also allow investigators/analysts to determine 'what' happened (focusing on the adverse outcome) and can be used along with secondary forms of analysis to determine 'why' they happened (negative or near-miss occurred) (Johnson, 2004). Examples include Root Cause Analysis (RCA) techniques like fishbone diagrams and 5-Whys techniques used for incident investigations in healthcare (Canham *et al.*, 2018). Other notable simple linear models include Multilinear Events Sequencing (MES) and Sequential Timing and Events Process (STEP). The main criticism of these linear models, according to Leveson (2011), is in their limited ability to analyse and convey multiple complex interactions between different entities within a complex socio-technical system.

2.5.2 Complex Linear Models

This model type assumes that serious outcomes occur due to the intersection of unsafe acts and latent conditions within complex socio-technical systems presenting linear pathways (Wienen *et al.*, 2017). Factors identified close to the target are denoted as proximate events (active failures), while factors away from the accident are considered organisational, environmental, and external. Different types fall under this type of model include some of the following:

2.5.2.1 Epidemiological Models

These models incorporate the ability to depict an adverse outcome as a product of complex interactions between different system components (entities and actors). The critical factor relates to analysing latent conditions existing in the system resulting in unsafe actions, which can eventually lead to the adverse event (Wienen *et al.*, 2017). An example of this type of model is Reason's Swiss Cheese Model (SCM), which describes the occurrence of system errors like medical mishaps (Reason, 1990; Perneger, 2005). This model is based on the concept of holes found in a natural cheese, depicting the conditions that were

not adequately dealt with by barriers and safeguards (Reason, 2000) (see figure 2-2). These barriers and safeguards by themselves may not be perfect due to human infallibility and limitations in how systems are designed and operated (Emslie, Knox and Pickstone, 2002; Carthey, 2013). These issues eventually lead to an adverse event (active error) that directly affects the patient (Reason, 1990, 1997, 2000; Elliott, Page and Worrall-Carter, 2012).

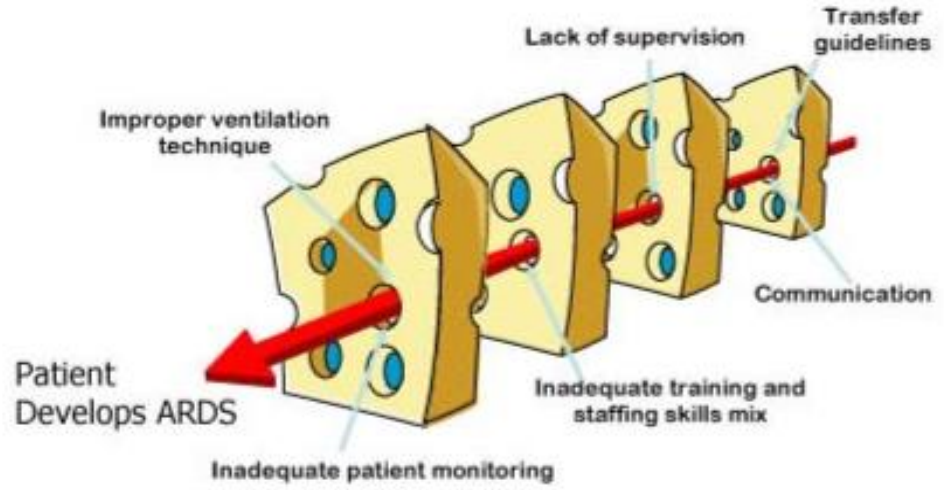


Figure 2-2: The Swiss cheese model of Accident Causation (Reason, 2000)

In addition to the definition in table 2-1, active failures are also considered direct errors made by a worker/operator causing an immediate effect on the patient (La Pietra *et al.*, 2005). Also, latent failures typically referred to as the "*inevitable resident pathogens*", are said to be conditions based on errors made by management personnel of an organisation (i.e., hospital management) (La Pietra *et al.*, 2005).

2.5.2.2 Systemic Models

These models were developed for analysing complex and multiple interactions with socio-technical systems. They are also suitable for examining human failures, including system failures as major contributing factors to adverse outcomes (Hollnagel, 2004; Toft *et al.*, 2012). In applying systemic models, adverse outcomes/accidents can happen due to the intersection of causal factors (human, technical, and environmental) existing in a specific time coincidentally (Hollnagel, 2004; Qureshi, 2007). They also regard accidents as emergent features occurring based on interactions between system components that can lead to the system being less safe due to overall degradation in its

performance (Qureshi, 2007). Another example of this model type is the AcciMap method.

2.5.3 Complex non-Linear Models

These models do not focus on identifying contributing factors from the accident but on identifying existing system constraints and feedback loops. This view means that an accident can occur resulting from the combination of mutually interacting variables occurring in real systems and how they can be understood and prevented (Toft *et al.*, 2012). Notable examples of these type of model that addresses the limitations with linear accident models include STAMP (Systems Theoretic Accident Model and Process) (Leveson, 2004)(Appendix A-3) and FRAM (Functional Resonance Accident Model) (Hollnagel, 2004; Woltjer, 2008). The STAMP model regards systems as interrelated components kept in dynamic equilibrium by control and information feedback loops. On the other hand, the FRAM approach models complex systems by focusing on their functional aspects and defining functions' dynamic interactions and modelling variability where it denotes the source for successes and failures (Hollnagel, 2012; Riccardo *et al.*, 2018)

2.6 SAA Approaches – Research-Practice

As earlier highlighted, Systemic Accident Analysis (SAA) approaches have been considered more suitable for analysing complex systems than linear-based methods (Leveson, 2011). They also support resilience engineering aspects and help healthcare systems anticipate any changes regarding risks before adverse outcomes occur (Hollnagel, Woods and Leveson, 2006). The resilience engineering perspective is considered a new emerging paradigm where concepts derived from previous perspectives are used to develop a coherent understanding of resilience in socio-technical systems (Hollnagel, Woods and Leveson, 2006). However, despite its benefits, they have not been readily adopted as part of current practice regarding incident analysis in healthcare due to over-reliance on RCA techniques (Canham *et al.*, 2018). Furthermore, there has been no study published in the literature on the practical application of the AcciMap method in live accident investigation and analysis in healthcare organisations (Wheway, 2020; Wheway and Jun, 2021).

Even though the concept of systems thinking has been advocated by the NHS authorities and Human Factors Ergonomics (HFE), their application for accident analysis has been "researched-focused" rather than "practice-focused". Example studies have compared systemic approaches (including the AcciMap method) with other non-systemic techniques, essentially highlighting their advantages (Salmon, Cornelissen and Trotter, 2012; Underwood and Waterson, 2014; Dixon, Waterson and Barnes, 2018). However, these benefits have yet to be fully realised by healthcare safety practitioners and adopted for live accident analysis within practices. Notably, from studies of Underwood and Waterson (2013) and Canham *et al.* (2018), the former extensively discussed the "research-practice gap" term regarding the use of SAA approaches, including STAMP and FRAM across multiple safety-critical domains. The latter focused on comparing RCA and the STAMP outcomes based on important usage characteristics, including usability, reliability, and validity within the healthcare context.

In examining the "research-practice gap", their findings were obtained after interviewing forty-two (42) participants experienced in incident analysis from different safety-critical domains and from across ten countries (Underwood and Waterson, 2013). Table 2-2 summarises key findings focused on the SAA dimensions, awareness, adoption, usage, organisational, and industry influences on the research-practice gap. Their study further discussed the benefits of adopting SAA approaches for "*gaining an improved understanding of accidents which may lead to more effective recommendations*" and promoted across safety-critical domains (Underwood and Waterson, 2013). This point raises the need to investigate the perception of applying an SAA approach as a tool for incident analysis, specifically by safety practitioners from the healthcare domain. Unfortunately, as earlier stated in this section, there have not been any studies that specifically evaluated the application of the AcciMap approach and understanding safety practitioners' perspectives. This fact makes the first research question in determining the perception of the AcciMap method for incident analysis by safety practitioners from the healthcare domain necessary.

Table 2-2: Summary of findings based on the SAA dimensions (Underwood and Waterson, 2013)

Dimension	Sub-Category	Conclusions
SAA Awareness	The current level of SAA awareness	While some systemic approaches are being utilised in some safety-critical industries, most practitioners (in practice) were still largely unaware of the most frequently cited approaches, including AcciMap, STAMP and FRAM but still very popular amongst researchers.
	Demand for SAA information	There is a reluctance to obtain new information that may necessitate adopting a systemic analysis tool. In addition, lack of time and resources in learning and researching new approaches due to the high work demand in their respective industries.
	The extent of training impacting awareness	The extent of training for accident investigations is dependent on the kind of role of practitioners in question. Those with lower levels of responsibility may not get a high level of relevant training.
	Accessibility of SAA information	In close relation to SAA training, individuals who did not receive formal training in SAA approaches for accident investigations may have limited access to SAA information, including scientific journals and conferences.
	Communication of SAA information	Researchers gain knowledge relating to SAA from conducting research, conferences, and networking with colleagues within the academic community. However, practitioners have cited the lack of communication between the academic research and practice communities due to these approaches being considered either too "conceptual" or providing little to no benefit.
SAA Adoption	The practicality of the analysis method	Practitioners' requirements are not being extensively considered, especially regarding the simplicity and practicality of utilising SAA approaches.
	Personal adoption criteria	Practitioners' training and experiences in using different accident models/methods may influence the choice of their approaches for conducting accident investigations.
	Accountability influence on analysis approach	The need to assign liability for an accident is influenced by the approach the safety practitioner utilises. For example, some practitioners focus on safety improvements, thereby avoiding apportioning blame, while others assign blame by focusing on the accident's commercial and legal implications. In addition, there was a need to demonstrate liability, e.g., where clients instruct safety professionals to use such tools to avoid "black spots" that may be found in their safety records.

Dimension	Sub-Category	Conclusions
	Model validation	Many practitioners consider this sub-category an important influence in adopting SAA approaches, focusing on how such approaches are extensively proven and tested.
SAA Usage	Usage resource constraints	Utilising more complex analysis techniques will depend on resources (funding) available, especially in analysing significant incidents. Time constraint is also considered a factor when conducting accident investigations.
	Model reliability	Factors that affect the reliability of outcomes include the background and experiences of individuals where results produced have variations. These variations result from the qualitative nature of systemic analysis tools, making it difficult for participants to reach firm conclusions.
	Data requirements of SAA	Several factors relating to data requirements were considered to impact the ability to apply systemic analysis methods. They included the system-wide data required to perform SAA not being available and accident information databases used to employ coding taxonomies influencing the data type collected and how their findings must be transposed into a non-systemic structure.
Organisational influences on the research-practice gap	Organisational policy	Organisational policies, in most cases, impact the type of accident analysis method used by individuals despite the freedom of choice regarding which approach to use. In addition, a link between organisational policy and safety culture was observed where the senior management partly dictates what accident approaches are utilised and instils safety culture.
Industry influences on the research-practice gap	Regulatory requirements	The degree of regulation significantly influences the technique types used for accident investigations and risk assessments in industries. Also, there was an indication that SAA regulations are not in place due to the lack of SAA awareness rather than the decision to reject them.
	Industry characteristics	The appropriateness of applying SAA approaches within any industry is dependent on the domain's characteristics, including the degree of operational complexity. For example, the STAMP approach is considered suitable in highly automated environments where software reliability is required.
	Resistance to change	The cost and effort needed to implement SAA methods through new regulations can create a situation where there is resistance.

2.7 Branford's Standardised AcciMap Approach

Branford (2007) investigated reliability and validity through the development of a "standardised" AcciMap approach (see figure 2-3) adapted from different variations of the initial AcciMap framework (Rasmussen and Svedung, 2000; Vicente and Christoffersen, 2006). This standardised approach also included guidelines for applying causal analysis and determining safety recommendations (Branford, 2007; Branford, Naikar and Hopkins, 2009). The main difference between Rasmussen and Branford's AcciMap representation is that the former has six (6) abstraction levels while the latter was condensed into four (4) levels (Branford, 2007, 2011). The latter approach did not include "Equipment and Surrounding level", and both "Technical & operational management" and "company management & local area government" were merged as "organisational". The external level of Branford's approach includes the merging of "Regulatory bodies & Associations" and "Government policies" (Branford, 2007).

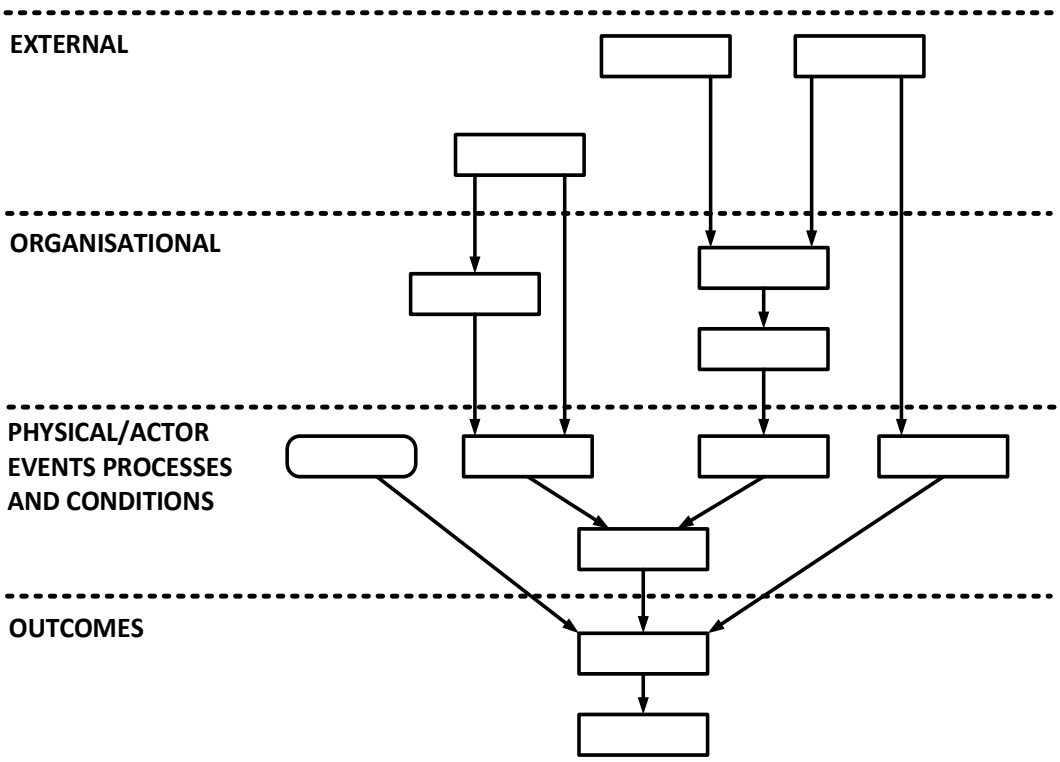


Figure 2-3: Standardised AcciMap Structure (Branford, 2007; Branford, Naikar and Hopkins, 2009)

The processes involved in analysing incidents using Branford's AcciMap guidelines for AcciMap construction include the following:

1.) Creating a blank AcciMap format on which to arrange the causes/contributing factors
2.) Identifying the adverse outcome of the incident
3.) Identifying contributing factors based on the incident report
4.) Determining the appropriate AcciMap level for each contributing factor identified
5.) Preparing the contributing factors representative of each AcciMap level
6.) Inserting causal links (relationships) to depict cause and effect between contributing factors
7.) Filling in the gaps left in the causal chains where information is missing
8.) Checking the causal logic and making sense of the sequence of events
9.) Formulating safety recommendations that are practical and feasible

These steps (guidelines) were developed as a means of enhancing the reliability of outcomes, safety recommendations and the validity of results, especially when measured in the absence of a "gold standard" (Branford, 2007).

2.8 The Relevance of the AcciMap approach

The AcciMap approach is arguably the most cited systemic accident approach (Salmon, Hulme, *et al.*, 2020). This argument was attributed to the extensive study on the evolution of the AcciMap method between 2000 to 2015 (Waterson *et al.*, 2017). However, it is not practically utilised for incident analysis as popularly as RCA techniques which have been well established as the toolkit for incident investigation, particularly in healthcare organisations. For example, in the UK, NHS boards and decision-makers have invested in programmes to help train staff to effectively conduct RCA despite evidence of its limitations (Braithwaite *et al.*, 2006; Bowie, Skinner and De Wet, 2013). Although the NHS has acknowledged the need to apply approaches that adopt a systems approach to incident analysis, noting that "*systems approach to safety recognises that incidents are linked to the system in which individuals are working*" (NHS Improvement, 2018). At the national level, the Healthcare Safety Investigation Branch (HSIB), the body responsible for investigating and analysing significant

incidents/accidents across NHS trusts, has utilised the AcciMap approach amongst other SAA approaches.

The AcciMap approach allows users to perform deeper analysis regarding system weakness within and outside the socio-technical system (Waterson *et al.*, 2017). This attribute makes the AcciMap method very applicable for accident analysis in healthcare. Branford's thesis identified the advantages/benefits of applying the AcciMap approach (Branford, 2007) as summarised below:

- Allows analysts to identify causal/contributing factors and extension of analysis beyond the organisational level. This benefit supports the inclusion of external factors, thus providing a comprehensive understanding of why an accident occurred within the broader socio-technical context and promoting the implementation of high-level corrective measures (Branford, 2007).
- Allows analysts the freedom of identifying causal factors without the restriction of using pre-defined causal categories typically featured in taxonomies/classification schemes. The method further enables analysts to highlight all possible causal factors, thereby reducing the probability of not identifying all of them. However, the disadvantage is that outcomes produced by multiple users may not be reliable (Branford, 2007).
- Provides unrestricted diagram formations, thereby not restricting how causal relationships are depicted in AcciMap outcomes. Some accident approaches like the Incident Cause Analysis Method (ICAM) assume that events resulting in an accident are sequenced in an order illustrated as causal trees (Branford, 2007). This causes 'direct' causal factors that do not fit into a sequence to be overlooked.
- Provides the advantage of organising causal factors into different abstraction levels illustrating the socio-technical context where the events took place. Causal factors are classified into their respective levels to differentiate between those within the organisation's control and the control of regulatory bodies and the government. Branford also cited other similar models like the Why-Because-Analysis (WBA) (Ladkin, 1999, 2005) and Snook's Causal Map (Snook, 2002), having the ability to classify factors based on their causal remoteness. However, they do not provide socio-technical levels to which

these factors can be arranged to explain why they contributed to the events at the physical level.

An essential benefit of the AcciMap approach is providing understanding and context regarding using health IT systems. This benefit also includes analysing how they can unintentionally but negatively impact patients' safety and identifying systemic factors that contributed to it. However, based on the findings of Underwood and Waterson (2013), the reliability and validity of systemic accident approaches, including the AcciMap method, have been questioned and cited as reasons why they have not been quite utilised in clinical practices. Therefore, for the AcciMap approach to be considered a valuable tool in healthcare, its reliability and validity will need improvement through the process of "remixing" with other techniques (Waterson *et al.*, 2017).

2.9 Review of AcciMap Research Studies

While the AcciMap approach is part of the broader Risk Management Framework (Chapter One), it has been utilised mainly as a standalone tool for either analysing case studies or in comparative studies with other accident causation approaches (Waterson *et al.*, 2017). In their subsequent findings, twenty-seven (27) significant studies were identified that applied the AcciMap approach (Appendix A-4). The AcciMap method was either used in a comparative analysis with other systematic or accident causation approaches or investigated major case incidents within different safety-critical domains. Their study also identified various safety-critical industries where the AcciMap method was applied and the methodology used, as summarised in table 2.3.

Table 2-3: Summary of the number and methodology of AcciMap studies between 2000 and 2015 based on different safety-critical domains (Waterson *et al.*, 2017)

Domain	No. of Studies	Study Methodology	Author(s)
Public Health	4	• Case Study Analysis – Testing RMF/AcciMap framework	Woo and Vicente (2003)
			Vicente and Christopherson (2006)
			Cassano-Piche *et al.* (2009)
		• Qualitative - Case Study Analysis	Waterson (2009)
Oil and Gas	2	• Qualitative - Case Study Analysis	Hopkins (2000)
			Tabibzadeh and Meshkati (2015)
Rail	2	• Accident causation comparison on Case Study	Ladkin (2005)
		• Qualitative - Case Study Analysis	Salmon *et al.* (2013)
Aerospace	1	Accident causation comparison on Case Study	Johnson and de Almeida (2008)
Outdoor Recreation	3	Case Study Analysis – Testing RMF/AcciMap framework	Salmon *et al.* (2010)
		Accident causation comparison on Case Study	Salmon *et al.* (2012)
		Application of hybrid approach on Case Study	Trotter *et al.* (2014)
Policing/Security	2	Qualitative - Case Study Analysis	Jenkins *et al.* (2010)
			Jenkins *et al.* (2011)
Manufacturing	1	Qualitative - Case Study Analysis	Le Coze (2010)
Nuclear	1	Qualitative - Case Study Analysis	Andersson (2010)
Aviation	4	Qualitative - Case Study Analysis	Branford (2011)
		Application of hybrid approach on Case Study	Debrincat, Bil and Clark (2013)
			Gong *et al.* (2014)
		Qualitative - Thematic Analysis	Harvey and Stanton (2014)
Transport	5	Accident causation comparison on	Underwood and

Domain	No. of Studies	Study Methodology	Author(s)
		Case Study	Waterson (2014)
		Qualitative - Case Study Analysis	Scott-Parker *et al.* (2015)
			Newman and Goode (2015)
			Stefanova *et al.* (2015)
			Chen *et al.* (2015)
Emergency Response	1	Qualitative - Case Study Analysis	Salmon *et al.* (2014)
Civil Engineering	1	Qualitative - Case Study Analysis	Fan *et al.* (2015)

However, their findings did not identify any study concerning the AcciMap approach used specifically within clinical practices during that same period. Based on the systematic literature search using the Scopus database (ScienceDirect), the keyword search "*healthcare*" AND ("healthcare" OR "medical" OR "clinical") were used to identify any previous studies. However, there were no recorded studies found from the results. Furthermore, from further refinement using another keyword search, "*AcciMap*" AND "*health IT*", no studies using the AcciMap approach for analysing health-IT/software-related incidents were found. Applying the AcciMap method to investigate this incident type (health-IT/software-related) is an important research study, especially in the growing area of health IT analysis and in realising the benefits of the systems thinking paradigm.

2.10 Remixing of the AcciMap approach

Waterson *et al.* (2017) study highlighted and explained the different remixing processes of the AcciMap approach. This study also included theory elaboration and use, practical trade-offs (reliability, validity, and utility), and the "bricolage" of the AcciMap approach. The third remixing process of the AcciMap method; the bricolage method, involves the "*construction of new forms of AcciMap, alongside combining components (e.g., error taxonomies, Swiss Cheese, HFACS) from other methods and models in order to embellish or improve the outputs from AcciMap analysis*" (Waterson *et al.*, 2017). The

authors reasoned that rather than developing another "novel" approach, the AcciMap method could be synthesised with existing accident analysis approaches (methods and models) (Stanton and Salmon, 2009; Goode *et al.*, 2017; Hulme *et al.*, 2019; Stanton *et al.*, 2019).

Their study also cited Salmon *et al.* (2012)'s work to support their argument in comparing AcciMap, HFACS and STAMP approaches. In that study, they argued that combining a method like the HFACS with the AcciMap method could enhance the reliability of outcomes and allow such "hybrid" AcciMap versions to be applied to multiple incidents. This point was derived from Salmon *et al.* (2012) study when comparing the AcciMap approach with HFACS and STAMP approaches. The authors specifically argued that the high reliability of the HFACS (taxonomy) could be synthesised with the AcciMap method. Their conclusions led to the development of the UPLOADS (Understanding and Preventing Led Outdoor Accidents Data System), an incident reporting and learning system for analysing incident data from led outdoor activity data in Australia (Goode *et al.*, 2017; Salmon *et al.*, 2017). There have also been other studies detailing the remixing of the AcciMap method with different accident causation approaches summarised in table 2-4 below.

Table 2-4: Summary of studies on the remixing of the AcciMap approach with other approaches (2000 to present)

Title of Paper	Approaches used	Research Objectives/Goals	Domain of Application	Authors and Year of Publication
An integrated approach to near-miss analysis combining AcciMap and Network Analysis	Combination of the **AcciMap** approach with Network analysis for identifying and evaluating system-wide protective practices.	• Identifying and evaluating system-wide protective practices from a set of led outdoor activity domain near-miss incidents. • Analysing the network of protective factors and relationships to provide a more comprehensive and richer analysis.	Led outdoors	Thoroman, Salmon and Goode (2020)

Title of Paper	Approaches used	Research Objectives/Goals	Domain of Application	Authors and Year of Publication
Assessing contributory factors in potential systemic accidents using AcciMap and integrated fuzzy ISM – MICMAC approach	Integrating the **AcciMap** approach with fuzzy Interpretative Structural Modelling (ISM) and Matrix of Cross Impact Multiplication Applied to Classification Method (MICMAC).	• Determining interactions amongst contributory factors and hierarchically representing these factors using the fuzzy ISM method. • Classifying contributing factors into different categories based on driving and dependence power values using the MICMAC method. • Determining the dominant contributory factors in a systemic accident using the degree of vertex by the MICMAC method.	Shipping	Wang *et al*. (2018)
An Accident Causation Analysis and Taxonomy (ACAT) model of complex industrial systems from both system safety and control system	Combination of the STAMP, and **AcciMap** approaches (more specifically using system safety and control theory perspectives)	• Addressing two basic issues of accident analysis; 1.) what is failure and 2.) how does the failure happen. • Combination of system factors and control functions to form a matrix model for analysis and classification.	Oil and Gas	Li *et al*. (2017)
A hybrid accident analysis method to assess potential navigational contingencies: the case of ship grounding	Combination of the **AcciMap** approach and fuzzy Analytical Network Process (ANP) method	• Enhancing safety by analytically analysing causes of marine accidents. • The AcciMap schematically marine accident marine accidents and the ANP technique analytically weights them.	Shipping	Akyuz (2015)
An integrated graphic-taxonomic-	Development of an Acci-Tree based on the	• Addressing limitations of existing accident	Aviation	Gong *et al*.(2014)

Title of Paper	Approaches used	Research Objectives/Goals	Domain of Application	Authors and Year of Publication
associative approach to analyse human factors in aviation accidents	combination of the **AcciMap** and HFACS approaches	approaches, including a description of inadequate human-aircraft environmental interactions and organisational deficiencies and lack of emphasis on latent unsafe factors outside accidents. • Enhancing the reliability of the graphic aspect and logicality of the taxonomic aspect to improve the completeness of the analysis.		
Assessing organisational factors in aircrafts using a hybrid Reason and AcciMap model	Developed using the Hybrid Reason model and **AcciMap** approach	• Causal analysis of recorded breakdowns in a safety-critical organisation utilising the strengths of both approaches.	Aviation	Debrincat, Bil and Clark (2013)
The Walkerton E. coli outbreak: a test of Rasmussen's framework for risk management in a dynamic society	Integration of Fault Trees with the **AcciMap** approach	• Testing some of the 'predictions' made by Rasmussen's (1997) Risk Management Framework	Public Health	Vicente and Christopherson (2006)

This remixing process can be applied in developing a hybrid AcciMap approach specific to analysing software/IT-related incidents in healthcare. It was also already highlighted earlier in this chapter how authors (Goode *et al.*, 2017); Stanton *et al.*, 2019) argued the need to develop a domain-specific AcciMap approach and how this process could enhance its reliability and validity.

2.11 Application of the AcciMap approach for Health IT Analysis

There has been no historical study based on the literature review regarding applying the AcciMap approach to clinical incidents based on Waterson *et al.* (2017)'s analysis. Only a few NHS trusts (e.g., NHS Nottinghamshire) and the Health Safety Investigation Branch (HSIB), a national regulatory body (instituted in 2017), utilises the AcciMap approach as part of their accident analysis toolkit in conducting causal analyses. However, at the start of this research, NHS boards in Scotland had not utilised the AcciMap approach for incident investigation. While this research involves investigating and assessing the AcciMap method, its culmination in developing a health-specific AcciMap approach will be applied for health IT analysis. This proposed AcciMap approach will then be compared with the standardised AcciMap approach to assess their reliability and validity based on causal/contributing factors, causal relationships, and safety recommendations. The application and assessment of both AcciMap versions will require using case incidents where clinical software contributed (directly or indirectly) to compromising patient safety.

2.12 Health Information Technology (HIT)

A "Health IT-enabled healthcare system" is regarded as both a safety-critical and a complex sociotechnical system (Begun, Zimmerman and Dooley, 2003; Singh and Sittig, 2015). This system also consists of the interconnection of elements comprising of people (users of IT systems), technology (software/hardware), processes, organisation, and the external environment (where policies are developed and enforced) (Sittig and Singh, 2010). Figure 2-4 shows the connection of these system components. The term "Health IT" broadly comprises "*all computer software used by health professionals and patients to support care*" (Magrabi *et al.*, 2016). Health IT also describes various technologies implemented for clinical purposes, including collection, transmission, display, and data storage (Salahuddin and Ismail, 2015). Its implementation has helped reduce medical errors that could lead to patient harm and improve clinical processes, workflow, and communication between clinicians for increased efficiency (Institute for Medicine, 2012).

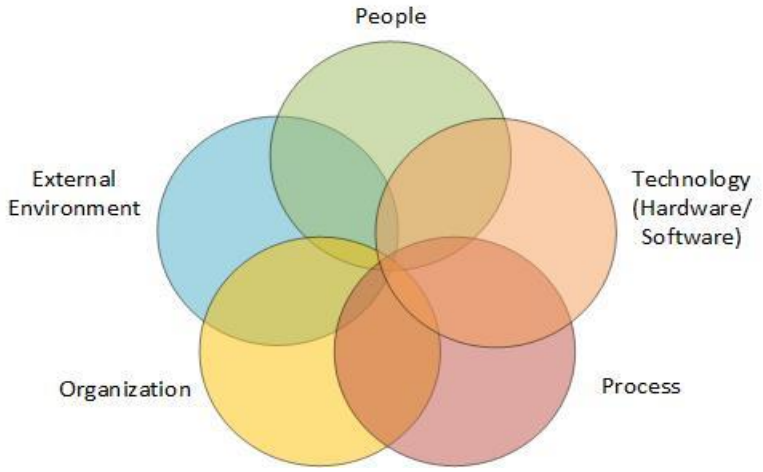


Figure 2-4: Sociotechnical System underlying health-IT related adverse events (adapted from Sittig and Singh, 2010; Harrington, Kennerly, and Johnson, 2011)

This fact is further supported based on the prediction made in 2001 by the Institute of Medicine (IOM) Committee on the Quality of Health Systems on the crucial roles of health IT. These roles include "*facilitating access to medical and medication information, assist with calculations, perform checks (in real-time or afterwards), assist with monitoring, and support communication between healthcare professionals*" (Institute for Medicine, 2001). In addition, the design, implementation, and use of health IT systems have added another complexity layer to an already complex healthcare system (Magrabi *et al.*, 2016). According to the Institute of Medicine (IOM) in their landmark report on "*To Err is Human,*" these incidents are regarded as "software-related or health IT-related" incidents (Institute for Medicine, 1999; Kohn *et al.*, 2000). Some of the issues affecting patient safety include usability, interoperability, health IT product fit with workflow, organisational, and external factors (policies).

2.12.1 Health IT and Patient Safety

Health IT utilisation has provided substantial benefits for health organisations by promoting safer and more efficient administering of healthcare (Herrick, Gorman and Goodman, 2010; Institute for Medicine, 2012; Singh and Sittig, 2015). These technologies include the Computerised Provider Order Entry System (CPOE), Electronic Medical Records (EMR), Clinical Decision Support Systems (CDSS), Electronic Prescribing (e-Prescribing) (Agrawal, 2016). Other software products

include smart infusion pumps, ventilators, pacemakers, computer systems for diagnosis and assessment (Thimbleby, 2013; Thomas and Thimbleby, 2018). Institute of Medicine (IOM) report pointed the importance of promoting patient safety through efficient design, implementation, and safe use of health IT systems within the sociotechnical context (Institute for Medicine, 2012). Its use also serves as a proactive safety management activity to reduce medical errors, prevent patient harm, and ensure safety.

2.12.2 Health IT Risks and Errors

Despite these benefits and the ever-evolving computer and information technology, it has also introduced unintentional consequences (Koppel *et al.*, 2005; Koppel, 2006; Buntin *et al.*, 2011; Magrabi *et al.*, 2016; Kim, Coiera and Magrabi, 2017). Technology (software/hardware) as a component of complex socio-technical systems is not isolated from other parts but requires interactions with intended users (clinicians) (Leveson, 2002). For instance, computing systems installed and utilised by practitioners can potentially have "computer bugs", resulting in unintended consequences eventually leading to patient harm (Magrabi *et al.*, 2016; Thomas and Thimbleby, 2018). According to the authors, these computer bugs are regarded as a "computer-related error" and can be overlooked by programmers and manufacturers (software vendors). Cheung *et al*. (2014), in their review of incidents associated with health IT, also noted after implementing CPOE systems in hospitals that while prescribing error rates reduced (between 29% to 96%), new forms of errors were introduced. An example will be when a user unintentionally selects a wrong item or patient due to these items being close to each other on the screen (juxtaposition error) (Cheung *et al.*, 2014).

Notable examples of computer-induced accidents include the famous Therac-25 accident (Leveson, 1995) regarding a massive overdose of radiation and the London-Ambulance Computer Aided Dispatch System (Finkelstein, 1993). While these examples are acknowledged as major software-related problems, errors in software systems were not the only factors that contributed to their respective adverse outcomes (Johnson, 2002). In addition, systemic factors (existing within organisational and external entities) relating to how IT systems were designed

and implemented can negatively impact patient safety (Institute for Medicine, 2012). One notable example of this was a study that examined the reasons behind the failed *UK National Programme for Information Technology (NPfIT)* (Waterson, 2014). The report summarised Ken Eason's analysis of why the national project was discontinued due to its failure in implementing a set of new HIT systems. Therefore, it's imperative to highlight cases where health-IT systems played a role in patient harm and analyse why it happened and how to prevent them from reoccurring.

2.12.3 Investigation of Health IT-related Incidents

Health IT analysis has become an emerging speciality and is considered a more specific area under the umbrella of the patient safety literature on incidents occurring in the healthcare system (Makeham *et al.*, 2017). According to the authors' systematic literature review, they identified twenty-one (21) investigations relating to HIT incidents where the majority of them ranged from clinical settings in six countries, including the UK, USA, the Netherlands, China, Australia, and Hong Kong (Makeham *et al.*, 2017). Further in their review, they identified that:

- Out of the 21 investigations, 3 were detailed and in-depth reviews on inpatient healthcare settings in the USA. From these three studies, 2 of them involved medication management systems including bar-coding and order entry systems (to be analysed in Chapter Four).
- Of these 21 studies, 13 reported on patient deaths, where 83 of them died due to health IT-related incidents. 66 of these deaths were from sentinel events investigated by the US Joint Commission.
- 15 out of 16 investigations focused on reports relating to patient harm, while the remaining was a near-miss.

Although their review did not include the Septra overdose incident (Wachter, 2015), which took place at the University of California (UCL) teaching hospital as this could also be classified as an in-depth case study (Chapter Six). Furthermore, based on the summary of findings from Magrabi *et al.* (2016) study, they identified health IT-related incidents as a growing problem and how they cause harm to patients. They are summarised as follows:

- US Food and Drug Administration (FDA) received 260 IT-related incident reports, where 44 of such incidents were linked to patient injuries, and six reported deaths (Magrabi *et al.*, 2012).
- Australian Incident Management Systems (AIMS) received 117 IT-related incidents between 2003 and 2005, where 38% (n = 44 incidents) of the incidents resulted in adverse consequences caused by treatment delays. However, no deaths were reported (Magrabi *et al.*, 2010).
- Regarding CPOE systems, the rate of computer-related paediatric errors resulted in 10 errors per 1000 patient-delays and 3.6 errors per 1000 patient-days relating to the rate of serious computer-related paediatric errors (Walsh *et al.*, 2006).
- IT-related medication errors where 4,416 incidents submitted to the Dutch Central Reporting System indicated that 16% (n = 707 incidents) of these incidents resulted from IT. Some of the notable errors include incorrect medication selection and prescription failure relating to CPOE systems (Cheung *et al.*, 2014).
- At the local level, EHR-related problems from 3,099 incident reports submitted to the Pennsylvania Patient Safety Authority between 2004 and 2012. Over 2,700 incidents were near-misses, and 15 resulted from patient harm (Sparnon and Marella, 2012).

In another related study, an analysis was undertaken involving a ten-year data collection of incidents in England and Wales taken from the National Reporting and Learning System (NRLS). From the data, 2,627 health-IT related failures were identified, where out of this, 82% (n = 2154 failures) did not result in patient harm, 13% (n = 342 failures) caused low harm, and the remaining 4% (n = 105 failures) contributed to patient death (Martin *et al.*, 2019). These example studies indicate the necessity of analysing IT-related incidents. While these examples focus on analysing quantitative data, the thesis will address the application and evaluation of the standardised and proposed AcciMap versions on qualitative data (using narrative case incidents). The domain-specific taxonomy to be developed based on the standardised AcciMap can then be applied to analyse quantitative data as part of future research.

2.13 Current Gap in Knowledge

Despite the impact of Rasmussen's work in the academic community and the popularity of the AcciMap as a systemic accident analysis (SAA) approach, there is little evidence that his methods have had similar success in practice (Salmon *et al.*, 2017). This evidence is supported by how National Health Services (NHS) trusts (and boards) have been very dependent on the use of RCA approaches like fishbone diagrams and barrier analysis (Canham *et al.*, 2018; Dixon, Waterson and Barnes, 2018). Systemic accident approaches are being gradually utilised for incident analysis in clinical settings either as standalone or with existing techniques like RCA and HFACS (Dixon, Waterson and Barnes, 2018). Also, as earlier highlighted in this chapter, validity, reliability, and usability (ease of learning) are considered essential characteristics in determining their appropriateness for accident analysis (Underwood and Waterson, 2014; Ryan, 2015). However, for this thesis, only the reliability and validity of the proposed AcciMap approach will be evaluated relating to research questions two and three.

A study that implemented the conclusion made from the work of Salmon *et al.* (2012) was the development of the taxonomy-based AcciMap approach (UPLOADS) specific to analysing outdoor activities data (Goode *et al.*, 2017; Salmon *et al.*, 2017). The additional purpose of their classification scheme was to analyse and classify multiple incident data, similar to how the HFACS approach is utilised. This concept can also be applied in developing a proposed AcciMap version for healthcare and specifically for health IT analysis to bridge the research-practice gap regarding using SAA approaches in practice. An important observation from the testing of the reliability and validity of the UPLOADS scheme based on the study methodology of both Salmon *et al.* (2017) and Goode *et al.* (2017) was that there was a set of causal/contributing factors. These factors, particularly from the latter study, were pre-determined and classified based on the UPLOAD taxonomy, with causal relationships identified and safety recommendations formulated. Their work also identified other ways of analysing incident data for testing their approach, including not using any pre-determined factors for classification. This option will require participants to use the proposed AcciMap method to qualitatively analyse a singular and

comprehensive incident to identify causal/contributing factors, classify them in sub-categories, and identify causal relationships. This approach will be applied in the reliability assessment in Chapter Six.

In addressing the research questions, the perception of using the standardised AcciMap approach will require evaluation, particularly among patient safety practitioners from the National Health Service (NHS) bodies and trusts. Observations and results of the initial assessment can significantly influence the development of the Medi-Socio AcciMap approach. Chapters Three and Four will address the evaluation and perception of Branford's AcciMap approach with patient safety practitioners. Chapter Five provides the methodology for developing the proposed (Medi-Socio) AcciMap framework based on existing taxonomies and applied for health IT analysis. Reliability (Chapter Six) and validity (Chapter Seven) assessments will compare the AcciMap approaches in answering the second and third research questions.

3.0 CHAPTER THREE: Application and assessment of the Standardised AcciMap approach

3.1 Introduction

This chapter addresses the first research question on evaluating clinical safety/risk management practitioners' perception of their first-time application of Branford's standardised AcciMap approach for accident analysis. A case study, "Wrong Patient" (Chassin and Becher, 2002), was used as part of the AcciMap training workshop involving practitioners across NHS boards in Scotland who have never applied a systemic accident approach in their respective practices. Subsequent sections will evaluate results from the survey instrument and AcciMap results comprising contributing factors, causal links and safety recommendations. The survey instrument focused on the usage characteristics criteria adapted from a previous study (Underwood, Waterson and Braithwaite, 2016) was used to evaluate their responses. Contributing factors, causal links and safety recommendations were compared between each team and expert outcomes from the incident. The benefits and limitations of applying the AcciMap approach based on their first-time use were discussed at the workshop's close.

3.2 Research Methodology

In exploring, applying, and assessing Branford's AcciMap approach with the proposed AcciMap taxonomy, a qualitative study involving a case study approach is considered most applicable in this study and subsequent chapters. Case study analysis consists of investigating "*a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and multiple sources of evidence are used*" (Yin, 1984). Using case studies to test a hypothesis also helps provide "empirical enquiry" in giving a detailed and in-depth explanation of that particular phenomenon (Yin, 1984; Wilson, 1979 cited in Branford, 2007). However, for this thesis, a case study approach is applied to address each research question. While each incident was randomly selected, they provided an opportunity for clinical safety participants to be familiar with them from a neutral standpoint and understand events and conditions that led to adverse outcomes.

The independent user's analysis of the incident and the resulting AcciMap outcomes are compared with one another (reliability) and with those of experts (validity). These outcomes will then be used qualitatively (visual observation) and quantitatively to assess and compare Branford's standardised AcciMap method and the proposed Medi-Socio AcciMap version. This process allows for insight to be gained regarding similarities and variations to determine where and why they occurred or potentially could have occurred (Branford, 2007). However, one limitation of applying the case study approach is dealing with different cognitive biases, such as subjective, researcher, and recall biases (Flyvbjerg, 2001). The nature of conducting case study analysis between users and from expert analyses is that it involves subjective judgements regarding the identification, placement, and classification of contributing factors identified. This study also extends to determining the similarity of contributing factors and safety recommendations from different users.

Quantitative analyses of results obtained also involve making subjective judgements on these aspects. However, as Branford's thesis noted, quantitative data derived from "intersubjective" decisions during content analysis are less open to criticisms regarding the data analysis. Another criticism of the case study approach is that findings from a single case cannot be generalised (Branford, 2007). However, it was noted that a sample representative of a broader population through random sampling would be necessary to generalise from a case study. Furthermore, such investigation will require repeating with a different set of users for the typicality of the results to be maintained (Flyvbjerg, 2001). However, single cases are beneficial for experimental purposes, especially at the preliminary stage, where hypotheses can be tested systematically using a more significant number of incidents.

In addressing the first research question, this study will involve a case incident, "Wrong Patient", published in the Annals of Medicine journal (Chassin and Becher, 2002). The incident was selected because the events took place in the USA and were unfamiliar to the participants. Participants will then apply the AcciMap approach and associated guidelines to identify causal/contributing factors and develop safety recommendations from their analyses. Participants

were trained to use the AcciMap method within the first hour. Then, participants were given two hours for the AcciMap analysis exercise. The following sections outline the study methodology.

3.2.1 Participants

A total of fifteen (n = 15) participants accepted the invitation and took part in the AcciMap training workshop. Information and consent forms were given to the participants and filled out before the workshop. Participants were composed of eight (8) territorial (regional) NHS boards (out of a total of 14 across Scotland who are responsible for improving the health of the population and delivery of frontline healthcare services) and three (3) special NHS boards (they provide specialist and national services) (NHSScotland, 2020). The roles and responsibilities of the participants across different NHS boards in Scotland included Clinical governance, Risk management, and Health and Safety management (see table 3-1).

Table 3-1: List of participants involved in the AcciMap Training Workshop (Edinburgh)

Participant	Role/Responsibility	Years of Experience (as of 2016)
1	Head of Clinical Governance and Risk Management	N/A
2	Senior Member, Healthcare Environmental Services	N/A
3	Corporate Risk Manager	15
4	Lead Clinical Risk Coordinator, Clinical Governance Support Unit	5
5	Head of Occupational Health & Safety	7
6	Risk Management Advisor (Patient Safety)	N/A
7	Clinical Risk Manager	10
8	Risk/Health & Safety Manager, Clinical Governance & Health & Safety team	7
9	Risk Manager, State Hospital	11
10	Head of Health and Safety	9
11	Risk Manager, Scottish Ambulance Service	N/A
12	Risk Management Service Support & Datix Systems Administrator	N/A
13	Risk & Safety Manager	N/A
14	Lead Clinical Risk Coordinator, Clinical Risk Management	5
15	Patient Safety Lead, Healthcare Improvement Scotland	4
N/A – Not available		

In addition, all participants have experience using Root Cause Analysis (RCA) techniques in their respective boards for incident analysis. The Healthcare Improvement Scotland (HIS) provided the ethics approval to conduct the workshop with invited clinical safety practitioners.

3.2.2 Training Provided

Training materials, including the case incident information and the AcciMap guidelines (Appendix B-1), were provided and distributed before the training and analysis workshop. On the day of the workshop, participants were introduced to the AcciMap approach and the broader Risk Management Framework (RMF). A case example of the application of the AcciMap method was also described to the participants.

3.2.3 Procedures

During the first section of the training, the clinical safety participants were introduced to the theory and practical AcciMap application using an example incident (Horsky, Kuperman and Patel, 2005). Participants were then randomly divided into three groups: teams A, B, and C, each comprising five members. To reduce bias, the incident information only contained the chronology (timeline) of events without any initial analyses and discussions from the original authors. Each team commenced their study of the incident within the next two hours assigned for the exercise. Also, each group was provided with A3 paper and sticky notes to construct their AcciMap outcomes. Safety recommendations were also developed after the teams completed their evaluations within the two-hour window. Each of the team's discussions as they were analysing the incident was also audio recorded. After their analyses, the teams were then required to review each other's results before the final discussion. Questionnaires were then distributed to participants after the focus group discussions were completed to end the workshop.

3.3 Case Incident One - Synopsis

The incident highlighted a type of medical error that occurred in a US-based hospital where the wrong patient underwent an invasive procedure (Chassin and Becher, 2002; Johnson, 2004). This incident was indicated to be very distressing

and warranted attention. Also, this type of event (wrong patient invasive procedure) was under-reported, according to Chassin and Becher (2002). The scenario involved a 67-year-old patient admitted to the hospital for cerebral angiography but mistakenly underwent an invasive cardiac electrophysiology procedure. A second patient, a 77-year-old, was transferred from another hospital for a cardiac electrophysiology procedure. Her procedure was delayed for two days and was intended to be the first case on the day of the first patient's planned discharge from the hospital. The complete timeline of the chronology of events is summarised (Appendix B-2). This incident was selected based on reasons regarding the type of error and the location where it occurred. This incident was reviewed and analysed using the institution's root cause analysis tool, where several distinct errors were discovered. According to the study, "no singular error" was identified, which could have led to the adverse event itself (Chassin and Becher, 2002).

3.4 Data Collection and Analysis

Data sources from the workshop consisted of audio recordings from each group designated as Team A, B, and C and survey data on the evaluation of the AcciMap method. In addition, the AcciMap outputs from each group were also collected, including safety recommendations.

3.4.1 AcciMap Analysis Workshop

After the exercise, each team reviewed and compared their findings with what other groups did in producing their outcomes. AcciMap results are compared and contrasted for similarities and differences in contributing factors using content analysis as a qualitative reliability measurement (Branford, 2007). The AcciMap results were also compared with external analysis of the case incident to determine if similar contributing factors and safety recommendations were identified (validity assessment).

3.4.2 AcciMap Evaluation Questionnaire

The evaluation questionnaire used for the workshop was from previous fieldwork utilizing another systemic accident method (STAMP) (Underwood, Waterson and Braithwaite, 2016). Data collected from the survey were analysed using

Microsoft Excel and R, a statistical software. The questionnaire consisted of twenty-two (22) questions relating to important aspects of an accident analysis approach, including usability and validity (Appendix B-3). These aspects were also used to evaluate the STAMP approach in a small investigation study with safety practitioners in the Railway domain. The questionnaire was distributed to the participants after the analysis exercise was completed.

3.4.3 Audio Recordings

Audio recordings were collected from each team after their analyses and final group discussions. They were manually transcribed to determine themes relating to the identified contributing factors. The audio data was used to ascertain their experiences after applying the AcciMap approach, including the advantages, limitations, and areas of improvement.

3.5 AcciMap Workshop Findings

Findings based on the survey instrument and the respective AcciMap results from the participants' analysis of the case study are divided into the following sections:

3.5.1 AcciMap Survey Analysis

The survey's average response to all questions (22) was neutral (in the range 2-4), as seen in table 3-2. However, there was a range of standard deviations across the questions meaning the spread of responses on each question varied. For example, question 16 (*AcciMap is easy to use in a team-based analysis*) has the lowest standard deviation (SD) value (0.641), meaning the average difference from the mean for each response keeps the response neutral. However, this question compares to question 7 (*AcciMap provides a comprehensive description of an accident*) for which the standard deviation is higher, with a value of 1.261, which means that the average difference between responses and the mean could change the response to be "agree" or "disagree". This point also means there is less certainty that this is a neutral response overall. Question 6 (sub-questions 6a to 6e) focused on the effectiveness of the AcciMap approach in identifying contributing factors based on "*technical components*", "*human factors*", "*organisational*", "*environmental*", and

"*external issues*". However, the outcome from those sub-questions indicated neutral responses based on their SD value except for sub-question 6e (*AcciMap effectively analysing contributing factors to an accident from External issues*) with a high SD score of 1.198, indicating responses were also spread out.

Table 3-2: Descriptive Statistics based on the Survey Questions (questions 4 to 22)

Question		N	Min	Max	Mean	SD
4.)	AcciMap is a suitable method for analysing accidents	13	3	6	3.92	.862
5.)	AcciMap effectively describes the timeline of events leading to the accident	13	0	3	2.23	1.013
6 a.)	AcciMap effectively analyses the contributing factors to an accident from Technical components	13	3	5	3.62	.650
6 b.)	AcciMap effectively analyses the contributing factors to an accident from Human factor issues	13	2	5	3.54	.776
6 c.)	AcciMap effectively analyses the contributing factors to an accident from Organisational issues	13	3	5	3.77	.725
6 d.)	AcciMap effectively analyses the contributing factors to an accident from Environmental issues	13	3	5	3.54	.660
6 e.)	AcciMap effectively analyses the contributing factors to an accident from External issues	13	0	5	3.54	1.198
7.)	AcciMap provides a comprehensive description of an accident	13	1	6	3.62	1.261
8.)	AcciMap effectively represents causal relationships between each level	13	3	6	3.38	.870
9.)	AcciMap accurately identifies the causes of an accident	13	3	6	3.23	.832
10.)	AcciMap can be applied to analyse any type of accident in NHS boards	13	2	6	3.54	1.266
11.)	AcciMap is an easy method to understand	13	3	6	3.85	.987
12.)	The terms and concepts used in the AcciMap method are clear and unambiguous	13	3	5	3.77	.725
13.)	It is easy to identify contributing factors that led to the accident	12	3	5	3.83	.718
14.)	It is easy to identify unsafe decisions that led to the accident	13	2	5	3.62	.768
15.)	AcciMap is an easy method to use for accident analysis	13	3	6	3.85	.987
16.)	AcciMap is easy to use in a team-based analysis	13	3	5	3.92	.641
17.)	AcciMap promotes team collaboration during analysis	13	2	5	3.08	1.115
18.)	AcciMap's graphical diagram is a useful communication tool	13	2	5	3.38	.870
19.)	It would be easy for me to become skilled at using the AcciMap method	13	3	6	3.15	.987
20.)	AcciMap analysis can be completed in an acceptable timescale (within a few hours of the workshop)	12	3	5	3.75	.754
21.)	AcciMap method is time consuming	13	1	5	3.08	1.038
22.)	I received sufficient introductory training in the use of the AcciMap method to effectively use this method	13	1	4	3.00	.913

Reasons for these neutral responses could relate to their first attempt at applying the AcciMap approach using the guidelines, understanding of the incident, and lack of substantial evidence at organisational and external levels. For example, one of the factors at the organisational level, *"electrophysiology laboratory computer not in sync with the hospital's main computer system"*, contributed to the patient subsequently not being adequately identified by the medical staff. However, further investigation will be needed to ascertain why that is the case, and the parties responsible would include the technical/IT department and hospital management. Other organisational factors were not based on explicit evidence but deduced based on the actions of medical staff. These include how they interacted with the patient (obtaining consent), misidentifying the patient, and inadequate communication with other staff (not using the patient's full name). There were also mixed responses from participants regarding the application of the AcciMap approach being a time-consuming process and the sufficiency of the training for effective use (questions 21 and 22).

Other aspects of the AcciMap method regarding identifying unsafe decisions (question 14) and terms and concepts being clear (question 12) also indicated mixed responses. These aspects may have been influenced by their level of satisfaction regarding the sufficiency of the AcciMap training workshop (question 22). Generally, the reasons for neutral responses from participants could be because of the following reasons:

- Neutral responses may be genuinely neutral, which potentially means participants see little difference or no advantages or disadvantages to other methods available.
- Neutral responses may indicate that a participant has not fully understood the AcciMap approach and so do not wish to comment strongly in either direction.
- Neutral responses may be caused by user fatigue, and this may mean that the survey may be too long for participants to concentrate for long enough.
- Neutral responses may occur due to a central tendency. This point means that participants may tend to answer more towards the centre of a scale than the stronger ends (strongly agree or strongly disagree).

However, their responses to questions of interest from the survey can be used to substantiate with findings from their respective AcciMap results regarding their first-time experience utilising the AcciMap approach. The following subsections elaborate on the results.

3.5.2 AcciMap Results

The AcciMap outputs produced by each Team A (figure 3-1), B (Appendix B-4) and C (Appendix B-5) based on initial observation showed similarities and differences in contributing factors identified. Each AcciMap output was compared with one another (reliability) and compared with findings obtained from an external (expert) review (validity) of the incident (section 3.6). Contributing factors identified based on evidence are denoted as regular boxes, while factors considered inferences are represented as broken boxes. The comparative study of AcciMap results between teams and external review are based on contributing factors, causal relationships, placement of factors and safety recommendations. These aspects are elaborated in section 3.7.

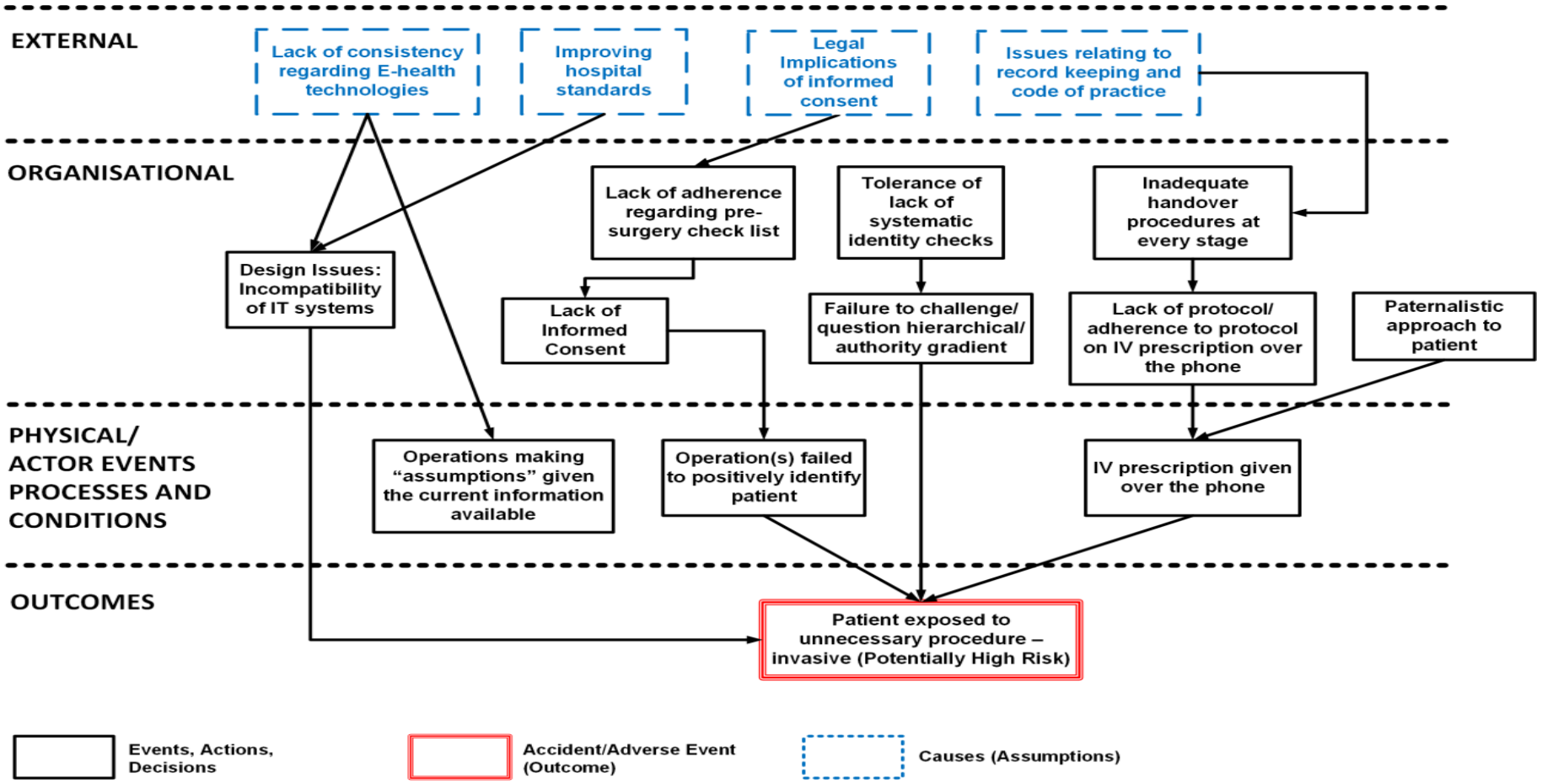


Figure 3-1: Team A - AcciMap Output of Case Study

Based on each team's contributing factors, similar factors were identified but expressed using different semantics. Their respective findings relating to some of the contributing factors from the incident identified are discussed in the following subsections:

3.5.2.1 Contributing Factor – Hospital's Computer Systems

All teams identified the contributing factor relating to the electrophysiology laboratory system. This factor was explicitly indicated as "*incompatibility of IT systems*" (Team A), "*electrophysiology system and hospital's main computer not communicating with one another*" (Team B), and "*separate computer systems not communicating with one another*" (Team C). Team B regarded issues relating to technology (Computer systems) not communicating with one another (Hospital's primary computer system) and how this contributed to the patient being misidentified ("Morrison" being confused with "Morris"). Team C also indicated issues relating to computing systems not communicating, leading to the patient's identity not being confirmed before the procedure commenced.

3.5.2.2 Contributing Factor – Patient Misidentification and Communication Issues

Several contributing factors identified by team C attributed to issues relating to "*patient identification*" and "*patient being ignored by the physician*" stem from communication issues regarding the identification of the correct patient (staff not verifying the identity of the patient, e.g., using the date of birth). One of the participants (Team C) pointed out this factor based on personal experience about a patient (ward):

> *"Every time the ward was handed over, they read the ward's date of birth."*

This step would be a barrier against misidentification, ensuring that the patient examined is the right one. They further reasoned those failures exist when identifying patients' names, even when two patients may be in entirely different hospital areas and the barriers that should be in place to prevent it. Regarding the patient ignored by the physician, participants from team B reasoned that

this was a result of other factors, including "*pressures of waiting time*" or "*inadequate training*". Finally, there were no indications among Team A participants regarding communication issues but indicated issues relating to other staff (operations) failing to identify the patient correctly.

3.5.2.3 Contributing Factor – Patient's Uninformed Consent

While differently worded, one of the contributing factors carried the same meaning and identified by teams A and B was the patient giving uninformed consent. Team A's analysis, for example, depicted this contributing factor as "*lack of informed consent*", to which one of the participants noted an issue of consent relating to the patient:

> *"Lacks the whole human factors elements to it; overburdened and exhausted physicians, they do not know the patients, they don't know if they actually spoke about what the procedure is."*

Another participant (Team A) supported this as a contributing factor and explained further that:

> *"Patients cannot frequently recall within hours of giving crucial information. But if we know that, why was it not getting spoken about earlier."*

Their observations would explain their reasoning for the mix-up regarding the patient giving consent. She consented but was not adequately informed about the type of procedure she would undergo. Also, the patient experiencing nauseating symptoms created a situation where assumptions about her condition led to the belief that she was indeed supposed to undergo such a procedure. The participants also acknowledged that consent regularly occurs in health practices, although the case incident did not state this. Team B participants similarly identified "patient giving an uninformed consent" as elaborated by one of the participants:

> *"I assume that in most healthcare establishments, when a patient says no, I do not want that (procedure), it happens, they pause and will not continue with the surgical operation."*

The concept of "surgical pause" was considered a contributing factor and was even deemed one of the holes in the Swiss Cheese by one participant! This factor, shared by another participant, indicated the need for absolute clarity regarding the "*pause*" in the process and to look for specific indicators to get a green light on whether to proceed with double checking if it is the right patient for the procedure. This measure also includes the need for double-checking the consent form, getting the paperwork right, checking if the patient understands the procedure, and evaluating whether it is safe to carry out the operation. If these indicators are not present, then the procedure should not even progress. In other words, the team determined that there were margins of failure in the system. However, team C did not explicitly include this contributing factor and suggested "*staff not listening to the patient and was not in agreement*" was a consent issue. This issue was because the preceding cause of that effect was "inadequate policies regarding patient consent" (organisational factor).

3.5.2.4 Contributing Factor – Organisational Issues

While participants were allowed to make inferences on contributing factors at the organisational level, they also identified factors based on the information available in the case study. For example, teams A and C identified a contributing factor relating to staff not challenging or questioning the higher hierarchy regarding the misidentification of the patient. Also, team A identified contributing factor "*tolerance of lack of systemic identity checks*" as a safety culture issue relating to the hospital's failure to conduct patient identity checks at different instances (at the physical level). However, this was noted as an assumption and not necessarily a fact. Finally, team B identified "*Management complacency*" as an organisational issue, and their reasoning behind this factor was highlighted by one of the participants (Team B):

> *"Allowing the staff to take unilateral decisions when they shouldn't as long as nothing goes wrong, then they are quite happy for that to let it go on."*

Several other organisational contributing factors were identified by team C including "staff not challenging", which was causally linked to another factor at the physical level ("study arranged despite no written order"). Contributing

factors including "*lack of safety culture*", "*lack of clinical governance*" were identified by team C as inferences. They considered these factors to be reasons that contributed to the organisational culture of developing shortcuts and workarounds.

3.5.2.5 Contributing Factor – External Issues

No contributing factors based on evidence in the case study were identified by any of the teams for the external level, but inferences were made. These inferences made by each group can be summarised based on their AcciMap outcomes in table 3-3 below:

Table 3-3: Contributing factors (Inferences) based on the case incident (Teams A, B, and C)

Team A	Team B	Team C
• Lack of consistency regarding E-health technologies • Improving hospital standards • Legal implications of informed consent • Issues relating to record-keeping and code of practice	• Waiting lists and targets from the government • Budgeting issues and cost cuttings • Set targets delivered to the organisation	• Issues regarding boarding from another hospital • Demand demographics • Waiting times and targets

Reasons behind each team's decision to include these contributing factors were not openly discussed in their analyses. However, it indicates differences based on their perception and understanding of possible systemic factors that created the climate for the events. The one inference at this level that was similar between teams B and C was "*waiting lists and targets*".

It was observed during the exercise that some of the participants employed human factors thinking and traditional techniques such as the 5-Whys and barrier analysis based on their experiences in conducting an incident investigation. Comparing the AcciMap outcomes by placing immediate causes after the incident at the "Physical Actors and Processes" level, we noticed similar events from the teams (particularly from Teams B and C). However, the causal linkages

constructed by each team appeared to show differences. These are discussed further in the following section of the comparative analysis of results.

3.6 External Analysis

The principal researcher and a clinical domain expert carried out an external (expert) analysis of the incident, as shown in figure 3-4. The result obtained from the incident analysis and used as part of the discussion regarding the face validity of findings obtained from the NHS participants. No contributing factors were identified at the external level due to a lack of evidence from the case incident. There were more contributing factors identified at the physical/actor level than from the results of participants. However, the reason for this is that the number of factors associated with the activities of the other medical staff involved led to the patient receiving a wrong procedure was identified. Additionally, other contributing factors (organisational level) include the perceived culture of not challenging senior staff members and policies regarding the verification of patients before undergoing any planned medical procedure. Other contributing factors identified include patients sharing a similar pseudonym (physical/actor level), and inadequate policy regarding clinical communication among medical staff" (organisational).

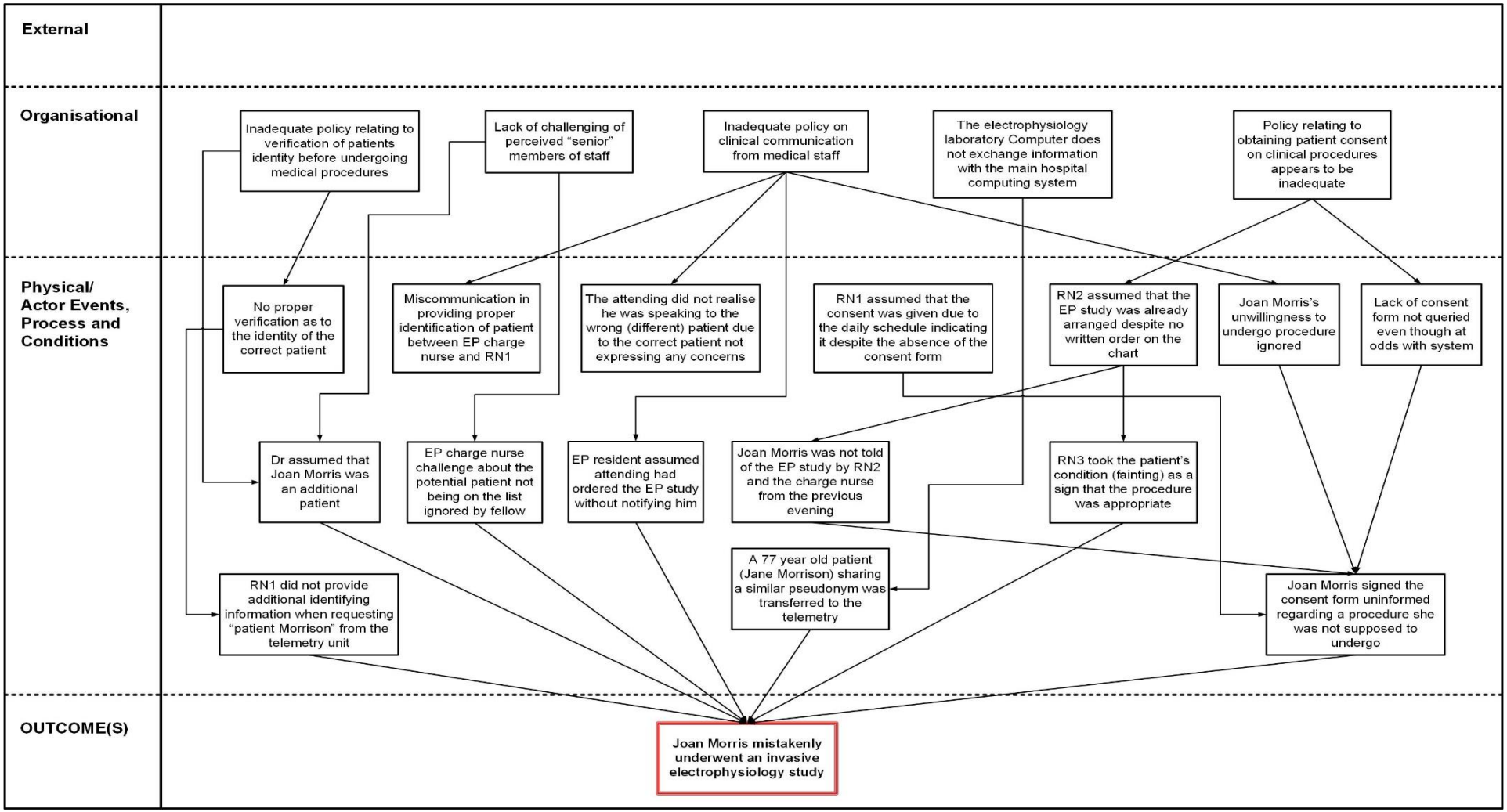


Figure 3-2: AcciMap Output of Case incident – External Review

3.7 Comparison of AcciMap Results

AcciMap results produced by each team were compared to assess the reliability of outcomes produced. Based on the qualitative evaluation approach adopted by Branford (2007), the following criteria used to evaluate the results include:

1.) Identification of causal/contributing factors at each AcciMap level
2.) Placement of causal/contributing factors at the appropriate AcciMap level
3.) Causal links (relationships) within and between each AcciMap level
4.) Safety recommendations

While each team would not produce the same AcciMap model output, the purpose was to determine if similar factors were identified, the level they were placed in, and if similar causal links between them could be identified. Also, wordings used to describe events (contributing factors) were not expected to be identical as long as they portrayed similar meanings.

3.7.1 Identification of Causes/Contributing Factors

Causal/contributing factors identified by each team for each AcciMap level is divided into two parts. First, the process of comparing contributing factors between groups involves using qualitative content analysis to determine similar contributing factors identified from each team's AcciMap results (Hignett and McDermottt, 2015). Each similar contributing factor is assigned an alphanumeric and colour coded as shown in figure 3-3. Second, the remaining contributing factors are uniquely identified from each team's AcciMap result.

3.7.1.1 Physical actor events Level

At the physical/actor events level, team A identified three (3) factors, team B identified thirteen (13), and team C identified seven (7) factors. The only similar contributing factor identified by all groups was the factor relating to "*patient identification*" (C-2) from figure 3-3. Other similar contributing factors identified include "*patient's wishes being ignored by medical personnel*" (C-4) by teams A and B and "*inadequate handover procedures/processes*" (C-6) by teams A and B (team B placed it at this level). Table 3-4 shows contributing factors distinctly identified by each team at this level.

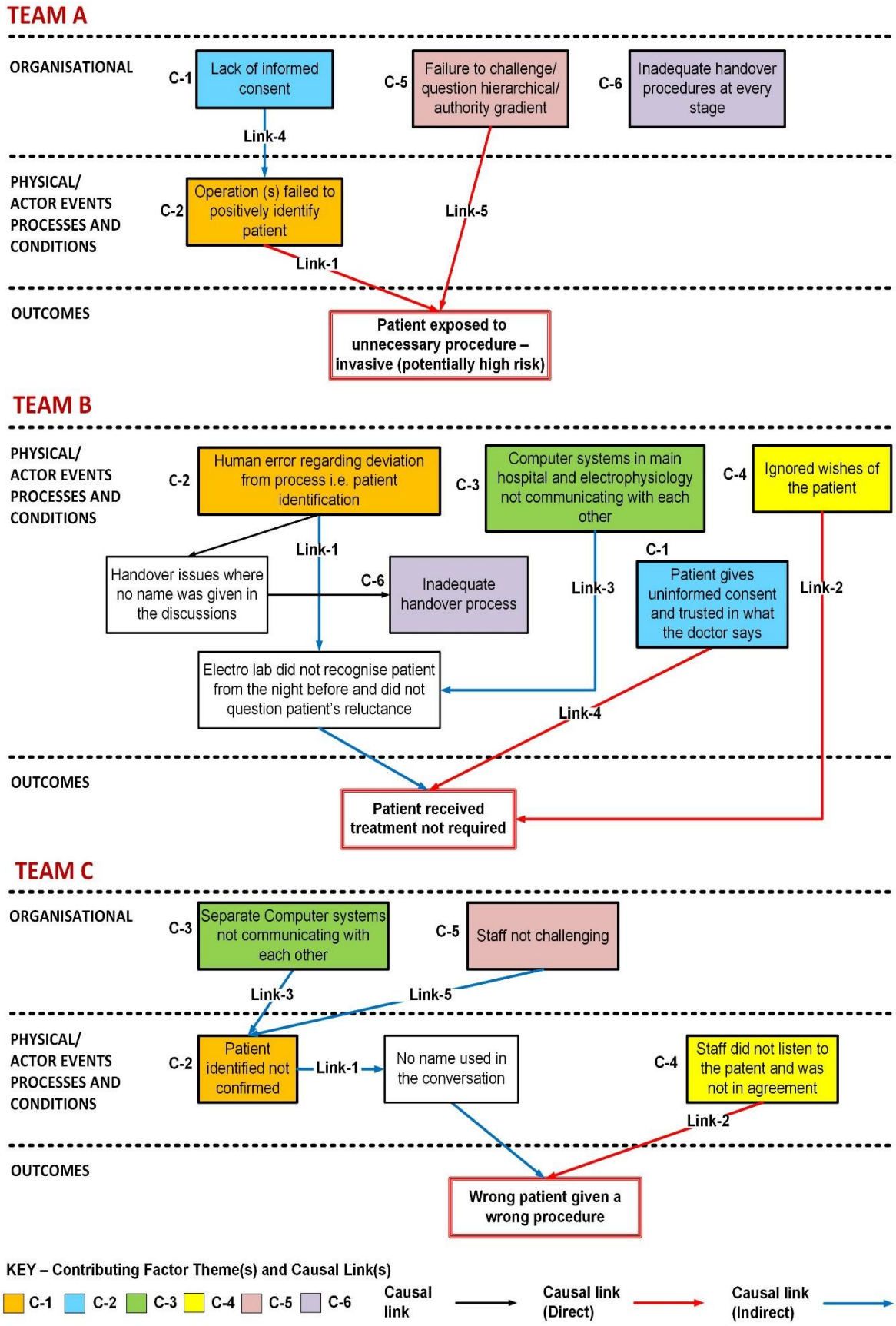


Figure 3-3: Causal relationships (between similar contributing factors) identified by all teams (A, B, and C)

Table 3-4: Contributing factors uniquely identified by each team (A, B, and C) (Physical/Actor Level)

Team A	Team B	Team C
Physical/Actor-Process Level		
• IV prescription is given over the phone • Operations making "assumptions" given the current information available	• The patient was nauseated and not feeling well while giving consent • Patient not being recognised by the attending in the electrophysiology lab the night before • Electro lab did not identify the patient from the night before and did not question the patient's reluctance • Assumptions by the neurosurgery team that his attending had ordered the study • The attending in electro lab did not recognise the patient from the night before • The fellow was aware of missing information but never followed up • All consents forms received except the wrong patient and then one additional consent form	• The patient delayed for two days • End of shift (the team did not provide context for this factor) • Study arranged despite no written order • The doctor instructs prescription for nausea rather than having a discussion • No name used in the conversation
Organisational Level		
• Design issues: incompatibility of IT systems • Lack of adherence regarding the pre-surgery checklist • Tolerance of systematic identity checks • Lack of protocol/adherence to the protocol on IV prescription over the phone	• Accepting patients from outside the hospital with no robust communications systems • Management allowance for procedures to go without written order for IN chart • Lack of auditing • Pressure of time for getting the list done by clinical staff • Lack of strategic systems to track patient's information • Lack of IT controls, strategy, and development • Poor training for staff regarding handover process	• Accepted shortcuts and workarounds created • Lack of inadequate policy regarding patient consent • ** Deficiencies of handover process/procedure/auditing/training • ** Lack of safety culture • ** Lack of clinical governance • ** Person-centred
External Level		
No contributing factor was identified at this level (see prior **table 3-3** for inferences at the external level)		
** Indicating inferences from the AcciMap analysis		

3.7.1.2 Organisational Level

At this level, team A identified eight (8) causes/contributing factors, team B identified seven (7), and team C identified eight (8), although out of that number, four (4) indicated as "assumptions". Similar contributing factors include "*medical staff not challenging authority*" (C-5) was identified by teams A and C.

Another similar contributing factor identified by groups B and C related to "*communication between computer systems*" (although this factor was placed at different AcciMap levels, as shown in subsection 3.5.2). The remaining contributing factor, "*issues relating to patient's informed consent*" (C-1), was identified by teams A and B (although team A placed this at the organisational level).

3.7.1.3 External Level

No similar contributing factors were identified at this level by the teams. The incident did not contain explicit evidence of the factors that contributed to the decisions made at the organisational level (subsection 3.5.2.5).

3.7.2 Placement of Causes/Contributing Factors

Placement of causes/contributing factors at the appropriate level is considered essential in addressing system areas that need improvement through safety measures (Branford, 2007). According to Branford's guidelines, the placement of contributing factors is determined if these factors were placed at the appropriate AcciMap level. Contributing factors attributed to patient misidentification, miscommunication with the patient (C-2), and patient giving uninformed consent (C-1) were all placed at the appropriate level (physical actors level). Another contributing factor, "*lack of communication between computer systems (C-3)*", particularly between the main hospital and the electrophysiology unit, was appropriately placed at the organisational level by teams A and C. However, Team B put that contributing factor at the physical/actor level instead of the organisational level as this was within the hospital organisation's control. Another contributing factor (C-6) was placed differently by teams A (organisational) and B (physical/actor).

3.7.3 Causal relationships (links) within and between AcciMap levels

This criterion is perhaps the most challenging when comparing causal relationships between similar contributing factors identified from all teams AcciMap results. Team B's outcome had the most causal links (31), with team A having fifteen (15) and team C having twenty-one (21) connections. A similar process used in identifying and coding similar contributing factors was used to identify causal links (direct and indirect) between teams. Each similar link

between factors was also coloured and assigned a code (see figure 3-3). Based on all causal relationships identified, the only causal relationship (direct and indirect) that was similar was in respect to patient misidentification leading to the effect of the wrong patient being administered a procedure (Teams A, B, and C) (**Link-1**). Other causal relationships between physical/actor, organisational and outcome levels that were similarly identified by the teams include:

a) The linkage (direct and indirect) between *"Wishes of patient ignored"* and *"Patient (Jane Morrison) being given an EP procedure"* – Teams B and C (**Link-2**)
b) The linkage (direct and indirect) between "*Computer systems not interacting (communication)with each other*" and "*patient receiving a wrong procedure*" – Teams B and C (**Link-3**)
c) The linkage (direct and indirect) between *"lack of informed consent from the patient"* and *"patient receiving a wrong procedure"* – Team A and B (**Link-4**)
d) The linkage (direct and indirect) between "*staff not challenging authority*" and *"patient receiving a wrong procedure"* – Team A and C (**Link-5**)

3.7.4 Safety Recommendations

Based on safety recommendations produced by each team, there were similarities and differences based on their respective analyses (see table 3-5). Similarities from the safety recommendations were also identified by determining themes using content analysis. These were also labelled using an alphanumeric code (designated as Safety recommendation – SR-1), and the themes identified from the teams consist of the following:

1.) Implementation of safety briefs (**SR-1**) - (Teams A and C),
2.) Reviewing processes relating to consent policy (**SR-2**) - (Teams B and C) and,
3.) Reviewing existing computer systems (**SR-3**) - (Team A and B).

These recommendations relate to contributing factors including handover processes, communication relating to computer systems, and patient consent policies.

Table 3-5: Safety recommendations of Teams A, B, and C based on Wrong Patient case incident

Team A	Team B	Team C
1.) A full review of systems **(SR-3)**. 2.) Implementing safety briefing surgical pause handover **(SR-1)**.	1.) The process for patient consent must be robust, and unless completed procedure must be halted. This process should be audited **(SR-2)**. 2.) Patient information systems must be able to share information. 3.) The compatibility of systems needs to be reviewed **(SR-3)**.	1.) Implementation of safety briefs to support the development of safety culture **(SR-1)**. 2.) Implementation of consent policy **(SR-2)**.

Comparing each team's safety recommendations with those produced from the external analysis (see table 3-6) shows similar outcomes relating to patient consent policies and reviewing computing systems in terms of synchronising with each other with updated patient information. However, other recommendations not indicated by respective teams include organisational safety culture regarding challenging hierarchy when reporting concerns and reviewing policies and training regarding patient identification. Another essential safety recommendation will be syncing information regarding the patient (i.e., identity) between computer systems within the organisation and setting up security checks to ensure patients' correct identification and procedure.

Table 3-6: Safety recommendations (external analysis) on the Wrong Patient case incident

Safety Recommendations
1.) **Patient Identification** a.) Review of the organisational policy on positive patient identification to ensure it is adequate, i.e., it contains clear instructions on triangulating a patient's identification – ask the patient their name, DoB (Date of Birth), and what they understand they are here for. b.) Develop appropriate training materials (online?) for this purpose c.) Implement a programme of mandatory training for all staff in patient-facing roles to ensure this is embedded in daily practice. 2.) **Patient Consent** a.) Review of the organisational policy on positive patient consent to ensure it is adequate, i.e., it contains clear descriptions of informed and uninformed consent and includes "break glass" conditions for when it is not possible to obtain informed consent. b.) Develop appropriate training materials (online?) for this purpose c.) Implement a programme of mandatory training for all staff in patient-facing roles to ensure this is embedded in daily practice.

Safety Recommendations

3.) **Clinical Communication**
   a.) Review of the organisational policy on positive patient consent to ensure it is adequate, i.e., it contains clear guidance on the mandatory information which should be relayed at any hand-over of a patient from one healthcare professional to another. This may benefit from the adoption of the SBAR approach – Situation, Background, Assessment, Recommendation.
   b.) Develop appropriate training materials (online?) for this purpose
   c.) Implement a programme of mandatory training for all staff in patient-facing roles to ensure this is embedded in daily practice.

4.) **Computing Systems**
   a.) Computer systems must be in sync within the hospital to be able to receive updated information regarding patients.

5.) **Culture of clinical hierarchy**
   a.) Review the organisational culture regarding any perceived clinical hierarchy and the abilities to challenge "upwards", e.g., Nurse to Doctor, Jnr Doc to Consultant, etc.
   b.) Introduce a duty of candour into all clinical staff contracts so that individuals are duty-bound to report any concerns within a "just" culture, without fear of recrimination.
   c.) Training and support for this implementation would also be required and would need to be led by the medical director.

3.8 Discussion

Based on the AcciMap results and responses from the survey data obtained from participants after the training workshop, the following subsections discuss their outcomes based on the survey, AcciMap analysis and challenges in applying the standardised AcciMap approach.

3.8.1 Application of the Standardised AcciMap Approach

Despite neutral responses to some of the questions in the survey, participants generally indicated an understanding and considered the AcciMap approach suitable for incident analysis. However, participants also discussed recommendations from their retrospective analysis to identify similarities. Regarding mapping the causal relationships between each level of the AcciMap, one participant noted some difficulty in understanding the role of 'actors' at the external level in contributing to the accident. The participant questioned the benefit of analysing systemic factors at the external level, especially regarding whether recommendations would improve system safety. However, this point wasn't supported by another participant in team C who believed that by

analysing the external level, one could determine possible latent conditions/weaknesses that enabled such an event to occur.

Organisational culture and inadequate systems were generally considered issues from the incident, particularly from team C. One participant noted that while this incident is only a "window", it was believed that the next step an organisation needs to take is to determine if this is a systemic issue. Another participant (Team A) opined that it would have been preferable to implement the AcciMap approach in their organisation's clinical incident scenarios. This point highlights the need for further investigation into the suitability of the AcciMap method, especially for live incident investigation in NHS boards. In their NHS practice, two participants were familiar with using a cause-and-effect template based on another systemic accident approach (Australian Transport Safety Bureau). Their experience in using this approach may have contributed to how they approached their analyses. Some participants utilised their experiences in using RCA techniques like barrier analysis and 5-why(s) in determining contributing factors. However, this is not considered a limitation in helping them determine contributing factors from the incident.

3.8.2 Method Usage Characteristics

Participants' perception of the AcciMap approach is discussed based on the usage characteristics framework (Underwood and Waterson, 2013, 2014; Underwood, Waterson and Braithwaite, 2016).

3.8.2.1 Graphical Representation of the Accident (Adverse outcome)

During discussions, participants generally agreed that using the AcciMap approach as a graphical tool can help investigators depict and identify specific problem areas that compromise patient safety. From the survey result, a high percentage of participants either "*agreed*" or "*slightly agreed*" that the graphical representation of the accident can serve as a valuable means of communication (question 18). Only one participant slightly disagreed with this point. Another participant noted that the mapping of contributing factors provides a helpful way of promoting discussions with higher management. However, another participant indicated that AcciMap diagrams could become too complex unless contributing factors, i.e., communication, staff competence,

"*are grouped under a higher hierarchy*". Regarding representing the timeline of events as specified in the case study, participants (6) generally disagreed regarding diagrammatically denoting timelines of the events. The remaining participants were neutral in their responses.

3.8.2.2 Data Requirements

One of the participants commented on the nature of the case study as an incident they experienced in their NHS board. The quality of the incident report also contributed to how each team interpreted the events that led to the patient receiving the wrong procedure. While they were guided using the table of contributing factors from Branford's training manual, they generally had varying views regarding systemic factors (organisational and external levels) that contributed to the adverse event. However, making inferences from the incident was encouraged as part of the analysis since this was an exploratory study. From their outcomes, there was an indication of the challenge in determining systemic factors at those levels.

3.8.2.3 Usability/Ease of Learning

Regarding the AcciMap approach's suitability for analysing accidents (question 4), the participants had a general agreement, with only two neutral. Results from the survey data indicated that participants "slightly agreed (4)", "agreed (2)", and "strongly agreed (1)" regarding the method's ease of use (question 16). The remaining participants (6) provided neutral responses. There were also neutral responses regarding its applicability to analyse accidents in NHS practices (question 10) and how easy it was to understand the AcciMap approach (questions 11). Finally, participants collectively agreed that, like any analysis tool, understanding and using the method effectively depends on the skills, knowledge, and experiences gained from previous investigations. This perception indicated that more training will be needed to use the AcciMap method effectively and is considered a vital process regarding validity. This last point was particularly emphasised by one of the participants during the discussion.

During the exercise, the participants generally did not indicate difficulty following guidelines regarding placing the contributing factors in the appropriate AcciMap levels. However, the challenging aspect of the activity was mapping

logical casual connections between each level (based on step 7 from Branford's AcciMap training manual). Their responses and discussions also indicated a mixed review regarding question 21 (the AcciMap being time-consuming). Although their analyses were completed within the two hours assigned, further refinement would have required more time.

3.8.2.4 Reliability of Analysis

AcciMap results produced by each team were compared for similarities and variations. The three groups identified similar contributing factors, but only one contributing factor relating to patient misidentification (C-2) was found by all teams and placed at the physical/actor level. Other similar contributing factors relating to patient consent (C-1) were identified by groups A and B, and communication issues between computer systems (C-3) and medical staff ignoring the patient (C-4) were determined by teams B and C. However, for the contributing factor (C-3), it was placed in different AcciMap levels by teams B (physical/actor level) and C (organisational level). Team B and C's reasoning behind their difference in positioning the factor (C-3) could be that computer systems not communicating with each other was a physical activity (team B). At the same time, this factor (C-3) could be considered an issue within the health organisation's control (team C). Similar to the contributing factor (C-1), team A's reasoning for placing it at the organisational level could be related to inadequate procedures for obtaining informed consent from patients. This can also be applied to the contributing factor (C-6) on inadequate handover processes placed at different levels.

3.8.2.5 Validity of analysis

Each team's respective AcciMap output was compared to the external AcciMap result of the incident. Comparing all similar contributing factors (C1 – C6) to the expert results, they were all identified as valid. However, it is possible that even if teams and experts identified a similar contributing factor, it might not be a valid contributing factor, mainly since the use of expert review serves as an alternative in the absence of a "*gold standard*" of measurement (Branford, 2007). Participants "slightly agreed" that the AcciMap approach effectively analysed contributing factors relating to technical components, human factors, organisational and environmental issues from the survey. However, concerning

external factors (sub-question 6e), there seemed to be a contradiction between the survey result and their AcciMap results (external level). This observation can be attributed to the incident not having enough information regarding external systemic factors. Also, being first-time users, the participants will need to review their analysis as they gain more understanding of the issues relating to why this kind of adverse event occurred.

3.8.3 Application Challenges

One of the challenges in applying the AcciMap approach to this report was the insufficiency of information at the external and even organisational levels regarding systemic factors contributing to human error. While this incident took place in the USA, it was also interesting to note from several participants how they had never experienced this type of incident in their respective practices. This point could have contributed to how participants analysed the incident due to unfamiliarity and how things work in UK health settings compared to their US counterparts. AcciMap results produced from the teams also indicated that despite team collaboration, the outcomes were quite different. These differences could have occurred because of their understanding of the incident, contributing factors each team could agree on, causal relationships, and the AcciMap levels they were placed. Also, their respective analyses did not include parties to which the safety recommendations are assigned (parties responsible for implementing them).

Regarding the potential for the AcciMap approach to be adopted for incident analysis in clinical practices, a crucial aspect noted in the workshop was its time-consuming nature. This factor may have influenced how they regarded the suitability of the AcciMap method for accident investigations compared to their experience using RCA techniques. The ability to use AcciMap for clinical studies (incident analysis) requires knowledge of the domain. Users are also required to correctly apply the guidelines in analysing major incidents and, where necessary, update the initial evaluation to produce a revised outcome. However, these processes can potentially take a considerable amount of time and effort, especially in a domain as complex as healthcare.

3.9 Limitations of the Study

Conducting training and evaluation of the AcciMap approach with NHS participants had its challenges. The length of time was insufficient for analysing and for participants to review their results. Despite the participants receiving the incident report a week before the workshop, they still needed to refer to some of its aspects, which affected the time necessary to review their analyses. While this study did not specifically focus on the time taken for each team to complete their evaluations, it is worth noting that this could impact the reliability of their respective outcomes. This viewpoint was also reflected in the survey result regarding completing analysis within the designated time (question 20) and if the approach is time-consuming (question 21). If more time had been allocated, it might have allowed each team to review their initial analyses, identify any missing information regarding contributing factors, and then refine their results. It was also impossible to conduct an immediate follow up to the workshop with participants to elaborate their reasoning behind their AcciMap results. This limitation was because of their unavailability due to their commitments in respective practices.

3.10 Conclusion

This chapter focused on gaining clinical safety practitioners' perception by evaluating their first-time application of the AcciMap method for incident analysis. Based on survey data, comparison of AcciMap results, and discussions with participants, there was a general appreciation of the benefits of the AcciMap approach. Participants found the AcciMap method regarding usability aspects, including its ease of use, serving as a communication tool, and fostering team collaboration generally positive. This point was attributed to how intuitive they found the method from their first-time application on this case incident. However, there were neutral responses regarding other aspects, including its intuitiveness and the time-consuming nature of the AcciMap method. They also indicated a need for further training and experience to apply the AcciMap method effectively.

Aspects relating to reliability and validity are also fundamental for any accident analytical approach to be valuable for accident analysis in healthcare. Based on one of the participants' responses, grouping contributing factors into different

hierarchical categories supports the need for developing a more structured AcciMap approach in addressing the remaining research questions. This point also strengthens Waterson *et al*. (2017) study on the necessity for improving the reliability and validity of the AcciMap approach. In addressing the study's main limitation, a more in-depth study of the application of Branford's AcciMap method will need to be implemented. Chapter Four will comprise a series of training and analysis workshops with a clinical safety expert in applying this approach to incidents. This study will extend this chapter in addressing the first research question on gaining further perspective on using this systemic approach for accident analysis in healthcare.

4.0 CHAPTER FOUR: Comparison of AcciMap Results and Safety Recommendations (Clinical Safety and AcciMap Experts)

4.1 Introduction

This chapter presents another exploratory research study on applying the standardised AcciMap approach as a tool for accident analysis in the National Health Service (NHS). In addressing study limitations from the previous chapter, a clinical safety expert from the National Services Scotland (NSS) was trained to apply Branford's standardised AcciMap approach. In addition, participants (clinical safety and the AcciMap experts) were involved in analysing the CPOE medication error incident. Their AcciMap outcomes, including contributing factors, causal links, and safety recommendations, were also compared. The purpose of this study concerning the first research question was to gain further insight from the clinical practitioner's first-time experience in applying the standardised AcciMap approach and determining its' advantages and limitations as a tool for accident analysis in healthcare.

4.2 Research Methodology

The study will apply a qualitative approach (using a case study) in analysing a health IT-related case incident (Medication dosing error) using the standardised AcciMap method. Findings between two different safety experts. The following subsections detail the study methodology.

4.2.1 Participants

Two participants participated in this study and were designated as Analyst-A (clinical expert) and Analyst-B (AcciMap expert). Analyst-A is an experienced Clinical Safety Officer and e-Pharmacist with over twenty-five years of experience in health informatics in addition to five years of safety auditing with the National Services Scotland (NSS). Analyst-B is an experienced human factors specialist with extensive knowledge and experience in human factors engineering and applying accident analysis approaches in the Railway industry.

4.2.2 Training Provided

The clinical safety expert organised AcciMap training sessions at the National Services Scotland (NSS), where each session lasted between two to three hours maximum. The participant was introduced to the concept of systems thinking, Branford's AcciMap approach, with its associated guidelines. The clinical safety expert was provided with example incidents, including the wrong patient (Chassin and Becher, 2002) used in the previous chapter. Another example incident, a clinical summary report relating to alert fatigue (International Normalised Ratio (INR) overshoot)(Agrawal, 2016), was also used in applying the AcciMap procedures and reviewed during training.

4.2.3 Study Design

After the training session, a case incident (CPOE medication dosage error) was then used for AcciMap analysis. Information on findings, including lessons learned and safety recommendations from the original documentation, was removed to help reduce any potential bias. Both participants were also told to focus only on the information available in the documentation and avoid making inferences (not supported by evidence from the incident report). Results obtained from analyst A were then compared with analyst B's AcciMap outcomes for any similarities and differences as part of the validation (content validity). This approach was utilised in the absence of a "gold standard" for objectively measuring the validity of outcomes; the closest alternative will be to compare results with those obtained from "expert" opinions (Branford, 2007). Finally, AcciMap results were then swapped between both analysts through email correspondence and were reviewed independently. This measure allowed them to review and understand the reasoning behind their choices in identifying contributing factors. Analyst A was subsequently interviewed after the exercise on his perception of the AcciMap approach in the final meeting.

4.3 Case Incident Two - Synopsis

The case incident consists of two clinical providers (A and B) involved in the administration of KCl (Potassium Chloride) using a Computerised Provider Order Entry system (CPOE) to an initially hypokalemic patient. The events leading to the patient receiving a high dosage of KCl and becoming hyperkalemic are detailed in the work of Horsky *et al.* (2005) (Appendix C-1). The complete

timeline of events that took place over three days is detailed in Appendix C-1. This incident is an example of a “software” or “health IT” related incident. This incident also describes a situation where the combination of technological factors, including how operators utilise them, increases patient risk, resulting in harm.

4.4 AcciMap Analysis

Both participants were given the case incident and independently analysed it and formulated their safety recommendations. Before applying the standardised AcciMap method to this incident, the first participant (Analyst-A) applied it to two example incidents used as part of the training process. Previous AcciMap analyses on those example incidents were also reviewed in subsequent training sessions to discuss any challenges encountered during the investigation. Figure 4-1 shows the final AcciMap outcome from the first participant.

The second participant (Analyst-B) based in Australia received and analysed the incident. The expert developed an initial AcciMap model of the incident but was subsequently re-analysed to produce the final version along with safety recommendations. Figure 4-2 shows analyst-B’s final AcciMap model. Both participants completed their analyses within one week and submitted their results which were then compared as detailed in the proceeding section (4.5). Also, their AcciMap outcomes were exchanged for each to review any similarities and variations regarding their analysis. Finally, the analyst-B’s AcciMap result served as the alternative standard because there wasn’t any existing gold measurement standard.

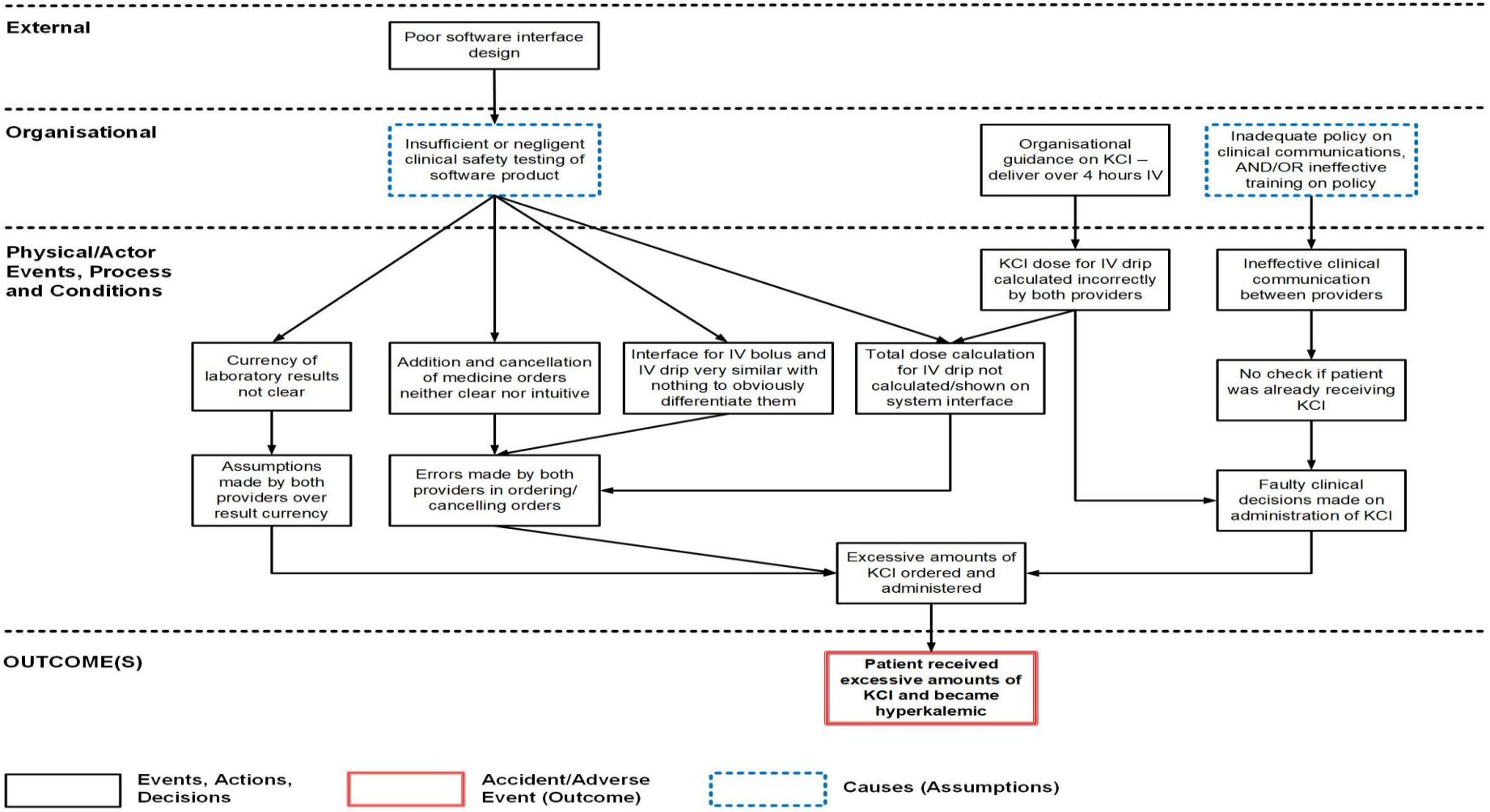


Figure 4-1: AcciMap Analysis of Analyst-A (Clinical Domain Expert)

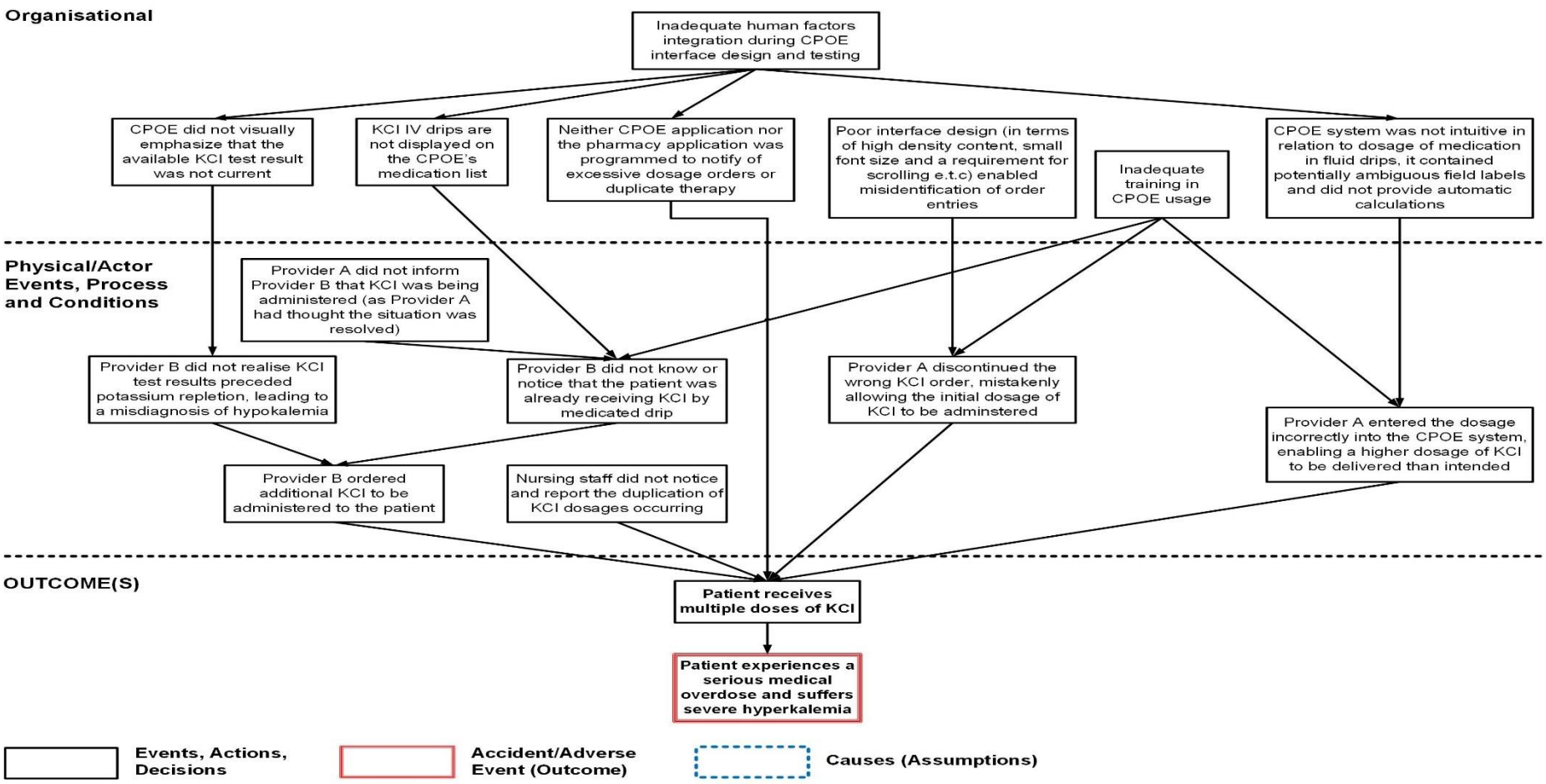


Figure 4-2: AcciMap Analysis of Analyst-B (AcciMap Expert)

4.5 Comparison of AcciMap Outcomes

The AcciMap results produced by both participants (Clinical and AcciMap experts) were compared and contrasted based on the same attributes used in the previous chapter when comparing each team's results (see section 3.7) as reiterated below:

1.) Identification of contributing factors at the AcciMap levels
2.) Placement of contributing factors at the appropriate AcciMap level
3.) Causal links between contributing factors
4.) Safety recommendations

Outcomes between both analysts are compared based on these AcciMap aspects described in Branford's thesis. This process of determining similarities regarding contributing factors, placement of factors, causal links and safety recommendations involves using qualitative content analysis similar to what was done in Chapter Three (see section 3.7). Any similar contributing factors were colour-coded and assigned an alphanumeric code. The same process was applied in identifying and labelling similar causal relationships (links). Contributing factors identified at the appropriate AcciMap level are also determined through visual observation and following Branford's AcciMap guidelines.

4.5.1 Identification of Contributing Factors at the AcciMap Levels

Causal/contributing factors identified were indicated as solid boxes, and other factors denoted as broken boxes are regarded as assumptions and were not used to compare each participant. Similar and varying factors were identified at each AcciMap level. For example, at the physical/actor activities/processes level, both analysts identified errors committed by Providers A and B regarding the KCl levels of the patient. When closely examining the participants' AcciMap results, contributing factors identified were extracted to determine if they conveyed similar meanings, as shown in figure 4-3. Based on qualitative content analysis, contributing factor themes (C1, C2, and C3) relating to how clinical providers A and B interacted with the CPOE system are denoted in table 4-1.

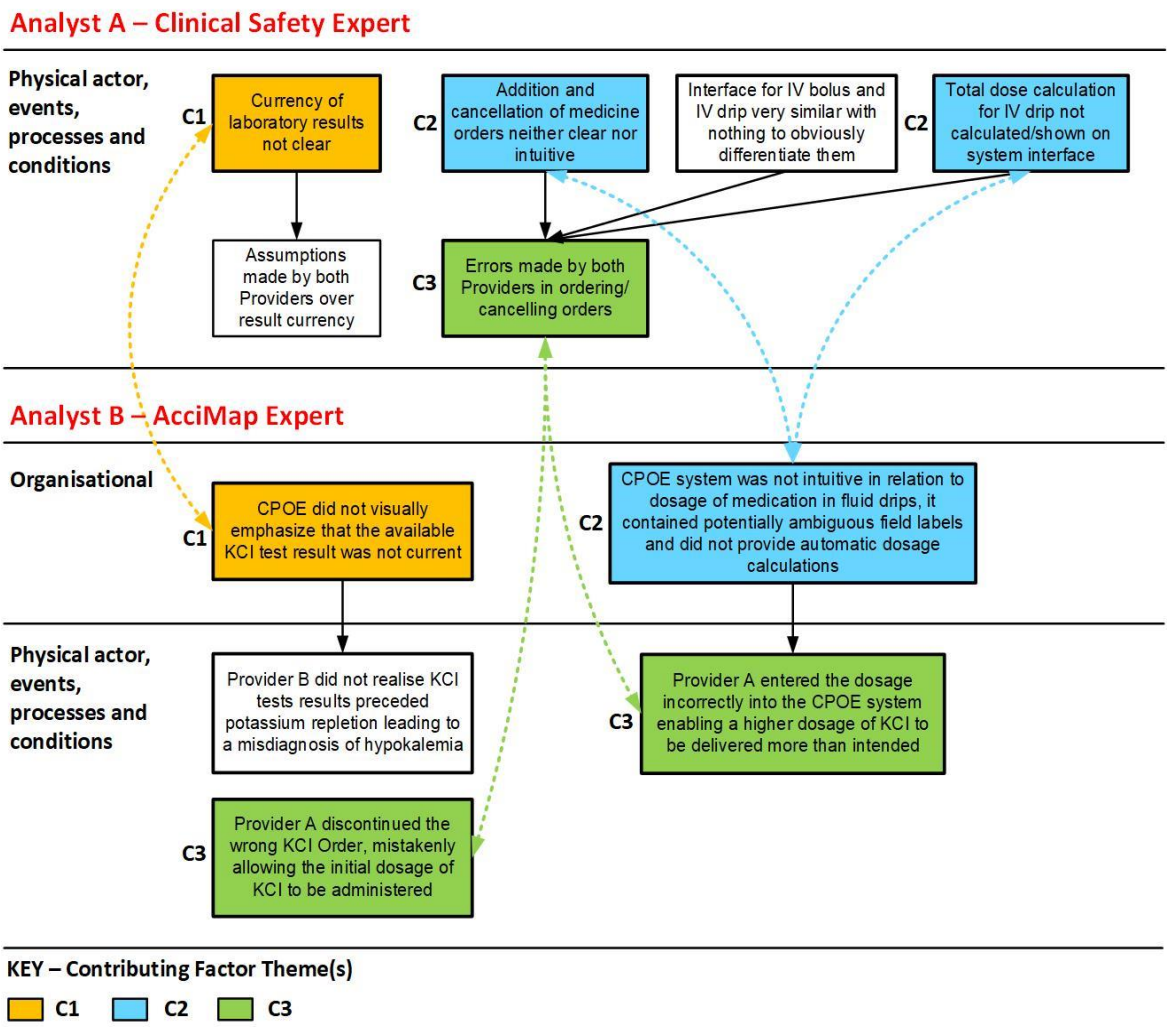


Figure 4-3: Comparing the identification of contributing factors relating to Providers (A and B) and the CPOE system between Analyst A and B

Table 4-1: Contributing factor themes identified by both analysts relating to Providers (A and B) interacting with the CPOE system

Code	Contributing Factor Themes
C1	The currency of the results displayed by the CPOE system and the results not being clear to the providers
C2	The CPOE system not being intuitive in terms of cancellation and addition of orders, interfaces for both IV and medicated drips looking similar, and dose calculations
C3	Errors made by providers A and B regarding ordering and cancelling orders caused the initial KCl dosage to be administered

Figure 4-4 shows the remaining contributing factor themes (C4, C5, and C6) identified by both participants but focused on the errors committed by clinical providers regarding the miscommunication when administering potassium chloride to the patient. Table 4-2 provides the summary of these contributing factors.

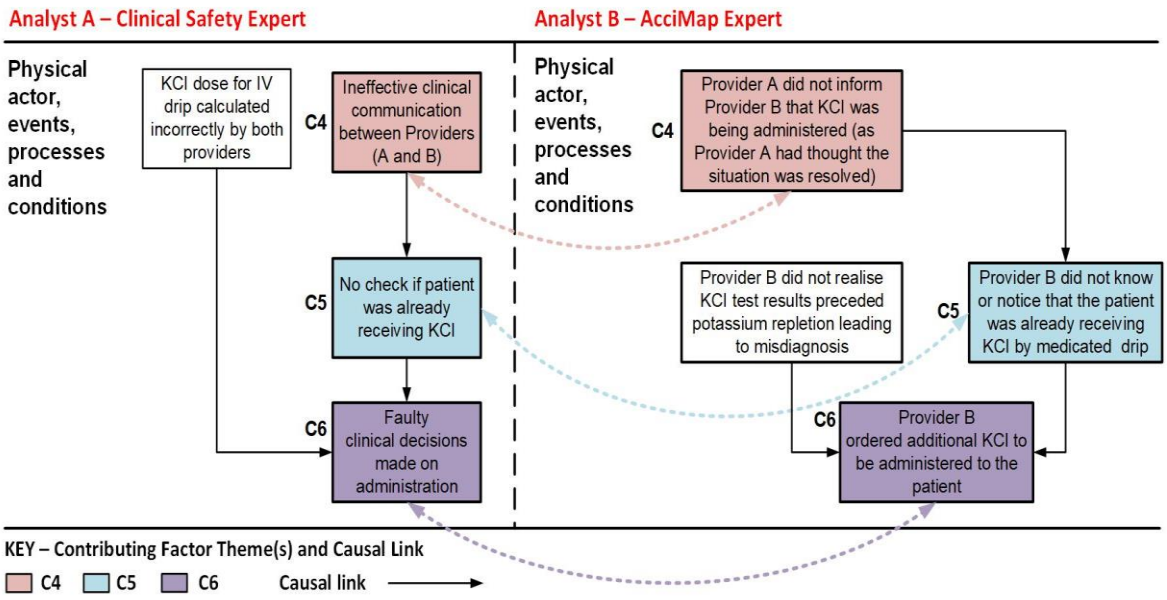


Figure 4-4: Comparing contributing factors relating to errors committed by Providers (A and B) between Analysts A and B

Table 4-2: Contributing factor themes identified by both analysts relating to errors committed by Providers A and B

Code	Contributing Factor Themes
C4	Miscommunication between providers A and B regarding the administration of KCl
C5	Provider B did not notice or check if the patient was already receiving KCl before administering an additional dose
C6	Provider B ordered additional KCl after not realising that the results preceded the KCl depletion

From both diagrams, there are instances where the clinical expert (analyst-A) may similarly identify a contributing factor determined by the AcciMap expert (analyst-B). For example, analyst A depicted two boxes denoting different design issues relating to the CPOE system. The clinical expert (analyst-A) made two distinct causal/contributing factors relating to specific CPOE issues (C2), which analyst-B identified in a singular box but conveying those factors. However, these contributing factor boxes represent a similar meaning to the contributing factor identified by analyst-B (C2) when combined into a single factor instead of one distinct factor. The reverse was also the case where the AcciMap expert identified a factor discovered by the clinical expert but is similarly expressed using multiple boxes. Contributing factor theme (C3) was identified as a distinct factor by the clinical expert (relating to both providers making errors regarding ordering and cancelling). It was recognised by the AcciMap expert as two separate contributing factor boxes but combined to convey a similar meaning.

This observation plays an important role when conducting a reliability assessment of factors between various users, especially when quantitatively measured. Table 4-3 consists of contributing factors that were uniquely identified by each participant based on their respective AcciMap model outputs.

Table 4-3: Contributing factors uniquely identified by Analysts A and B

	Analyst-A (Clinical Safety Expert)	Analyst-B (AcciMap Expert)
Physical actor events, processes, and conditions	• KCI dose for IV drip calculated incorrectly by both providers • Assumptions made by both providers over result currency • Excessive amounts of KCI ordered and administered	• Nursing staff not noticing and reporting duplication of orders • Provider B did not realise KCI test results preceded potassium repletion, leading to a misdiagnosis of hypokalemia
Organisational	• Organisational guidance on KCI delivery over 4 hours • *Insufficient or clinical safety testing of software product* • *Inadequate policy on clinical communications and/or ineffective training on policy*	• Inadequate human factors integration in design and testing • Inadequate training in the use of the CPOE system • Poor interface design leading to misidentification of order entries • Neither the CPOE application nor the pharmacy application was programmed to notify of excessive dosage orders or duplicate therapy • KCI IV drips are not displayed on the CPOE' medication list
External	• Poor software interface design	• None
• ***Inferences***		

4.5.2 Placement of Contributing Factors at the AcciMap Levels

The placement of causes/contributing factors was indicated as red boxes to distinguish variations between analyst-A and analyst-B, as shown in figure 4-5. For instance, differences were observed when comparing the placement of contributing factors relating to the CPOE system, C1 (*currency of results displayed and not clear to the providers*) and C2 (*CPOE system not being intuitive*). Analyst-A identified these factors at the physical/actor activities level while analyst-B associated them at the organisational level. However, the other contributing, C3 (*errors committed by both providers in ordering and cancelling orders*), was identified and placed by both participants at the physical/actor level. Relating to the differences in contributing factor placement, comparing the arrangement of C1 and C2 by analyst-A with analyst-

B, these themes are considered the responsibility of the health organisation as noted by analyst-B rather than the providers' activities.

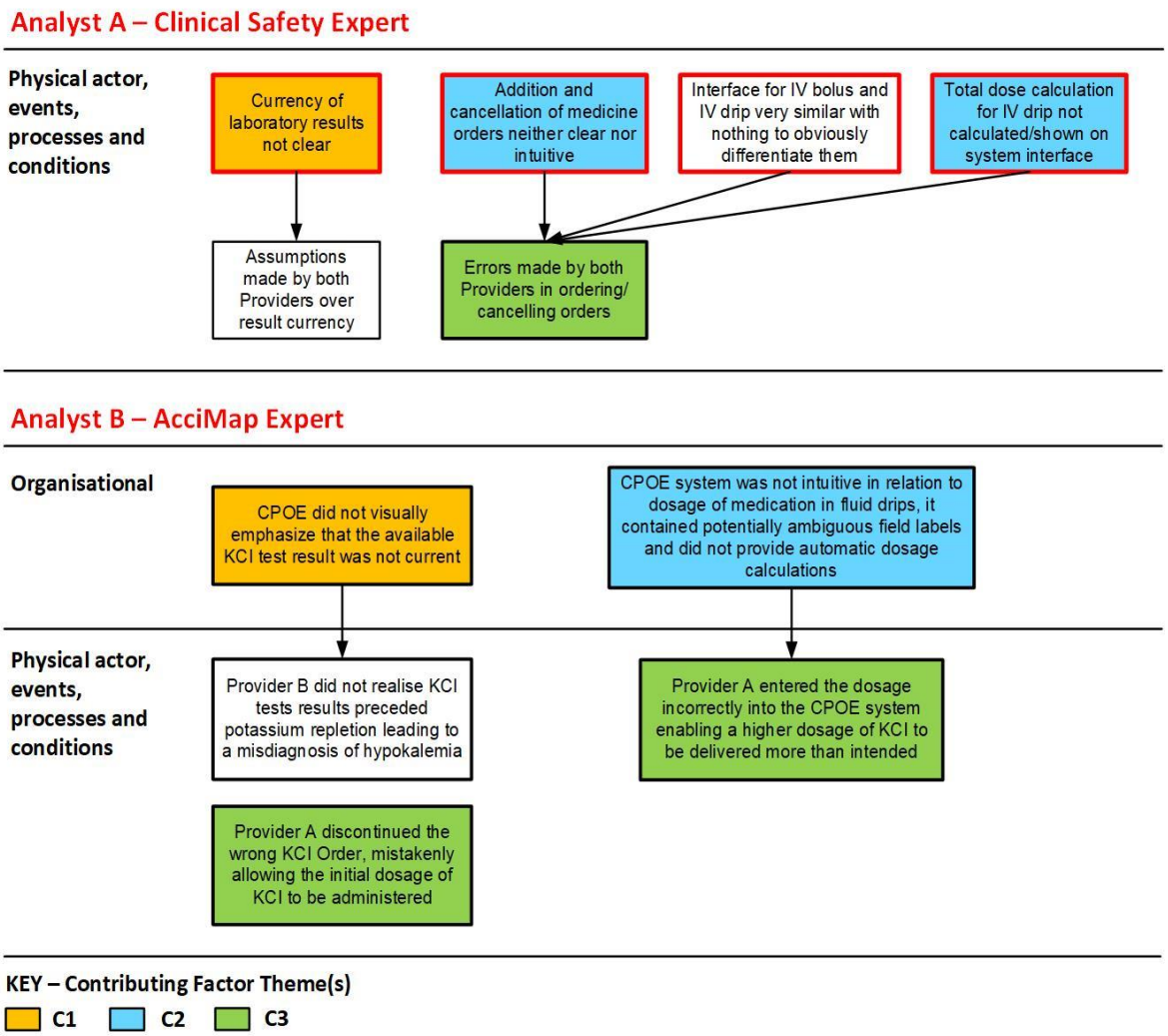


Figure 4-5: Comparison of placement of contributing factors between Analysts (A and B)

The other contributing factor themes, C4 (*miscommunication between providers*), C5 (*provider B not checking before administering additional KCl*), and C6 (*faulty decisions regarding the ordering of additional KCl*), were similarly placed at the same level (physical/actor activities) by both participants. Branford's thesis noted the importance of positioning identified causal/contributing factors at the appropriate level to identify parties responsible for implementing safety recommendations.

4.5.3 Causal Links within and between AcciMap Levels

In identifying causal relationships from both participants' AcciMap model outputs, the focus is on observing if similar links are discovered between similar contributing factors. Based on the previous figures depicting different contributing factor themes identified from their AcciMap models, similar causal links indicated as red lines were identified as shown in figures 4-6 (C2 and C3) and 4-7 (C4, C5 and C6). Table 4-4 provides the summary of similar causal links between both participants.

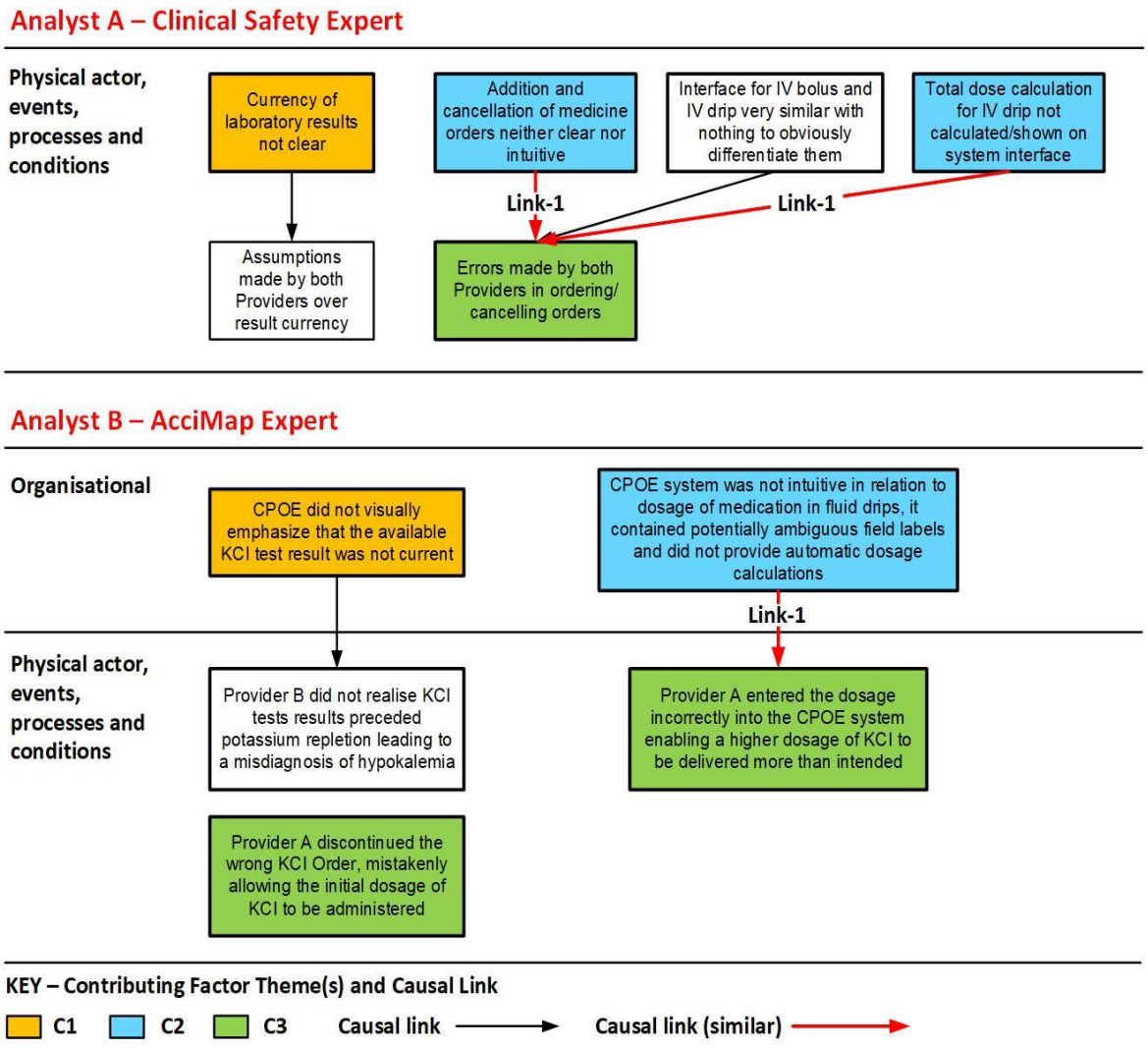


Figure 4-6: Causal linkages depicting errors made by providers (A) due to a combination of software design issues (CPOE)

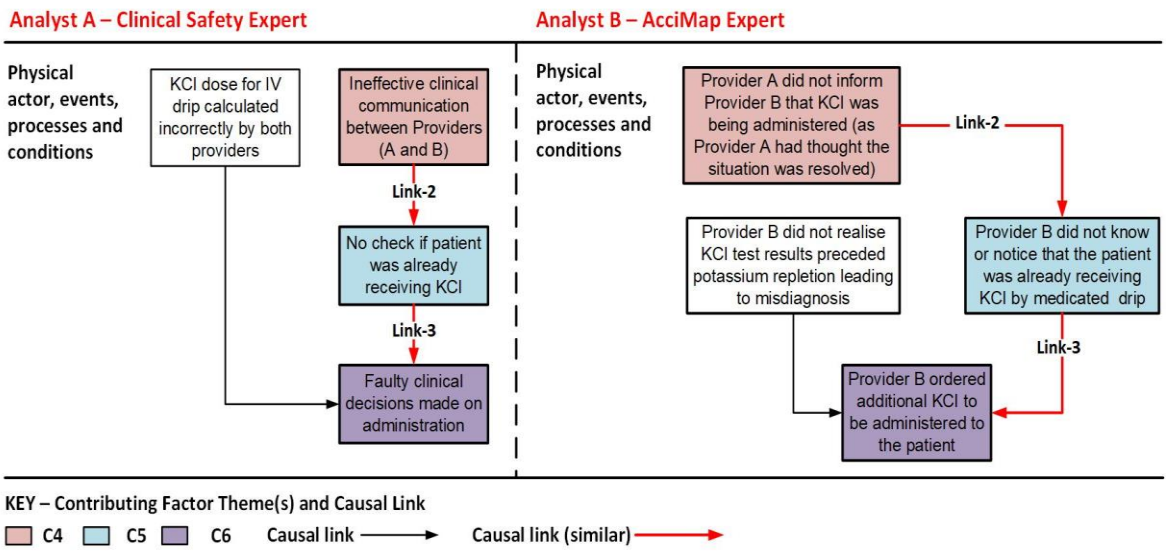


Figure 4-7: Causal linkages depicting the patient receiving a high dose of KCl due to lack of communication and omission between providers A and B

Table 4-4: Similar causal links by identified by Analysts A and B

Code	Causal relationships
Link-1	The causal link between contributing factor theme C2 and C3
Link-2	The causal link between contributing factor theme C4 and C5
Link-3	The causal link between contributing factor theme C5 and C6

The common causal link (link-1) was between C2 (issues relating to the design of the CPOE system) and C3 (errors made in entering wrong orders into the system) (see figure 4-6). Because the three contributing factor boxes identified by analyst-A constitute a single box when similarly recognised by analyst-B (C2), the causal links are also combined to portray a singular causal link (link-1) which makes it like analyst-B's causal relationship. The remaining causal links (link-2 and link-3) were based on contributing factor themes (C4, C5, and C6). Other causal links not similarly identified from both results indicate how participants depicted relationships between contributing factors they interpreted from the incident report.

4.5.4 Comparing Safety Recommendations

Each participant developed their safety recommendations after completing their analysis of the incident. These measures were compared for similarities and variations. Table 4-5 below shows safety recommendations developed by analyst-A and analyst-B based on their analyses.

Table 4-5: Safety recommendations from Analyst A and B based on the CPOE Medication Error case incident

Analyst-A (Clinical Safety Expert)	Analyst-B (AcciMap Expert)
1.) **External:** a. Software suppliers (vendor) to review lessons learned from the incident and provide proposals for design improvement to reduce current clinical risks within the system. This should include: i. Developing clear signage within the interface to easily differentiate between IV/IM bolus and IV infusion (delivery over time). ii. Ensuring a total dose to be delivered onscreen for IV infusion calculation checks. iii. Improving the visibility of the age of the most recent lab result available for the patient. iv. Improve the functionality of medicine order management – ordering and cancellation processes. v. Improving visualisation of all current medications regardless of route of administration onto a single screen. vi. Providing additional alerts where a new medicine order duplicates a current active medicine order. b. Software suppliers to provide evidence of clinical safety testing and user acceptance testing, including test scripts for scenarios. c. Software suppliers to provide easy access to training materials with a particular focus on the management of medication orders, including cancellations. d. Software suppliers to develop feedback mechanisms from customers on functional issues/bugs/clinical safety improvements. 2.) **Organisational:** a. Review policy/guidance on KCl IV delivery with specific reference to CPOE system interface (current interface immediately and updated interface in time for an upgrade)	1.) Comprehensive human factors review and interface design evaluation of the CPOE system to be undertaken and action taken to facilitate error reduction, detection, and recovery. 2.) The CPOE interface design should be reviewed and revised to ensure that: a. The currency of test results is evident b. Medications provided by IV drips are included in medication lists c. Human-computer interaction design principles are followed to facilitate easy identification and interpretation of order entries, and, d. IV dosage input options are clear, unambiguous, meet requirements (expectations) and provide automatic dosage calculations to aid error prevention. 3.) The CPOE application should be programmed to notify clinicians of excessive dosage orders and duplicate therapy. 4.) The pharmacy application provider should be programmed to display alerts regarding excessive dosage orders and duplicate therapy. 5.) Staff training concerning the utilisation of the CPOE system should be reviewed and revised where necessary to ensure staff have the required skills, knowledge, and competency to correctly enter dosage information and interpret the data provided in the CPOE system.

Analyst-A (Clinical Safety Expert)	Analyst-B (AcciMap Expert)
b. Review policy/guidance on clinical communication and instigate "mandatory for all clinical staff" training on this. c. Set up formal service management arrangements (ITIL standard) for system supplier engagement to ensure clinical safety and other functional issues can be fed back to the supplier. d. Instigate the role of clinical safety officer concerning Health IT systems as a single point of contact for clinical safety-related IT issues.	

Both participants (clinical and AcciMap experts) produced similar measures relating to the functionality and improving the interface of the CPOE system. For example, both indicated the necessity of incorporating safety alerts regarding excessive and duplicate doses administered. Also, improving the interface usability of the application, including visualisation and improved identification of order entries, was similarly recommended by both participants. However, the only additional recommendation not included in the original incident report was reviewing staff training on utilising the CPOE system and interpreting the data correctly. This safety proposal was formulated by the AcciMap expert (Analyst-B).

The differences between both participants' recommendations were in identifying safety measures from the external level. For instance, analyst-A only identified a singular contributing factor relating to software vendors in incorporating safety measures based on lessons learned to reduce clinical risks at the external level. At the organisational level, analyst-A included the need for reviewing the KCI delivery concerning CPOE systems and, more interestingly, emphasised the role of a clinical safety officer. On the other hand, safety recommendations identified by analyst-B did not include any systemic countermeasures for the external level. The AcciMap expert reasoned that there were no causal relationships that extended to the external level. The reason for this was, for instance, the lack of contributing factors to explain why none of the other staff failed to identify dosage duplication and why the CPOE system installed was presumably done without appropriate user testing and human

factors input. An insightful observation about these safety measures shows how their interpretation of the incident and AcciMap analysis influences the recommendations developed and the parties responsible for them. In addition, their background experience also appears to influence their formulation of these recommendations. This observation is seen in the clinical expert's background in pharmacy and health informatics, detailing aspects relating to the CPOE system's design and functionality and reviewing policies on KCI IV delivery.

4.6 Review of the AcciMap Analysis (Analyst-A)

The AcciMap results were exchanged with each other after completing their analysis. This process was to allow analyst-B to review and comment on any variations regarding the AcciMap model. Another purpose was to enable the AcciMap expert (Analyst-B), having developed the AcciMap guidelines, to ascertain how the clinical expert applied it. Comments from analyst-B are indicated with direct quotes below:

1) Comments on the application of the AcciMap approach on the case incident by analyst-B was summarised as follows:

> *"Analyst-A has included assumed contributing factors (shown in the dotted boxes). This is appropriate and useful, and I endorse this approach, but it is not part of the published AcciMap guidelines that I believe we were asked to follow, which is why I didn't include any of these in my AcciMap. That is the source of one of the differences between our AcciMap results".* (**Analyst-B)**

Analyst-B noted the addition of broken boxes representing inferred contributing factors but without concrete evidence to support its inclusion. This "key" is not originally part of Branford's standardised AcciMap format but was used to gain insight into other potential factors that participants may infer from the case incident. The comment below is regarding this issue:

> "*The key you've put at the bottom (with one box for Events, Actions, Decisions, and another for the Accident/Adverse Event and the dotted one for Causes) does not reflect my AcciMap format. In my opinion, anything in the Outcomes level is an Outcome, so there is no need to label it a second time. The other analyst listed one; I listed two. Also, all of the boxes in my AcciMap are contributing factors. They are events, decisions, or actions too, but the critical bit is that they're contributing factors, so if you label them as something else, it may confuse people. If*

you want to stick with my original format, your key would just have "contributing factors" for the normal boxes. If you want to expand to include assumed factors, the dashed boxes could also be in the key, with "contributing factors (assumed)" as the label". **(Analyst-B)**

This comment relates to the keys that the principal researcher set for this study's purposes. Branford's original format denoted boxes as causal/contributing factors identified based on evidence from the incident report. However, broken boxes indicated for inferred factors will not be used in the remaining chapters of the thesis.

2) Comments regarding the development of their respective AcciMap outcomes:

- *"The analyst A's AcciMap is well-formed and intuitive and provides a useful chart of the events, decisions, and actions leading to the event. However, in my opinion, there are four very minor deviations from the published AcciMap guidelines in this AcciMap":*

  - *"There are four contributing factors at the Physical/Actor Events, Processes, and Conditions level that I feel would fit more appropriately at the Organisational level (because they relate to interface design issues). These are "**Currency of laboratory results not clear**", "**Addition and cancellation of medicine orders neither clear nor intuitive**", "**Interface for IV bolus and IV drip very similar with nothing to obviously differentiate them**", and "**Total dose calculation for IV drip not calculated/shown on system interface**". If these are shifted up to the Organisational level, it clarifies that this is something that the organisation can control/influence and enables corrective actions to be formed based on those factors (which I think would be appropriate)."*

  - *"Similarly, it can be argued that the contributing factor "**Poor software interface design**" is actually an Organisational factor (rather than External). The 'external' level is for factors that are beyond the control of the organisation(s) involved. Poor interface design is within the control of the organisation that produced this item, so I would place it at the Organisational level".*

  - *"There is one causal link that appears incorrect. The AcciMap outcome suggests that "**KCl dose for IV drip calculated incorrectly by both providers**" contributed to "**Total dose calculation for IV drip not calculated/shown on system interface**". I think the arrow may be the wrong way around (i.e., the latter actually contributed to the former)".*

  - *"There is one factor, "**Organisational guidance on KCl - deliver over 4 Hrs IV**", which I don't think meets the criterion of using wording that makes it clear how things might have been different (noted in Step 5*

of the AcciMap guidelines). I also don't think the meaning of that factor is clear". **(Analyst-B).**

3.) Comments on similarities and variations in AcciMap results produced:

- *"I believe the two analyses are quite similar. There were two factors in mine that were not in analyst A's AcciMap (namely "**Neither CPOE application nor the pharmacy application were programmed to notify of excessive dosage orders or duplicate therapy**" and "**Inadequate training in CPOE usage**"). I don't believe either factor was referred to at all in analyst A's AcciMap. It would be interesting to see if analyst A believes that these are valid factors on second thought. If so, this would reinforce the importance of using multiple analysts (so that more ideas are considered and discussed)".*

- *"I believe there was only one factor in analyst A's AcciMap that was not also in mine - regarding "**clinical communications**". I agree with the inclusion of this factor as an "assumed contributing factor". If I had been asked to include assumed factors, I would have included "**Inadequate handover process and/or training**", which I believe is essentially the same as this. I think the source of this difference relates to different instructions given to / interpreted by the analysts relating to whether to include assumed factors or not. I certainly agree this factor is appropriate".*

- *"I am unsure of the meaning of "**Organisational guidance on KCl - deliver over 4Hrs IV**", so I cannot determine whether that one refers to the same concepts as my factors relating to the lack of automatic dosage calculations or something different".*

- *"In all other cases, I believe the same essential concepts are included in both. There are variations in the wording, level of detail, and the number of factors used to convey the message (as would be expected, as this was what happened in my reliability study discussed in my thesis), but I believe that with the exception of the two mentioned above, the same essential factors are included in both analyses".*

- *"There are significant variations in which level the AcciMap factors have been placed in. This would result in very different safety recommendations if these were developed from the AcciMap (as recommendations typically do not address items at the Physical/Actor Events Processes and Conditions level, which would mean that none of Analyst A's factors relating to clarity of lab results and other interface issues would be addressed). As noted above, I believe these are errors in the application of the AcciMap guidelines, and I expect these variations just reflect analyst A's inexperience with AcciMap levels".*

- *"Novice users typically require some practice and experience to get a full understanding of the appropriate levels for contributing factors, and often, errors are picked up when safety recommendations are developed (which was not done in this case). My guess is that this difference reflects inexperience only".* **(Analyst-B)**

4.7 Interview Session with Clinical Domain Expert (Analyst-A)

After completing the AcciMap analysis, a semi-structured interview was conducted, with questions focusing on the clinical expert's experience applying the AcciMap method. The duration of the interview process was within two hours. Responses to the specific questions of interest are indicated with direct quotes shown below:

1.) **Question:** Did you find the AcciMap intuitive in understanding how it is applied?

Response: *"Conceptually yes, I think it's something in which people will have to be trained, essentially someone being able to have a quick read and then apply it."*

The participant generally did not perceive the AcciMap approach as completely intuitive and felt adequate training was needed to apply the method effectively. For instance, the participant had to cross-reference with the manual regarding where to place contributing factors and how they were causally linked to determine the flow of causation (relating to what flows from one causal factor to another).

2.) **Question:** What has been your experience based on case analysis using the AcciMap approach?

Response: *"It's been reasonably painless, I would say, some of the examples and it's partly due to my training because pharmacists tend to be quite detailed led and therefore particularly with the second case example, there were big gaps in data because there was nothing in the second case example that gave us clues and so we had to make some suppositions. For example, there was no evidence of organisational policies if the system actually made you why you would click through an alert, which will be very important, especially around the design of the product. If you get multiple alerts and you are able to bypass them with no record of why you did that, that is a really big missing gap in an auditory as to why someone did something!!"*

Based on a previous incident analysis (INR overshoot incident) used during training, the participant noted how potential missing information could create a situation where suppositions are made to ascertain why certain events or decisions at the organisational level were taken in the first place. Regarding the model's ability to graphically depict causal factors and causal relationships compared to RCA techniques (i.e., fishbone diagrams), the participant noted the following:

"It's still a reasonably straightforward technique. I tend to be quite visual, but for people who are not visually oriented, it may tend to be quite challenging. I've always used mind maps, in my head, I am actually going through a mind map and going through all the things that are in play and trying to strike them off and determine where to put them in the diagram and trying to cross-reference from what my mental mind map is suggesting to me that we need to cover".

The clinical expert also noted doing multiple passes (iterations) of analyses and ensuring that anything that needed to be added was included in the final AcciMap result. In addition, the following comment was made regarding the participant's experiences applying the AcciMap method to incidents based on the information content:

"The first one had a greater level of detail, and because we deal with adverse events, my mindset is always checking on which information is missing and needing to go back and ask further questions through emails and getting screenshots. This can include determining if the system behaves that way, what is the alert like, and getting a screenshot to have some sort of assessment, and how does the company rate the alert just to try and determine if this is a design flaw or an issue with the functionality that allows people to ignore any type of alert."

This response was also based on the previous analysis of the incident relating to alert fatigue (Agrawal, 2016) used as part of the AcciMap training.

3.) **Question:** What was your experience using the AcciMap approach to identify unsafe decisions from the case study?

Response: *"Part of that is identified by how well documented the case study is. If it's not documented in the case study, it's difficult to guarantee if there were unsafe decisions. For example, the decision to multiply ignore an alert is an unsafe action, and it's more of a decision followed by action. We do not know what has caused that to happen, which may be due to multiple contributing factors like environmental distractions or not recognising it as a problem to a lack of rating systems. An unsafe decision is not something on its own, but it's part of a parlour of things that surround it. We may not know if the decisions were unsafe, but we can question the decisions made, and until we have more information, only then can we find out if they are unsafe."*

This response was regarding identifying contributing factors, particularly at organisational and external levels. The participant also noted that it depended on how explanatory the report was and if it captured relevant information regarding decisions and conditions at both levels. The

participant's response was also related to the analysis of the alert fatigue (INR overshoot incident) (Agrawal, 2016).

4.) **Question:** Did you find the guidelines for applying the AcciMap approach helpful in your analysis?

Response: *"I would say to a point because there is always an issue about language, especially a type of language used in one environment could mean something else in another environment".*

In terms of formulating safety recommendations, the participant also found the process (step 9 of Branford's training manual) straightforward and, as a tool, considered the AcciMap approach to be practical.

5.) **Question:** What are the advantages of using the standardised AcciMap approach?

Response: "*This is partly an assumption but what I get in using fishbone is that it allows for grouping of factors but does not give a link through, and that is what I like about AcciMap. What interests me is about multiple factors converging to create an environment or situation where the holes in the cheese appear. We do have to remember that it's an incredibly complex environment in healthcare or what I would like to call a complex adaptive system. The AcciMap helps to tell a story from a bigger picture to a small picture, and out of that, very neatly flows recommendations. I think the ease of coming to a list of recommendations is a major benefit.*"

This comment indicated agreement with Svedung and Rasmussen (2000), Branford (2007), and Salmon *et al.* (2012) on the benefits of applying the AcciMap approach, especially when analysing complex adaptive socio-technical systems.

6.) **Question:** What are the limitations of the AcciMap approach?

Response: "*I think the limitation is user-dependent and helping to make it more intuitive with nice tight guidance about things to consider. Limitations may be software-based (basically using tools like Microsoft Visio). On its flip side, it provides an opportunity to develop a very easy to use freeware app that does AcciMap analysis".*

Another comment that could be considered a limitation is the ability of the AcciMap approach to be used quickly (on the hoof) to analyse a severe incident. Based on the participant's comment, for example, analyst-A noted that:

> *"With the fishbone technique, it's easy to be able to identify factors quickly even though it does not employ linkages. The ability of the AcciMap approach to be used for rapid deployment in a live situation will be a massive advantage and will be a key factor".*

This point can be corroborated with the previous study (Chapter Three) regarding the time-consuming nature of the AcciMap approach, especially when considering the comprehensiveness of an incident report. There is also the aspect of evaluating the cost versus priorities regarding the level of risk from an incident and deciding if the AcciMap approach or an RCA technique is more suitable depending on the nature of the report and resources available (Health and Safety Executive, 2004).

The clinical expert further noted that if applying the AcciMap approach depends on software utilised (e.g., Microsoft Visio), it will be challenging for users to implement it. The reason was that the cost of acquiring the necessary license for Microsoft applications might not be considered worth it in applying the AcciMap approach compared to the case of using existing RCA tools, which only requires minimal resources, e.g., papers. Although, it was acknowledged that papers and sticky notes could be used as alternatives for AcciMap analysis. However, this limitation also presents an opportunity of developing a freeware app specifically for creating AcciMap outcomes from incidents citing his own experience in using a free app (e.g., Gliffy) for his AcciMap analyses. However, the limitation of using such freeware apps is due to specific features not being available. Based on the interview summary, it was opined that while the AcciMap approach offers a different way of analysing contributing factors from an incident, its applicability will be further enhanced if developed as a software toolkit for NHS boards.

4.8 Discussion

In investigating the perception of applying the AcciMap method, the clinical safety expert had previously never used any systemic accident analysis approach in practice. Therefore, the clinical expert participated in training sessions to understand the concept of systems thinking and how the AcciMap method was applied. After the training sessions involving application on two cases, including the wrong patient incident (Chapter Three), the CPOE medication error incident

was used for comparative purposes. AcciMap results compared contributing factors, causal links, placement of factors and safety recommendations between clinical and the AcciMap experts. This exercise was also used to ascertain the clinical expert's experiences applying the method, including the guidelines and the AcciMap expert's review of the AcciMap analysis.

Comparing both sets of results indicated that while there were similarities and differences regarding contributing factors. There was a situation where a contributing factor the clinical expert identified was presented vaguely or with little detail. The contributing factor (*poor software interface design*) will appear to be associated with the contributing factor theme (C3). However, the lack of detail regarding which interface design issue it referred to did not allow this factor to be regarded similarly. Also, there were significant variations regarding the placement of some contributing factors in different AcciMap levels. For instance, the reasoning behind the clinical expert's decision for placing factors relating to the CPOE system at the physical/actor level could be because of the interactions between the providers and the CPOE system that facilitated errors. The AcciMap expert determined that they should have been set at the organisational level instead. Based on the AcciMap expert's review, the reason was that health IT systems were within the control of the health organisation. Also, several contributing factors were identified by the AcciMap expert that was not specified in the clinical expert's AcciMap diagram. This observation was a result of how both experts understood and interpreted the incident.

Safety recommendations also showed some similarities between both participants, particularly in improving the interface and functionality of the CPOE system. The clinical expert provided greater detail of recommendations relating to health software providers/suppliers (external level) and review of policies regarding communication and training materials (organisational level). The contributing factor mentioned earlier (*poor software interface design*) identified at the external level was also recognised by the AcciMap expert as an organisational factor. This variation ultimately influenced the type of safety measure proposed by the clinical expert, which was explicitly directed to software providers (vendors) in improving the design of the CPOE system. Other safety recommendations identified by the AcciMap expert, including staff

training and reprogramming the pharmacy application to display alerts for excessive dosage orders, were not recognised by the clinical expert. The reason was due to contributing factors associated with the pharmacy application and inadequate training using the CPOE system. Regarding causal links, only one causal link was revealed to be incorrect, according to the AcciMap expert. The AcciMap analyst determined that the causal direction between "*providers incorrectly calculating the KCl dose*" and "*the total dose calculation for the IV drip not calculated on the interface*" was wrong and should have been in the reverse direction. No other causal links were indicated to be incorrect, according to analyst-B.

Based on the interview with the clinical expert, details were drawn regarding the participant's experience of applying the AcciMap method. From the usability aspect, the participant was able to use the AcciMap guidelines in analysing the incidents. However, drawbacks were also highlighted by the clinical expert. One notable disadvantage was the time-consuming nature of its application for incident analysis. This point relates to the participant's experience using RCA techniques (i.e., fishbone diagrams) currently applied for incident analysis in healthcare. Closely following this demerit, another issue raised was the practical feasibility of using the AcciMap approach, especially during live accident investigations. The clinical safety expert also noted doing multiple iterations, requiring referral to the AcciMap guidelines to complete the analysis. The participant opined that for the AcciMap method to be widely adopted as a systemic toolkit, it needs to have the ability to quickly analyse incidents without requiring additional resources in a demanding and complex healthcare system. As earlier mentioned, this view was based on his experience using the fishbone diagram technique during incident investigations.

This point can be regarded as one of the present challenges of why this systemic approach has not been readily applied for incident investigations in healthcare and the continued dependence on existing RCA techniques (Canham *et al.*, 2018). Also, these arguments substantiate findings from Chapter Three (survey and discussions) on the usefulness of the AcciMap method. However, the clinical safety expert noted how helpful the approach was in developing safety recommendations after analysis. This view was undoubtedly reflected in the

safety measures derived and the clinical safety expert's background knowledge in health informatics and experience using IT systems (e.g., CPOE system). Overall, the participant found applying the AcciMap method to be understandable and to a degree pragmatic. However, as noted earlier in this discussion, considerable training and resources are needed to perform a thorough analysis and apply the guidelines correctly to produce valid AcciMap outcomes.

4.9 Limitations of the Study

Attempts were made to involve clinical safety practitioners from the previous AcciMap study (Chapter Three). Involving additional participants, especially those with clinical safety experience (e.g., NHS Digital) working with IT systems, would have allowed further insights to be made from the CPOE medication error incident. In addition, this step would have allowed for determining if multiple users would reach similar conclusions after applying the AcciMap approach. However, due to this limitation, findings from a single participant's point of view had to be compared with expert analysis. This limitation further highlights Branford's recommendation suggesting that a team-based approach to analysing adverse incidents may provide a more comprehensive view of the accident than from an individualistic viewpoint.

Another limitation was that while the AcciMap expert's opinion on the clinical expert's analysis was considered, the study did not capture the processes each expert came to arrive at their respective AcciMap model outputs and safety recommendations. This limitation can be circumvented by using audio/video recordings to capture relevant data by observing how participants analyse and apply the AcciMap guidelines during incident analysis. This approach would have allowed participants to explain their outcomes, decisions behind them and any challenges they encountered. However, this process was not practically feasible due to their work schedule and unavailability (different time zones).

4.10 Conclusion

This study in this chapter builds on the previous chapter on evaluating Branford's standardised AcciMap approach concerning the first research question in ascertaining participants' perception of the method for incident analysis in the NHS. This chapter presented a more focused study on its application and subsequent analysis of a health IT-related incident by two different safety experts. While there is a general appreciation regarding the methodology of the AcciMap approach incorporating systems thinking compared to RCA approaches, the clinical expert's responses were mixed regarding aspects of the AcciMap method. Both experts' analyses clearly showed that despite similarities identified, there were still variations from the outcomes, particularly regarding the placement of contributing factors. The clinical expert's experiences using the AcciMap approach focused on its suitability, especially when analysing incidents without spending much time and resources. Outcomes from this study and Chapter Three indicate a need for more research and training involving multiple clinical safety practitioners, especially in practice. This process will include developing strict guidance regarding analysis based on supporting evidence and comparing their findings and safety recommendations.

5.0 CHAPTER FIVE: Development of a proposed Medi-Socio AcciMap Taxonomy Approach

5.1 Introduction

One notable recommendation from the pilot AcciMap training workshop (Chapter Three) that supports the objective of this thesis was the need for incorporating a taxonomy based on the AcciMap approach for identifying and classifying contributing factors. Taxonomies help provide structure and organise knowledge of a field, thus assisting researchers in studying relationships from concepts and hypothesising about these relationships (Glass and Vessey, 1995). They also help researchers and practitioners understand and analyse complex domains (Nickerson, Varshney and Muntermann, 2012). This chapter presents the development of a proposed new approach, the ***Medical-Sociotechnical (Medi-Socio) AcciMap taxonomy approach***, in addressing the second and third research questions on reliability and validity, respectively. This new AcciMap approach specific to the healthcare domain is based on the standardised AcciMap format and applied for incident analysis (health IT analysis). In addition, this chapter details the development process involved in building the initial taxonomy using existing socio-technical models and medical-related taxonomies identified. Subject matter experts (human factors, patient safety, and IT professionals) from the National Health Service (NHS) refined the initial structure to produce the final AcciMap taxonomy version.

5.2 Research Methodology

Taxonomy development broadly involves two processes. The first process is further divided into several sub-processes based on the methodology for developing taxonomies (Nickerson, Varshney and Muntermann, 2012; Mrosek, Dehling and Sunyaev, 2015; Usman *et al.*, 2017). These sub-processes constitute the flow chart of the taxonomy development, as shown in figure 5-1.

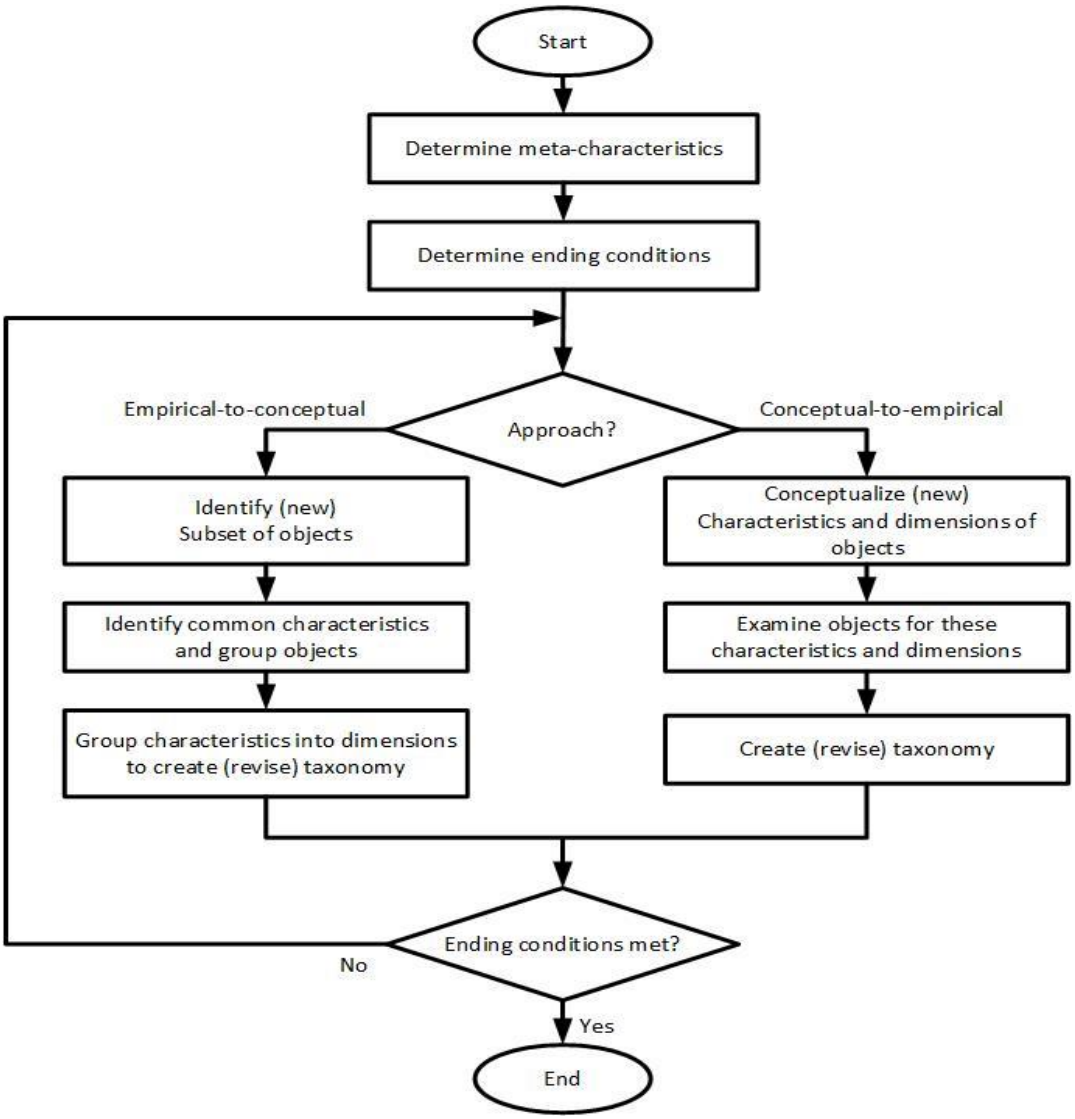


Figure 5-1: Flowchart of the taxonomy development adapted for the proposed Medi-Socio AcciMap taxonomy (Nickerson, Varshney and Muntermann, 2012)

These sub-processes, documented particularly by Nickerson *et al.* (2012), provide systematic guidance for the taxonomy development process include the following steps:

1.) Identification of meta-characteristics which for this chapter refers to "system categories" ("*sociotechnical aspects or dimensions*") corresponding with each AcciMap level (Physical/Actor activities, Organisational, and External). For each meta-characteristic, corresponding characteristics (sub-categories or contributing factors) are identified, which must be mutually exclusive and exhaustive (Nickerson, Varshney and Muntermann, 2012; Mrosek, Dehling and Sunyaev, 2015).
2.) Specifying ending conditions that can be objective or subjective for each meta-characteristic (system category) and associated characteristics

(contributing factors). The former ending type concentrates on the taxonomy's dimensions having mutually exclusive and exhaustive attributes. The latter type focuses on questions on the taxonomy being concise, robust, comprehensible, explanatory and extensible (Nickerson, Varshney and Muntermann, 2012; Mrosek, Dehling and Sunyaev, 2015) (see table 5-1).

3.) Determining which approach to use for each iterative pass until the ending conditions are achieved. The process could either be "*empirical-to-conceptual*", which involves obtaining dimensions and characteristics from empirical data or "*conceptual-to-empirical*", which derives its taxonomy from conceptualisation based on knowledge and experience of existing foundations (Nickerson, Varshney and Muntermann, 2012; Mrosek, Dehling and Sunyaev, 2015).

Table 5-1: Objective and Subjective ending conditions (adapted from Nickerson, Varshney and Muntermann, 2012)

Type	Conditions
Objective ending	• All objects or a representative sample of objects have been examined • No object was merged with a similar object or split into multiple objects in the last iteration • At least one object is classified under every characteristic of every dimension • No new dimensions or characteristics were added in the last iteration • No dimensions or characteristics were merged or split in the last iteration • Every dimension is unique and not repeated (i.e., no duplicate dimension) • Every characteristic is unique within its dimension (i.e., no duplicate characteristic within a dimension) • Each cell (combination of characteristics) is unique and is not repeated (i.e., no cell duplication)
Subjective ending	• **Concise** - Taxonomy being meaningful without being overwhelming • **Robust** – Dimensions and characteristics providing differentiation among objects • **Comprehensive** – Ability to classify all objects or a random sample of objects within the domain of interest • **Extendible** – Ability to accommodate a new dimension or new characteristic of an existing dimension easily • **Explanatory** – Ability of dimensions and characteristics to explain objects

Socio-technical models/approaches and relevant taxonomies were identified to initiate the first development process. Two significant studies that systematically classified taxonomies/classification schemes were identified from previous analyses. These studies mainly focused on human factors and medical

errors within healthcare (Taib *et al.*, 2011; Mitchell *et al.*, 2014). Taib *et al.* (2011) systematically compared twenty-six medical error taxonomies based on the human factors perspective. These taxonomies were also classified based on domain specificity being either "generic" or "domain-specific", with the latter applying to different aspects of the healthcare system (e.g., International taxonomy of medical errors in Primary care). Mitchell *et al.* (2014) also conducted a systematic review of human factors classification frameworks that identified causal factors, including human factors. In addition, existing health IT-related frameworks and literature identified contributing factors from utilising health IT systems based on functionality, usability, and safety management (Schneider *et al.*, 2014; Salahuddin and Ismail, 2015; Brindley and White, 2016a).

The second process focuses on refining the initial AcciMap taxonomy (categories and sub-categories), which can also be considered part of the iteration process in the taxonomy development. This process will primarily involve discussing and obtaining feedback from various Subject Matter Experts (SMEs) experienced in clinical safety management, human factors and health IT from across NHS boards/trusts and NHS Digital. The final iteration process involved a patient safety team from NHS Nottinghamshire reviewing the initial taxonomy structure to determine changes/alterations. This safety team has practical experience applying the original AcciMap version (Rasmussen and Svedung, 2000) for analysing severe incidents in their trust. They have utilised the method combined with a popular taxonomic approach, the Human Factors and Classification Scheme (HFACS) (Wiegmann and Shappell, 2003). The evaluation of the final version of the Medi-Socio AcciMap taxonomy will be elaborated in subsequent Chapters Six and Seven, respectively.

5.3 Development of the Medi-Socio AcciMap Taxonomy

In the taxonomy development, system categories (socio-technical aspects) and causal/contributing factors (sub-categories) are derived based on existing socio-technical models and frameworks. Based on the taxonomy development flowchart, the choice of which approach to use when iterating was based on the availability of the empirical data when deriving system categories and sub-categories. These activities constitute the development of the first version of

the Medi-Socio AcciMap taxonomy approach. Also, it is vital to establish the validity of the categories and sub-categories identified as part of the development procedure. This process includes assigning contributing factors to the appropriate category and system categories to the proper AcciMap level. The last point particularly relates to Branford's thesis in analysing and determining which level (party) is responsible for any subsequent safety recommendation to mitigate or prevent reoccurrence. The following subsections detail the Medi-Socio AcciMap development.

5.3.1 First Iteration

The empirical-to-conceptual approach was used to identify "***sociotechnical aspects"*** (system categories) associated with each AcciMap level and contributing factors (sub-categories). This approach was applied to identify categories from existing socio-technical models and taxonomies used in healthcare. This approach was also utilised when identifying and determining contributing factors to be associated with each system category. The initial structure of the Medi-Socio AcciMap taxonomy consisted of four levels of granularity. These include the "***AcciMap level"*** based on the standardised AcciMap format, "***System-level"*** consisting of sociotechnical aspects or categories for each AcciMap level, and "***Descriptor level"*** consisting of the specific sub-categories for each category. The final level, **"*Highly specific level"*,** consists of an additional level of subcategories associated with each sub-category where applicable. However, this level was initially created to include specific sub-categories.

5.3.1.1 Sociotechnical Aspects (System Categories)

The first AcciMap level (Physical/actor activities and processes) consists of clinical teams' activities (actions, decisions, and non-concordance) relating to patients. System categories "*Staff*" and "*Patient*" were assigned to this AcciMap level to convey these contributing factors. The "*Staff*" category is divided into separate considerations; "*Staff-individual*" focusing on actions and decisions of individual persons, and the "*Staff-team*" category comprising of actions and decisions by a group of clinicians that may compromise patient safety. "Medical Environment" considers the state of the working climate, including the physical environment where patients and clinicians reside. System categories for the

organisational level (technical and local management levels) comprise aspects within the control of health organisations. Aspects relating to software/hardware and their functionality in enabling interactions with clinicians and Management entities (IT and hospital) were derived from relevant IT literature on health IT-related classification schemes/frameworks and (Institute for Medicine, 2012; Schneider *et al.*, 2014; Salahuddin and Ismail, 2015; White, 2018). Other categories added include "*Equipment*" relating to non-IT related factors and "*Technical*" relating to factors not solely focused on software or hardware aspects. These initial categories were obtained from similar dimensions found in existing sociotechnical models and contributing frameworks, as detailed in table 5-2.

Table 5-2: Initial socio-technical aspects (System categories) associated with each AcciMap Level

AcciMap Level	Sociotechnical Aspect - Category	Sociotechnical Models/Taxonomy Categories (References)
Physical/Actor Level	Patient	1.) Adapted based on the "***Person***" category from the SEIPS model (Appendix D-1) and Eight-dimensional Sociotechnical model (Appendix D-2) (Sittig and Singh, 2010; Holden *et al.*, 2013). 2.) Adapted based on the "***Patient factors***" from the London Protocol Contributory Framework (Appendix D-3) (Taylor-Adams and Vincent, 2004; Vincent, Burnett and Carthey, 2014).
	Staff – Individual [1]	1.) Adapted based on the "***Individual factors***" category from the London Protocol Contributory Framework (Taylor-Adams and Vincent, 2004; Vincent, Burnett and Carthey, 2014). 2.) Adapted based on the category "***Team factors***" from the London Protocol Contributory Framework (*same source as the first point*).
	Staff – Teams [2]	
	Medical Environment	1.) Adapted based on the category "***Environment factors***" from the London Protocol Contributory Framework and the Human Factors and Classification System (Appendix D-4)(Taylor-Adams and Vincent, 2004; Diller *et al.*, 2014).
Organisational Level - Technical & Operational Management	Equipment (Non-IT)	1.) Adapted based on the category "***Medical equipment***" from the Human Factors Classification Framework (Appendix D-5) (Mitchell, Williamson and Molesworth, 2016).
	Technical	1.) Adapted based on the "***Technical***" category from the JCAHO Patient Event Taxonomy (Appendix D-

AcciMap Level	Sociotechnical Aspect - Category	Sociotechnical Models/Taxonomy Categories (References)
		6)(Chang *et al.*, 2005).
	Information Technology (IT)	1.) Adapted based on the "***Hardware and Software***" dimension from the Eight-dimensional Sociotechnical model.
	Human-Computer Interaction	1.) Adapted based on the classification of health IT safety use antecedents (Salahuddin and Ismail, 2015).
	IT Management	1.) Adapted based on the notes from Clinical Risk Management Data Safety, NHS Digital Report, (Brindley and White, 2016a; White, 2018).
Organisational Level – Local Management	Clinical Management	1.) Adapted based on the "***Management***" category from the Human Factors Framework (Appendix D-7) (healthcare) (Henriksen *et al.*, 2008).
	Hospital (Senior) Management	
External Level	Health IT Vendor	1.) Adapted from the Institute of Medicine (2012).
	Government [1, 2]	1.) Adapted based on the "***External environment***" category from the Human Factors Framework. 2.) Adapted based on the "***Regulatory bodies***" and "**Government**" categories from UPLOADS Classification Scheme (Appendix D-8) (Goode *et al.*, 2015; Salmon *et al.*, 2017).
	Regulatory Bodies [1]	
	Professional Bodies/Associations	1.) Feedback from an experienced e-health specialist on the proposed model from the National Scottish Services (NSS). 2.) Adapted based on the "***Professional bodies***" UPLOADS Classification Scheme (Goode *et al.*, 2015; Salmon *et al.*, 2017).

5.3.1.2 Contributing Factors (Sub-Categories)

Figure 5-2 shows the first iteration of the Medi-Socio AcciMap taxonomy (version 1.0) detailing each AcciMap level, the system categories, and associated contributing factors. The empirical-to-conceptual approach was applied to identify contributing factors for each system category since there was sufficient information. Some contributing factors identified for each category are commonly identified from different taxonomies and classification systems used in other safety-critical domains. For example, a common contributing factor like "*inadequate communication and feedback*" is a regular but crucial aspect

identified by different taxonomies. However, other factors particular to the health system will relate to system categories like the “patient-related”, consisting of the patient’s complexity and medication condition.

The empirical-to-conceptual method was also applied in identifying categories and sub-categories at the organisational level. However, data was limited when deriving contributing factors associated with system categories at the external level. For example, contributing factors related to the system category, “Professional Bodies/Associations”, were derived using the “intuitive approach” (Nickerson, Varshney and Muntermann, 2012). This approach was applied based on discussions with the clinical safety officer (Chapter Four) and his understanding of external entities and factors affecting system safety. However, the Medi-Socio AcciMap taxonomy approach can potentially include other systemic factors from new empirical data. In finalising the first iteration, the “*Other*” sub-category was assigned to comprise any factor identified from an incident not classified under any other sub-categories. The “*Unclassifiable*” category includes factors not classified under any pre-defined system categories at each AcciMap level. System categories and contributing factors were assigned specific codes (nano codes) for classification during incident analysis. In reviewing the initial taxonomy, specific system categories were marked in grey, indicating needed changes, and contributing factors (shown in red) were removed during the second iteration stage.

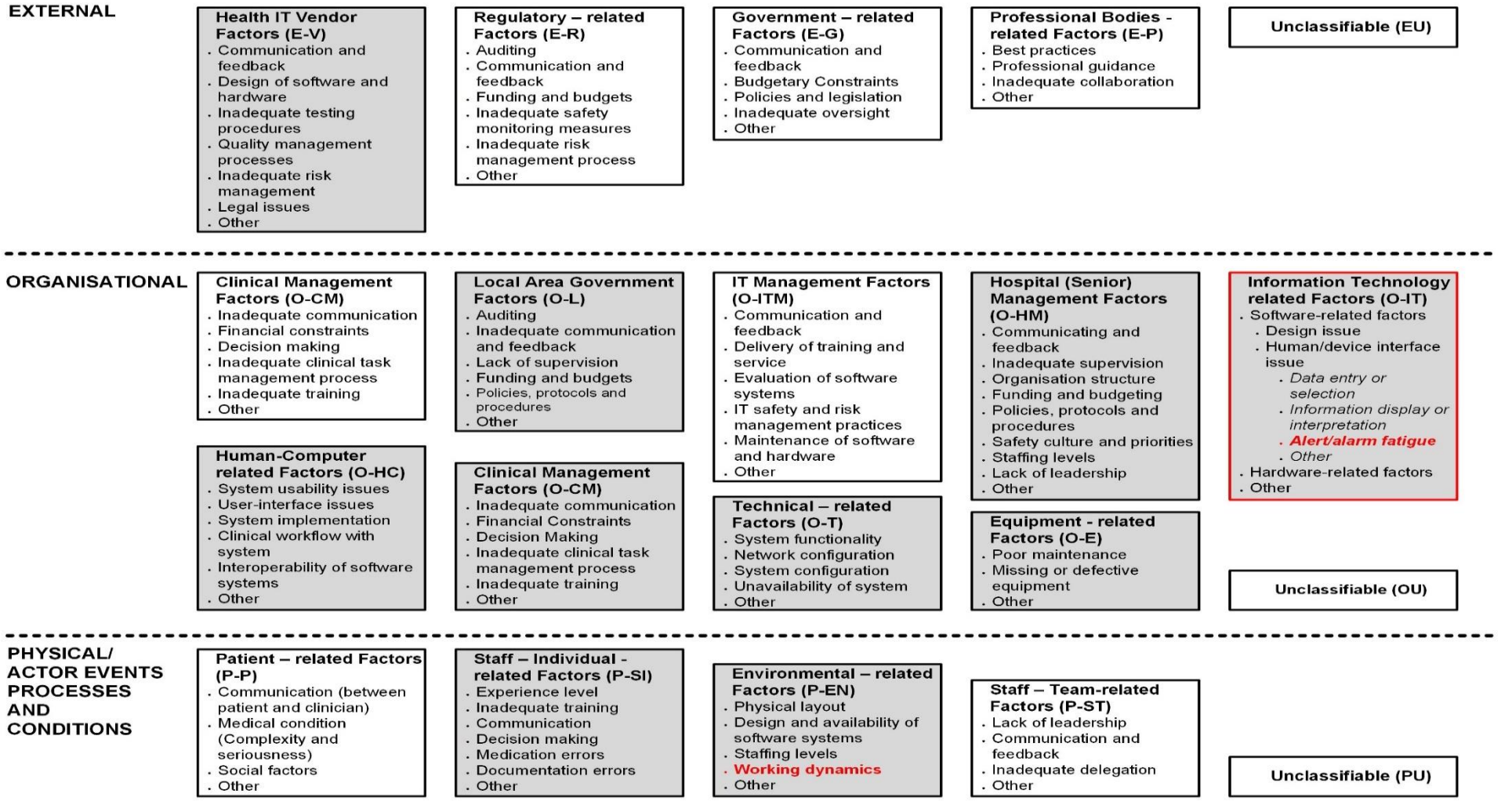


Figure 5-2: Initial version of the Medi-Socio AcciMap taxonomy model (version 1.0)

5.3.2 Second Iteration

After developing the initial Medi-Socio AcciMap taxonomy structure, it was imperative to determine the content validity of the categories and sub-categories. This process involved discussions with Subject Matter Experts (SMEs) who have experience conducting accident investigations in their respective healthcare practices. First, SMEs were contacted through email correspondence, with the initial taxonomy structure for feedback and comments. Subsequently, and where possible, meetings were held to clarify aspects of the taxonomy.

5.3.2.1 Review from Subject Matter Experts (SMEs)

For the second iteration, five subject matter experts (SMEs) were involved comprising of human factors specialists (3), a clinical risk manager (1), and a clinical safety officer (1). Four of them work with the National Health Service (England and Scotland), with the remaining (who developed the standardised AcciMap) established in the Railway domain (Australia). Each of the SMEs (denoted with an SME-Number) then provided their feedback on the clarity of contributing factors and the placement of the socio-technical aspects initially placed in the taxonomy. Table 5-3 below details the changes based on their feedback.

Table 5-3: Changes to the initial Medi-Socio AcciMap Taxonomy from Subject Matter Experts (4)

Subject Matter Expert (SME)	Category (Socio-Technical Aspect)	Sub-Category (Contributing Factors)	Review/Comment(s)
SME-1	• Addition of the category "Professional Bodies/Associations" factors at the external level.	• Contributing factors associated with this category include current best practices, current professional guidance.	• Addition of this category to consider external entities like Royal Colleges.
SME-2	Changes to categories • Patient-related factors, • Environmental-related factors, • Staff-individual and • Staff-team-related factors	• Social factors, design and availability of software, staffing, documentation issues, leadership, delegation, and supervision to be considered as organisational factors.	• Noted some of the contributing factors that fitted better at the organisational level instead of the Physical/actor level because they are not "direct precursors" to the incident
	Changes to categories • IT Management, • Equipment-related factors, and	• Inclusion of selection of systems (hardware, software) as contributing factors.	• "Selection of systems" is a contributing factor considered within the control of

Subject Matter Expert (SME)	Category (Socio-Technical Aspect)	Sub-Category (Contributing Factors)	Review/Comment(s)
	• Hospital Management factors. • Adjusting the category "Local Area Government" to be moved to the external level.	• Including contributing factors like poor maintenance of equipment, defective or missing equipment, unsuitable equipment. • Inclusion of contributing factors internal auditing and inspections, enforcement of rules and procedures, staff selection, and training provision. • Changing the contributing factor "staffing levels" to "Inadequate staffing levels".	the health organisations to determine which systems are most suitably and appropriately selected.
	• Adjusting the category "Health IT Vendor" factors to the Organisational level rather than the external level.	• No comments.	• Consideration was made regarding placing this category at the organisational level because the associated contributing factors are within the control of the health organisation.
SME-3	• Reviewing categories ○ Patient-related Factors ○ Staff-Team-related factors ○ Environment-related factors" categories	• Reviewing contributing factors; ○ Medical Condition (Complexity and Seriousness) – ***Patient-related factor***. ○ Team structure – *Staff-**Team related factor***. ○ Workload and Shift patterns – ***Environment-related factor***.	• No comments.
SME-4	• No comments	• Inclusion of a contributing factor relating to "Procurement of IT systems and equipment".	• No comments.

Based on the field meeting with a human factors specialist (SME-5), discussions took place regarding the AcciMap methodology and the structure of the proposed AcciMap version. The accident "outcome" of the AcciMap model was reviewed with suggestions of changes. This comment was based on the SEIPS model, where outcomes should not only focus on the immediate adverse result (relating to the

patient) but should consider other effects on the health organisation's reputation and medical staff involved. Also, this viewpoint can be extended to include companies (Health IT vendors) responsible for developing any specific software product. However, this comment was not considered for the proposed AcciMap taxonomy because the underlying structure needed to be consistent with Branford's system. Also, SME-5 emphasised the importance of ensuring that the identified contributing factors are "*neurally-themed*" to avoid making the taxonomy negative-centric. Based on observation of contributing factors at the physical/actor level, the semantics of contributing factors needed to be adjusted to convey them as neutrally themed factors. For instance, the contributing factor, "Inadequate communication & feedback", was changed simply to "Communication & feedback", as was the case of another factor ", lack of leadership", was to be changed to either "Leadership" or "Inadequate leadership". Another aspect noticed was the similarity of contributing factors like the "Inadequate risk management process" and "clinical risk management process", which needed to be reformatted to avoid having overlapping factors.

5.3.2.2 Review from Patient Safety Team (NHS, Nottinghamshire)

The final review of the taxonomy involved a collaborative workshop meeting with a patient safety team based in NHS Nottinghamshire. The patient safety team is composed of the safety lead and two additional clinical support staff. All team members have also applied the AcciMap approach and other methods like the HFACS, which they sometimes use to analyse serious incidents. Before the scheduled meeting, the initial taxonomy and its guidance documentation were shared via email correspondence with the team's patient safety lead. Each category (particularly the greyed boxes) and associated contributing factors were reviewed for each AcciMap level. Discussions and consensus were reached with the patient safety lead where there were any disagreements regarding the clarity or relevance of contributing factors. In some cases, contributing factors or categories that were not part of the initial taxonomy were also identified during the review. Table 5-4 details the review and proposed recommendations during the workshop.

Table 5-4: Review of the initial Medi-Socio AcciMap Taxonomy Categories

System Category	Review/Comments	Proposed Recommendation(s)
Environmental-related factors	• This category could be considered at the physical level as long as a category at the organisational level links to this category. • There was an agreement regarding the contributing factor "physical Layout", but the other factors were considered organisational factors that can potentially affect activities at the physical level.	• This category is to be considered as part of the physical/Actor activities level in consideration of the working environment that may affect the physical activities of both patients and clinicians. • Contributing factors (working dynamics and staffing levels) to be removed and refitted with relevant categories at the organisational level.
Staff-Individual related factors	• Medication errors and documentation errors are regarded as examples falling under contributing factor "Communication".	• Contributing factor "Inadequate training" to be considered an organisational factor rather than a physical one. • Addition of a contributing factor "non-concordance" indicating unsafe acts of individual clinicians at the physical level. • Factor "Experience level" to be rephrased.
Staff-Team related factors	• Factors regarding "lack of leadership" and "Inadequate delegation" were not considered appropriate for this category.	• Restructuring this category to include contributing factor "non-concordance" relating to unsafe acts that team members could commit at the physical level.
Patient-related factors	• No changes were needed on the contributing factors already associated with this category.	• Addition of contributing factors regarding unsafe acts (non-concordance) of patients (e.g., where patients may not follow the prescription from medical personnel).
Information Technology related factors	• Comments were provided on contributing factors associated with this category. However, there was a consensual agreement that changes were needed, particularly with hardware and software sub-categories.	• Restructuring factors, particularly with changes under the factor "human/device interface", sub-categories needed to be associated with the category "Human-Computer", which focuses on the usability of software systems.

System Category	Review/Comments	Proposed Recommendation(s)
Hospital (Senior) Management factors	• There was a general agreement on contributing factors but noted that "safety culture and priorities" needed to be clarified for prospective users when evaluating the approach. • Contributing factors "Inadequate supervision" and "Lack of leadership" were considered synonymous because the former was deemed to be encompassed under the latter factor. • "Organisational structure" was not deemed to be necessary for this category.	• Reconsideration and clarification of the contributing factor "safety culture". • Removing the factor "Inadequate supervision" but leaving "lack of leadership". • Removing the factor "Organisational structure". • Rephrasing factor "Staffing levels" to "Staffing recruitment or human resources".
Equipment related factors	• There was an agreement on contributing factors assigned to this category.	• No recommendations.
Technical-related factors	• After discussion, it was agreed that this category was not relevant, and factors associated with this could be assigned to other system categories, particularly the Information Technology category.	• Removing this system category and re-examining contributing factors to be assigned to relevant system categories.
Human-Computer related factors	• There was discussion on what the contributing factor "clinical workflow with systems" meant. After establishing its definition in terms of how software systems help facilitate the clinical process of patients, it was agreed that this factor is best suited for the "information technology" category. • It was agreed that contributing factors associated with this category would need to be reviewed, mainly focusing on aspects relating to health IT system usability.	• Reviewing of contributing factors associated with this category focusing on the usability of health IT systems.
IT Management factors	• The only review for contributing factors for this category was rephrasing the "Maintenance of software and hardware" contributing factor.	• Reviewing of contributing factors associated with this system category.
Clinical Management factors	• This system category was considered redundant, and that contributing factors could also be associated with the system category "Hospital (Senior) Management factors.	• Removing the redundant system category and reviewing contributing factors to be associated with the Hospital Management category.

System Category	Review/Comments	Proposed Recommendation(s)
Local Area Government factors	• This system category was considered redundant, and that contributing factors could be linked to system categories at the external level especially relating to Regulatory and Government entities. • Creating an additional system category relating to local supervision of medical staff was considered and discussed regarding its placement at the Physical-Actor level (First AcciMap level).	• Removing this system category because the category did not contribute to the overall concept of the proposed AcciMap approach. • Addition of a new system category "Staff – Local Management" at the Physical/Actor level.
Health IT Vendor factors	• There was an agreement on contributing factors associated with this category, but a consensus was needed regarding which AcciMap level was considered appropriate in depicting this aspect.	• This system category was to be moved to the organisational level (specifically under the organisational – management level) due to links associated with software products from IT vendors and collaboration with hospital management and IT management categories.
Regulatory related factors	• No additional factors were considered for this category. However, there was general agreement with the associated factors.	• No recommendations
Government-related factors	• There was also agreement on contributing factors associated with this system category.	• No recommendations
Professional bodies/Association factors	• There was disagreement regarding the relevance of this system category. Questions raised included how this category potentially influences other aspects at both organisational and physical levels in contributing to any adverse event. • There was divided opinion regarding contributing factors assigned to the professional category, especially "professional guidance". • Other contributing factors include "Evidence-based practices (e.g., where National Guidance may conflict with one another).	• No recommendation was given, but a review with existing taxonomies was needed to justify the inclusion of this category.
	*** Greyed areas indicating categories subject to change	

The final taxonomy development process involved applying the ending conditions for system categories at each AcciMap level and sub-categories for each category. After the second iteration, system categories for each AcciMap level were agreed to conceptually portray aspects of a healthcare system. No other system categories were added to the taxonomy after changes were made during the second iteration. As noted in previous subsections, the "unclassifiable" category was added to capture any new data regarding system categories not included in the updated Medi-Socio AcciMap version. When considering each category's contributing factors, it was determined that the identified factors satisfied the subjective ending condition criteria, especially after the review from the patient safety team. Also, no additional system categories were required (added) after the second iteration when considering the objective ending conditions criteria. However, health IT-related system categories and associated contributing factors were not confirmed due to non-feedback from relevant clinical IT practitioners (NHS Digital).

5.4 Changes to the initial Medi-Socio AcciMap taxonomy

Based on the review of the initial taxonomy and feedback from the author of the standardised AcciMap approach (second iteration), fundamental changes were made, particularly regarding contributing factors at the physical/actor-activities level. The "highly specific" level regarding subcategories (see subsection 5.3.1) was not included in the final proposed AcciMap structure. Causal/Contributing factors relating to categories patient and staff (individual and teams) needed to have subcategories regarding "Unsafe Acts" and "*Unsafe Acts – Violations*" (adapted from the HFACS approach). This requirement agrees with the safety team's review, except that instead of the term "*violations*", "*non-concordance*" is used. These comprise of actions/activities of medical practitioners relating to how they use clinical software systems and how this may unintentionally translate into actions that may put a patient at risk. Other changes include alterations to the "information technology" category where software and hardware-related factors were expanded based on factors adapted from health IT classification schemes. Contributing factors associated with the category "Human-Computer" were reviewed and changed to develop usability aspects relating to health IT systems (Salahuddin and Ismail, 2015). System categories "*Local Area Government*" and "*Technical*" were removed after changes to the

"*Clinical Management*" and "*Information Technology*" categories. Also, the "*Health IT vendor*" category was moved from the external to the organisational (Management) level. This category was regarded as an organisational aspect where relationships can be identified between management implementing health IT systems and IT vendors responsible for designing and ensuring achievable safety standards.

Based on the review from the patient safety team, the only aspect of the taxonomy where more evaluation was needed was the system category "*Professional Bodies/Associations*". However, from the previous review from one of the SMEs (SME-1), this category was considered relevant to the proposed AcciMap approach. Also, with the addition of the category "*Staff-Local (clinical) Management*", the patient safety team recommended including contributing factor "*non-concordance*" associated with unsafe acts. The addition of this factor is due to instances where letting staff get away with bad practices may be allowed by managers (supervisors). They also reasoned that local clinical managers are also front liners and can make "operational" decisions, allow for safe practice and assess risks. After these changes, each system category and subcategories were re-assigned with unique nano codes. Figure 5-3 shows the updated Medi-Socio AcciMap taxonomy (version 2.0) where each AcciMap level details each system category and their subcategories as shown in figures 5-4 (Physical/actor activities & processes), 5-5 (Organisational), and 5-6 (External), respectively. In addition, each sub-category is described in the guidance notes for the professional participants (see Appendix D-9).

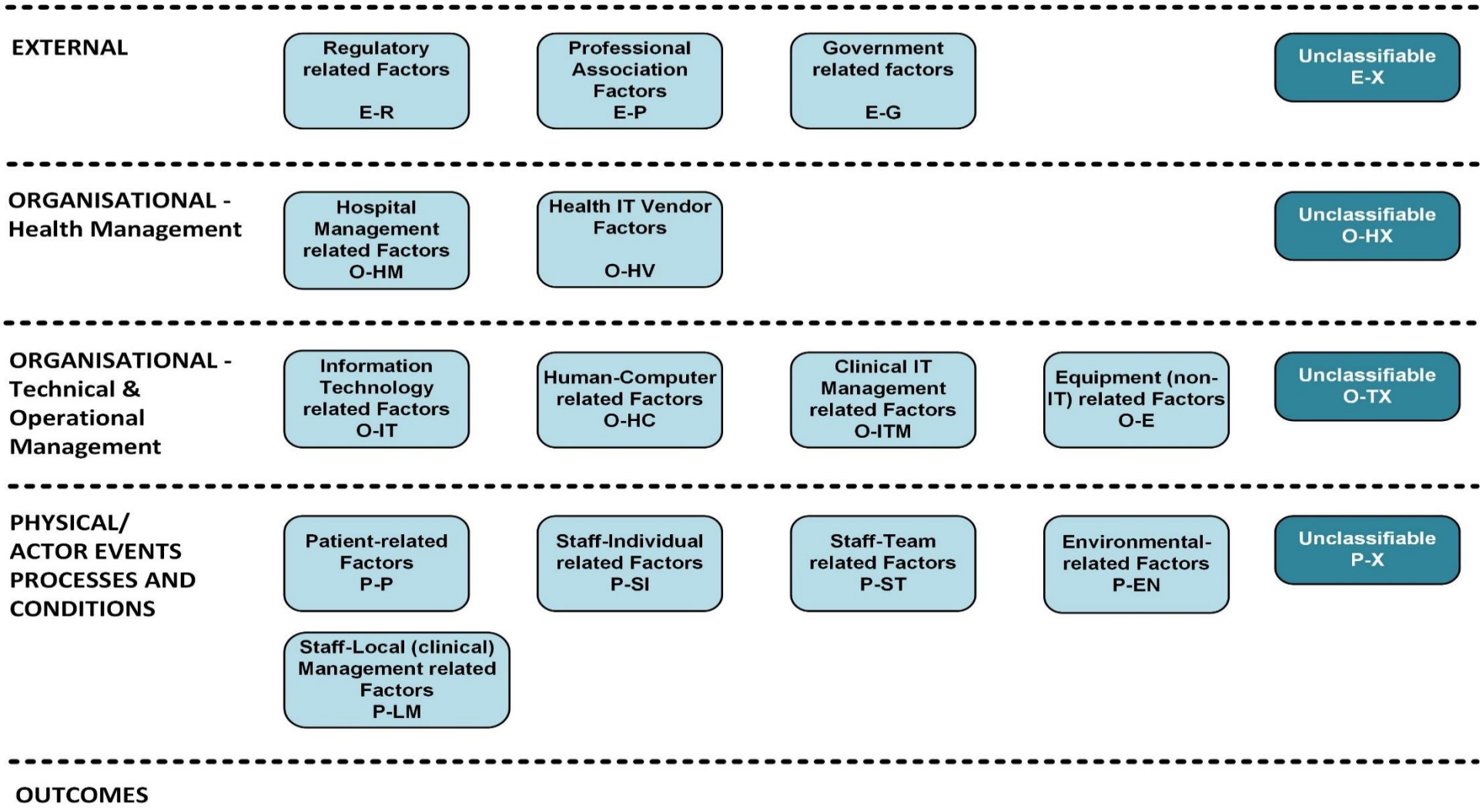


Figure 5-3: Updated Medi-Socio AcciMap taxonomy approach (version 2.0)

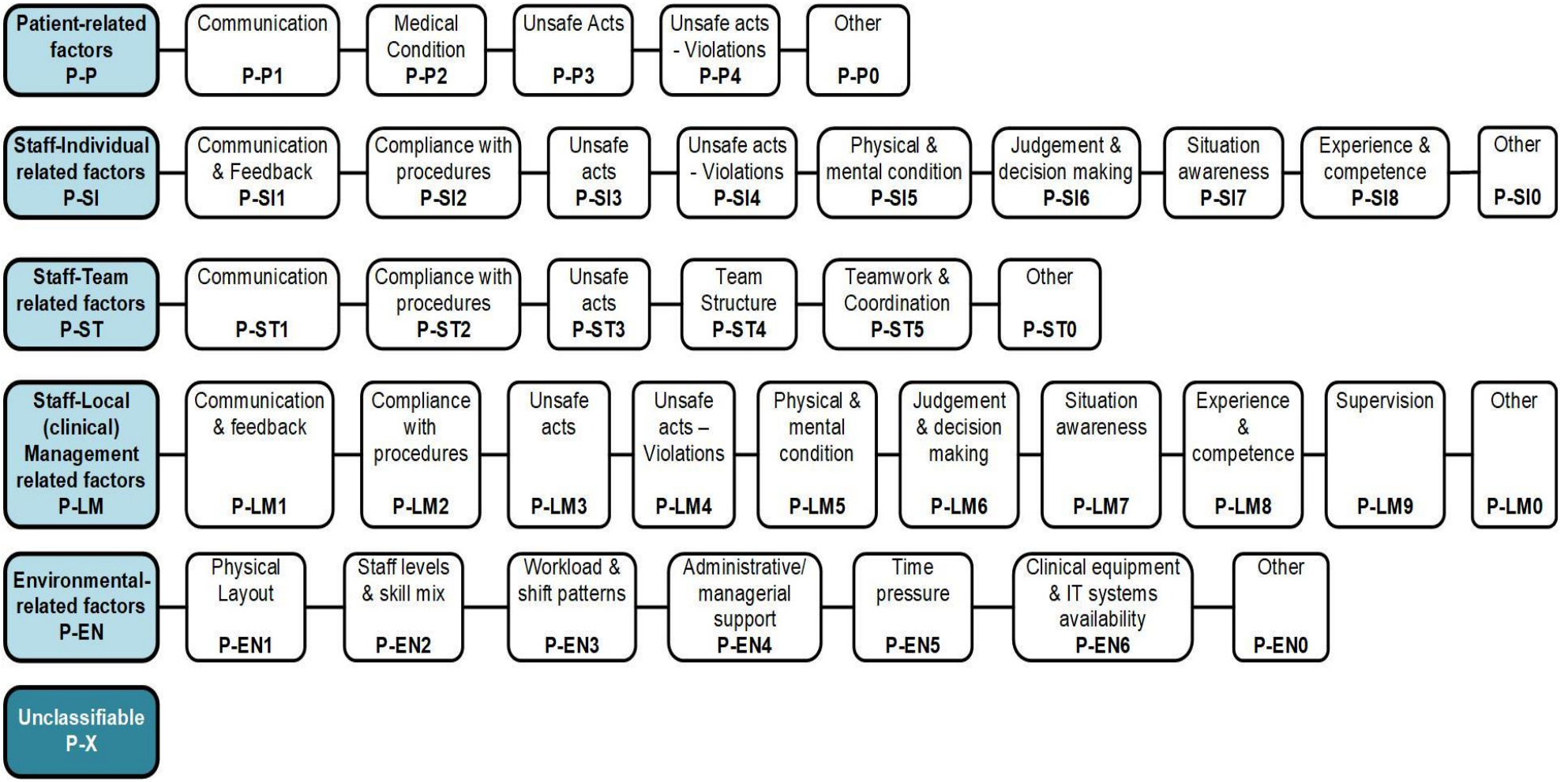


Figure 5-4: Medi-Socio AcciMap taxonomy approach – Physical – Actor activities & processes Level

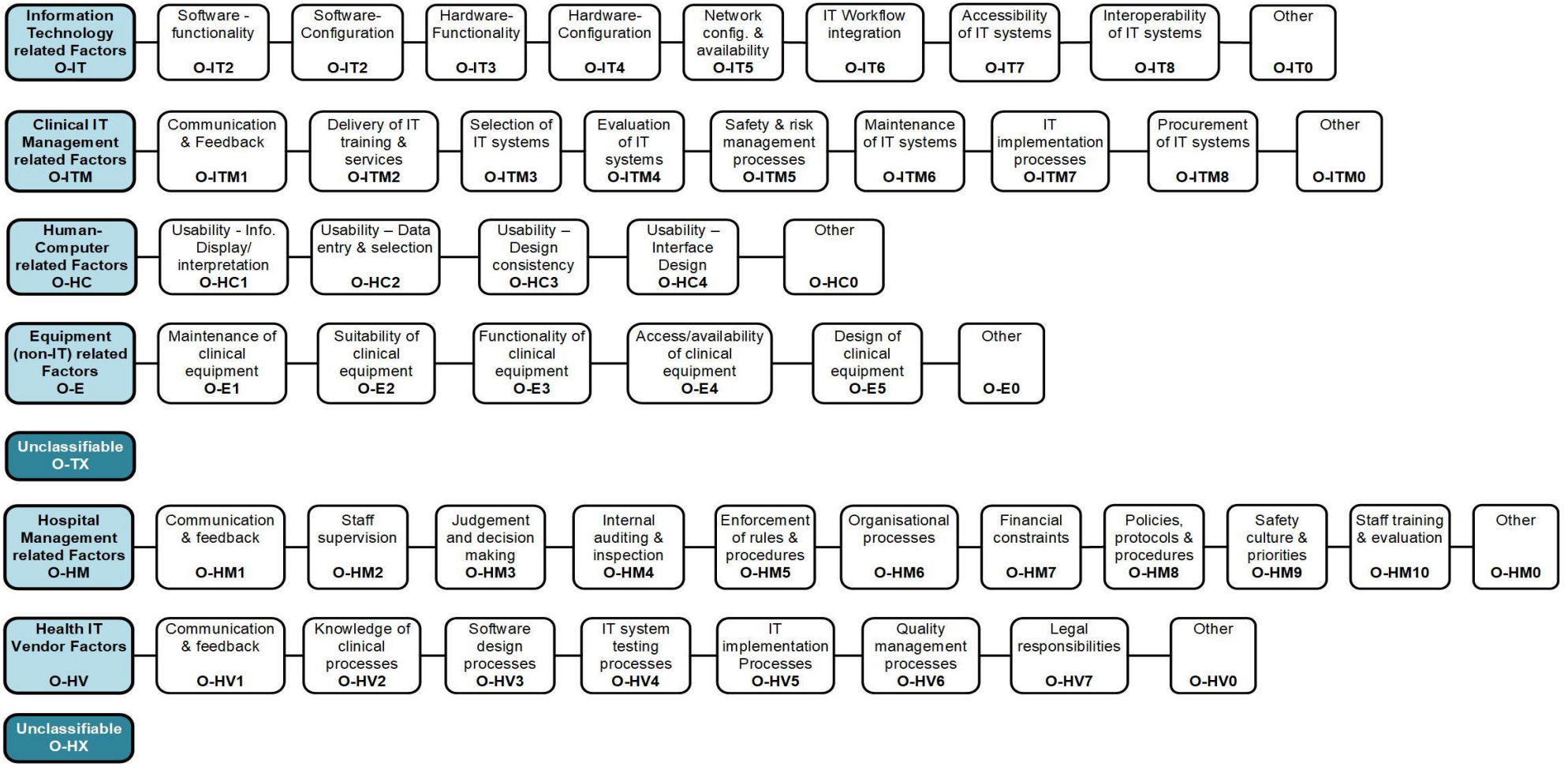


Figure 5-5: Medi-Socio AcciMap taxonomy approach – Organisational (Technical/Operational and Health Management) Level

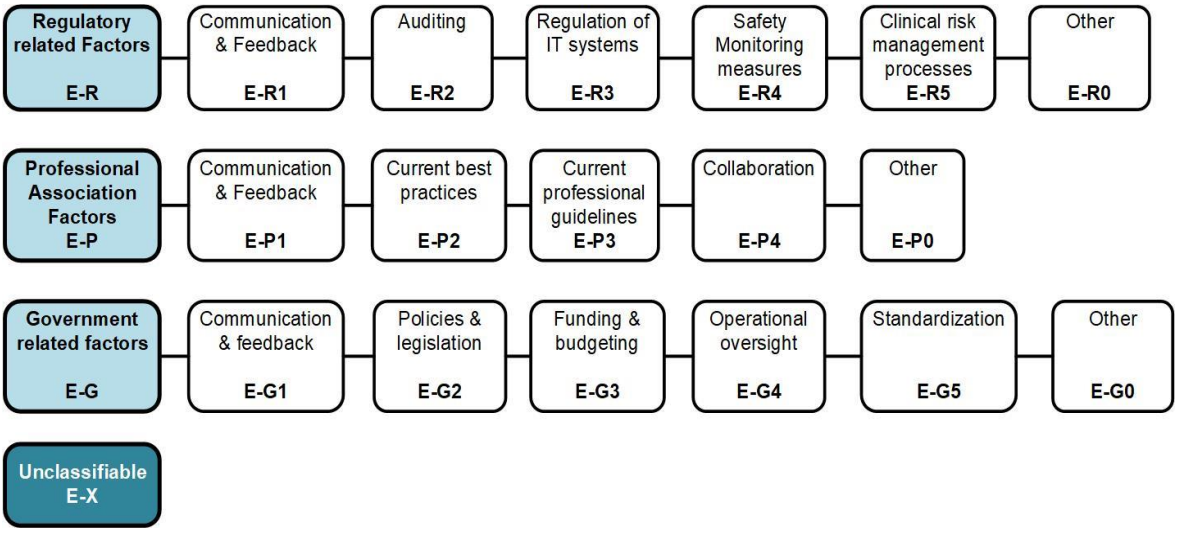


Figure 5-6: Medi-Socio AcciMap taxonomy model approach – External Level

Tables 5-5, 5-6, and 5-7 detail the updated Medi-Socio AcciMap taxonomy structure based on corresponding AcciMap levels with system categories, contributing factors (subcategories) and existing taxonomies/schemes they were derived.

Table 5-5: Contributing factors associated with each system category – Physical/Actor activities level

System Category (Socio-technical Aspect)	Contributing Factors (Subcategories)	Taxonomies/Classification Frameworks/Citations
Patient	• Communication (between patient and clinician) [1,2,3,7] • Medical condition (Complexity and seriousness) [1,7] • Unsafe acts [4,5,6] • Unsafe acts – Violations (non-concordance) [4,5,6] • Other	1.) Vincent's London Protocol framework for incident analysis (Taylor-Adams and Vincent, 2004). 2.) Human Factors Classification scheme for patient safety (Mitchell, Williamson and Molesworth, 2016). 3.) Adapted as a critical contributing factor (e.g., the case of insufficient communication due to lack of engagement between patients and doctors relating to E-prescribing errors) (Manias *et al.*, 2015). 4.) Human Factors and Classification System (HFACS) (Wiegmann and Shappell, 2003; Diller *et al.*, 2014). 5.) UPLOADS classification scheme (Goode *et al.*, 2017; Salmon *et al.*, 2017). 6.) A fieldwork evaluation of the

System Category (Socio-technical Aspect)	Contributing Factors (Subcategories)	Taxonomies/Classification Frameworks/Citations
		proposed taxonomy with the patient safety team, National Health Service, Nottingham (2018). 7.) Human error taxonomy system for evaluating patient safety event (Itoh, Omata and Andersen, 2009).
Staff – Individual	• Communication and feedback [1, 5] • Compliance with procedures [3] • Unsafe acts [2, 4] • Unsafe acts – Violations (non-concordance) [2, 4] • Physical and mental condition [1] • Judgement and decision making [3] • Situation awareness [2, 3] • Experience and competence [3] • Other	1.) Vincent's London Protocol framework for incident analysis (Taylor-Adams and Vincent, 2004). 2.) Human Factors and Classification System (HFACS) (Wiegmann and Shappell, 2003; Diller *et al.*, 2014). 3.) UPLOADS classification scheme (Goode *et al.*, 2017; Salmon *et al.*, 2017). 4.) Fieldwork evaluation of the proposed model with the patient safety team, NHS Nottinghamshire (2018). 5.) Human error taxonomy system for evaluating patient safety event (Itoh, Omata and Andersen, 2009).
Staff – Team	• Communication and feedback [1,5,7] • Compliance with procedures [2] • Unsafe acts [3, 4, 6] • Team structure [1,2] • Teamwork and coordination [1, 2] • Other	1.) Vincent's London Protocol framework for incident analysis (Taylor-Adams and Vincent, 2004). 2.) UPLOADS classification scheme (Goode *et al.*, 2017; Salmon *et al.*, 2017). 3.) Human Factors and Classification System (HFACS) (Wiegmann and Shappell, 2003; Diller *et al.*, 2014). 4.) Performance Influencing Factors (PIF) taxonomy (Kim and Jung, 2003). 5.) Severe medication errors (Chang, 2007). 6.) Fieldwork evaluation of the proposed model with a patient safety team, National Health Service, Nottingham (2018). 7.) Severe and non-severe medication errors (Chang and Mark, 2009).
Staff – Local (Clinical) Management	• Communication and feedback [1,6] • Compliance with procedures [2] • Unsafe acts [2, 4, 5]	1.) Vincent's London Protocol framework for incident analysis (Taylor-Adams and Vincent, 2004). 2.) UPLOADS classification scheme

System Category (Socio-technical Aspect)	Contributing Factors (Subcategories)	Taxonomies/Classification Frameworks/Citations
	• Unsafe acts – Violations (non-concordance) [2, 4, 5] • Physical and mental condition [1, 2, 4] • Judgement and decision making [2] • Situation awareness [2] • Experience and competence [2] • Supervision [2, 5] • Other	(Goode *et al.*, 2017; Salmon *et al.*, 2017). 3.) Human Factors Classification Framework (HFCF) for patient safety (Mitchell, Williamson and Molesworth, 2016). 4.) Human Factors and Classification Systems (HFACS) (Wiegmann and Shappell, 2003). 5.) Fieldwork evaluation of the proposed model with a human factors specialist and personnel experienced incident analysis, National Health Service, Nottingham (2018). 6.) Human error taxonomy system for evaluating patient safety event (Itoh, Omata and Andersen, 2009).
Environment	• Physical Layout [1, 2] • Staffing levels and skill mix [1, 2,4] • Workload and shift patterns [1] • Administrative/managerial support [1] • Time pressure [1,3,5] • Clinical equipment and IT systems availability [3] • Other	1.) Vincent's London Protocol framework for incident analysis (Taylor-Adams and Vincent, 2004). 2.) Human Factors Classification Framework (HFCF) for patient safety (Mitchell, Williamson and Molesworth, 2016). 3.) Adapted based on the classification of health IT safety use antecedents (Salahuddin and Ismail, 2015). 4.) Medication error records from MEDMARX in post-anaesthesia care units (PACU) (Hicks *et al.*, 2004). 5.) Human error taxonomy system for evaluating patient safety event (Itoh, Omata and Andersen, 2009).

Table 5-6: Contributing factors associated with each system category-Organisational level (Technical/Operational and Health Management)

System Category (Socio-technical Aspect)	Contributing Factors (Subcategories)	Taxonomies/Classification Frameworks/Citations
Information Technology	• Software-functionality [1,2,3,4,6] • Software-configuration [1,2,3,4,6] • Hardware-functionality [1,2,5] • Hardware-configuration [1,2,5] • Network configuration and availability [1] • IT workflow integration [4] • Accessibility of IT systems [1]	1.) Adapted based on the Magrabi's HIT framework (Magrabi *et al.*, 2010, 2016). 2.) Sociotechnical model for health IT (Sittig and Singh, 2010, 2011). 3.) Common Formats classification system (Schneider *et al.*, 2014). 4.) Institute of Medicine (Institute for

System Category (Socio-technical Aspect)	Contributing Factors (Subcategories)	Taxonomies/Classification Frameworks/Citations
	• Interoperability of IT systems [4]	Medicine, 2012). 5.) Adapted based on the classification of health IT safety use antecedents (Salahuddin and Ismail, 2015). 6.) Final Report on identifying and addressing unsafe conditions associated with Health IT, ECRI Institute (Wallace *et al.*, 2013).
Clinical IT Management	• Communication and feedback [1] • Delivery of IT training and service [1,3] • Selection of IT systems [5] • Evaluation of IT systems [4] • Safety and risk management practices [2] • Maintenance of IT systems [1,4] • IT implementation processes [1,5] • Procurement of IT systems [2,4,6] • Other	1.) Health IT and patient safety (Institute for Medicine, 2012). 2.) Clinical Risk Management Data Safety, NHS Digital Report, (Brindley and White, 2016b, 2016a; White, 2018). 3.) Safety of health IT (training) (Agrawal, 2016). 4.) Evaluating health IT systems (Heathfield, Pitty and Hanka, 1998; Yusof *et al.*, 2008; Lee, 2016). 5.) Selection, implementation and adoption of health IT (Lorenzi *et al.*, 2009; Cresswell, Bates and Sheikh, 2013). 6.) Feedback from a human factors specialist, NHS, Scotland.
Human-Computer	• Usability – Information display/interpretation [1, 2, 3, 4, 5] • Usability – Data entry and selection [1, 2, 3, 4, 5] • Usability – Design Consistency [1, 2, 3, 4, 5] • Usability – Interface design [1, 2, 3, 4, 5] • Other	1.) Classification of health IT safety use antecedents (Salahuddin and Ismail, 2015). 2.) Common Formats classification (Schneider *et al.*, 2014). 3.) Adapted from Magrabi's Health Information Technology (IT) framework (Magrabi *et al.*, 2010, 2016). 4.) Usability of Healthcare Information Technology (Kushniruk *et al.*, 2005, 2010). 5.) Electronic Health Records (Wilcox, Chen and Hripcsak, 2011).
Equipment (non-IT)	• Maintenance of clinical equipment [1, 2] • Suitability of clinical equipment [1, 2] • Functionality of clinical equipment [1, 2] • Access/availability of clinical equipment [3] • Design of clinical equipment [1,	1.) Adapted from the JCAHO Patient Event taxonomy (under "Technical" sub-category – Facilities) (Chang *et al.*, 2005). 2.) Based on the evaluation and feedback of the proposed model from human factors specialists from the National Health Service (NHS).

System Category (Socio-technical Aspect)	Contributing Factors (Subcategories)	Taxonomies/Classification Frameworks/Citations
	[2] • Other	3.) Adapted from Magrabi's Health Information Technology (IT) framework (Magrabi *et al.*, 2010; Magrabi *et al.*, 2016).
Hospital (High-level) Management	• Communication and feedback [1,2] • Staff supervision [1,2] • Judgement and decision making [2] • Internal auditing and inspection [1,2] • Enforcement of rules and procedures [1,4] • Organisational processes [1,2] • Financial constraints [1,2] • Policies, protocols, and procedures [1,2] • Safety culture and priorities [3,4] • Staff training and evaluation [4] • Other	1.) Vincent's London Protocol framework for incident analysis (Taylor-Adams and Vincent, 2004). 2.) UPLOADS classification scheme (Goode *et al.*, 2017; Salmon *et al.*, 2017). 3.) **Safety culture** in this context: "*Installation of an order entry system in a hospital with a poor safety culture or an inadequate IT network might lead to new errors*" (Magrabi *et al.*, 2016). 4.) Human error taxonomy system for evaluating patient safety event (Itoh, Omata and Andersen, 2009).
Health Information Technology (IT) Vendor	• Communication and feedback [1,2] • Knowledge of clinical processes [1,2] • Software design processes [1,2,] • IT system testing processes [1,2,5] • IT implementation processes [1,3] • Quality management processes [1,4] • Legal responsibilities [1,6] • Other	1.) Health IT and patient safety (Institute for Medicine, 2012). 2.) Safety of health IT (training) (Agrawal, 2016). 3.) Selection, implementation, and adoption of health IT (Lorenzi *et al.*, 2009; Cresswell, Bates and Sheikh, 2013). 4.) Classification of health IT safety use antecedents (Salahuddin and Ismail, 2015). 5.) Clinical Risk Management Data Safety, NHS Digital Report, (Brindley and White, 2016b, 2016a). 6.) Healthcare IT vendor "hold harmless" clause (Koppel and Kreda, 2009).

Table 5-7: Contributing factors associated with each system category – External level

System Category (Socio-technical Aspect)	Contributing Factors (Subcategories)	Taxonomies/Classification Frameworks/Citations
Government	• Communication and feedback [1, 2] • Policies and legislation [2,5] • Funding and budgeting [2] • Operational oversight (via certification) [4, 5] • Standardisation (via guidelines) [3, 4] • Other	1.) Vincent's London Protocol framework for incident analysis (Taylor-Adams and Vincent, 2004). 2.) UPLOADS classification scheme (Goode *et al.*, 2017; Salmon *et al.*, 2017). 3.) Report of the National Advisory Group on Health Information Technology in England (Wachter, 2016). 4.) Identifying patient safety problems associated with IT in general practice (Magrabi *et al.*, 2016). 5.) Institute of Medicine (Institute for Medicine, 2012).
Regulatory bodies	• Communication and feedback [1, 2] • Auditing [2] • Regulation on health IT systems [4] • Safety monitoring measures [4] • Clinical risk Management processes [3, 4] • Other	1.) Vincent's London Protocol framework for incident analysis (Taylor-Adams and Vincent, 2004). 2.) UPLOADS classification scheme (Goode *et al.*, 2017; Salmon *et al.*, 2017). 3.) JCAHO classification framework for patient safety developed by the World Health Organisation (WHO) (Chang *et al.*, 2005). 4.) Clinical Risk Management Data Safety, NHS Digital Report, (Brindley and White, 2016b, 2016a; White, 2018).
Professional Bodies/Associations	• Communication and feedback [1,2] • Current best practices [3] • Current professional guidance [3] • Collaboration [3] • Other	1.) Vincent's London Protocol framework for incident analysis (Taylor-Adams and Vincent, 2004). 2.) UPLOADS classification scheme (Goode *et al.*, 2017; Salmon *et al.*, 2017). 3.) Feedback from an experienced e-health specialist on the proposed model from the National Scottish Services (NSS).

5.5 Medi-Socio AcciMap Taxonomy – AcciMap and System Levels

Based on the updated Medi-Socio AcciMap version, the following subsections briefly describe each AcciMap level and its respective system (socio-technical) categories:

5.5.1 Physical/Actor Activities, Events and Conditions:

Comprises entities (actors) at the front line and directly related to the events that led to an accident or a near miss. At this level, the focus is on the events that "directly" led to the accident. These include actions, errors and violations that directly caused the adverse outcome to occur. This level also describes potentially complex interactions between patients, clinicians, and software system utilisation and how they can potentially contribute to a hazardous situation. The system components at this level include "*Patient*" and "*Staff*", which comprises different medical practitioners. Categories within this level include the following broad contributing factors:

5.5.1.1 Patient-related Factors

This category comprises contributing factors relating to patients, including medical conditions and actions/decisions (unsafe acts) taken that directly or indirectly resulted in an adverse outcome. In addition, factors associated with this category include communication between patients and medical staff.

5.5.1.2 Staff-related Factors

It consists of contributing factors relating to clinical staff that was directly involved with patients. This broad category is further classified into individually related, team-related, and local management related factors. Contributing factors include, for example, issues relating to effective communication with both patients and fellow staff, unsafe actions, decision making, and experience.

5.5.1.3 Environmental Factors

It consists of contributing factors relating to the condition of the environment where patients and clinical staff are operating. These include physical structure, staff level, workload and shift patterns, and how these can influence the performance of clinical staff working in those physical settings.

5.5.2 Organisational Level

This level comprises IT management, hospital management, health IT, and associated contributing factors relating to existing latent conditions that can potentially facilitate the occurrence and trajectory of the adverse outcome. This level also describes decisions taken within the health organisation, even including decisions previously taken that created an environment for errors to occur at the physical level. This level is divided into two other levels consisting of "*technical & operational management*" and "*company management/local area planning*" based on the original AcciMap format (Rasmussen and Svedung, 2000; Svedung and Rasmussen, 2002). The system components and their associated contributing factors are included as follows:

5.5.2.1 Hospital Management Factors

Contributing factors relating to decisions made at the top-tier hospital management regarding the implementation of procedures, protocols regarding the safety of patients. Other essential factors include staff supervision, internal auditing, rules and procedures, policies and protocols, and safety culture. Financial constraint regarding budgeting is another contributing factor, primarily related to hiring staff, training them, and implementing new technologies that fit clinical processes.

5.5.2.2 Information Technology (IT) Management Factors

Contributing factors relating to the design and implementation of various health IT products and how they can affect the clinical staff's utilisation of these technological products. This category broadly comprises factors relating to evaluating existing health IT systems, procurement, implementation, and maintenance. Other factors include communication between IT vendors and professionals regarding the development of software products and training for staff in using these products.

5.5.2.3 Information Technology factors

Contributing factors relating to the design of health IT products and how they are used by medical staff efficiently. This category focuses on aspects of health IT systems, including software functionality and configuration, hardware configuration, and facilitating clinical workflow integration.

5.5.2.4 Equipment-related Factors

Contributing factors in this category relate to non-IT devices. This category essentially includes the design, suitability, functionality, and maintenance of medical equipment in clinical settings. Issues also included relates to the availability of medical equipment and if they support the workflow of medical units that utilises them.

5.5.2.5 Human-Computer related Factors

One of the contributing factors relating to human-computer interactions focuses on the usability of health IT products. Usability in this category includes interface design, data entry/selection, and information display.

5.5.2.6 Health IT Vendor Factors

This category comprises contributing factors including knowledge of clinical operations, quality management, health IT implementation, software design, and legal responsibilities. In addition, communication with the hospital's management regarding the design and implementation of fit health IT products are among contributing factors in this category.

5.5.3 External Level

Contributing factors relating to decisions and actions taken outside health organisations by different entities regarding improving patient and system safety. The contributing factors identified at this level include the following:

5.5.3.1 Professional Body Factors

This system category includes factors associated with the effectiveness of existing best practices concerning safety and IT governance. Also included is how relevant health professional bodies communicate and collaborate with other external entities (government) and organisations (hospital).

5.5.3.2 Regulatory Factors

Contributing factors include communication between relevant regulatory bodies with other external entities (e.g., government) and organisations (healthcare). This system category also consists of the efficiency of safety monitoring measures, auditing, and regulation of existing health IT systems.

5.5.3.3 Government Factors

Contributing factors relating to government influence include communication with hospital management and other external entities regarding patient safety. Other contributing factors include the effectiveness of operational oversight and standardisation regarding clinical operations and risk management.

5.6 Analysis of Health IT-related Case Studies

The case incident (CPOE medication error) used in the previous chapter served as a test trial for applying the initial structure of the Medi-Socio AcciMap taxonomy. The incident was analysed and validated by the same AcciMap expert involved in the previous study. The following steps involved in applying the AcciMap taxonomy include:

1.) Analysis of the chronology of events that led to the adverse outcome or near miss.
2.) Determining the "system categories" at the AcciMap level from the case incident. For example, in the analysis of the medication dosing error, at the physical/actor levels, the clinical providers (A and B) and the patient that was initially hypokalemic will be classified under the "*staff-related*" and "*patient-related*" factors, respectively.
3.) Contributing factors are determined using the taxonomy and classified under appropriate sub-categories associated with each system or socio-technical category.
4.) A similar process is repeated in the other AcciMap levels at the organisational and external levels.
5.) Causal relationships are then depicted between the contributing factors within and between the system components.

5.7 Maintenance of the Medi-Socio AcciMap Taxonomy

Maintenance of the Medi-Socio AcciMap taxonomy involves iteration to include newer themes not included in this version or combine existing contributing factors (sub-categories) that overlap (to be discussed further in the final chapter). In section 5.4, the subcategory "*Other*" and category "*Unclassifiable*" can be used to obtain themes to refine the proposed taxonomy to create new system categories and contributing factors. While the methodology adopted for its development mainly focused on using existing classification schemes,

maintaining, and improving the taxonomy will also involve continued application and feedback from target end-users in the healthcare domain. This feedback process will require specialists on human factors, patient safety and clinical risk, and IT management (e.g., NHS digital).

5.8 Evaluation of the Medi-Socio AcciMap Taxonomy

Like any accident analytical approach, its taxonomy must achieve a recommended level of *reliability* (results between multiple users) and *validity* (results between users and experts). While reliability studies typically use the minimum benchmark of seventy per cent (70%), indicating high (acceptable) reliability, there isn't any hard-set rule to determine its base value (Goode *et al.*, 2017; Waterson *et al.*, 2017). Past theses, including those of Branford (2007) and Shorrock (2003), particularly the latter, highlighted the need for classification schemes to achieve acceptable levels of validity and reliability. The pilot study (Chapter Three) highlighted these separate terms and elaborated in Chapters Six and Seven. These include its internal and external validity, briefly discussed in the proceeding subsections.

5.8.1 Internal Validity

Several criteria used to determine the internal validity of an accident analysis approach, or specifically, a taxonomy (Shorrock, 2003), are summarised as follows:

1.) The first criterion focuses on how reliable an instrument is, in this case, a classification scheme or model (Shorrock, 2003). This criterion also includes its ability for the tool to be used reliably by multiple independent users (inter-reliability) and by the same user(s) over time (intra-reliability) (Ross, Wallace and Davies, 2004; Wallace and Ross, 2006).

2.) The second criterion focuses on mutual exclusivity (as earlier pointed in this chapter) on a similar horizontal level where only one entity (e.g., causal/contributing factor) can be placed into one grouping or category. While this is considered an essential property of a classification system in an ideal abstract sense (Bowker and Star, 1999), Shorrock noted that some behavioural taxonomists disagree regarding the need for this attribute.

3.) The third criterion focuses on the extent to which a taxonomy/classification scheme is considered comprehensive or

exhaustive. Comprehensiveness and reliability are often referred to as "content validity" (Shorrock, 2003).

4.) The final criterion focuses on relationships between and within categories defined in a taxonomy system (Bowker and Star, 1999). Also, this criterion is regarded as more subjective (Shorrock, 2003).

5.8.2 External Validity

External validity focuses on the extent to which a taxonomy fulfils the objectives for which it was developed (Fleishman and Quaintance, 1984; Beaubien and Baker, 2002). Three critical indicators in considering the external validity include:

1.) Generalizability of the scheme's findings,
2.) The extent to which the taxonomy is utilised to solve challenges, and,
3.) Resources and training expended by users to use the taxonomy efficiently (Beaubien and Baker, 2002).

When considering the external validity of any classification schemes or accident approach, the instrument should achieve the objectives for which it was developed (Shorrock, 2003; Branford, 2007). Aspects of external validity include *face validity,* where outcomes from its application should look valid based on results produced and end-users who utilise it for analysis (Shorrock, 2003). However, face validity is not the most robust type for validity assessment and will not be applied to evaluate the proposed AcciMap approach.

Finally, in evaluating the proposed AcciMap version, the aspect of placement of contributing factors will not be used to compare findings. Chapters Three and Four had included this aspect when comparing results between participants after applying the standardised AcciMap version. However, the Medi-Socio AcciMap taxonomy incorporates system categories already assigned to appropriate AcciMap levels after initial development and feedback from SMEs. Therefore, the aspects of evaluation will primarily focus on causal/contributing factors, causal relationships, and safety recommendations.

5.9 Limitation of the Study

There were substantial challenges during the development phase of the proposed AcciMap taxonomy. One of such challenges included acquiring further feedback from additional SMEs on system categories and contributing factors. For example, despite contacting other safety specialists across NHS boards and trusts, there was limited or no feedback due to time constraints and unavailability. In addition, clinical IT practitioners (NHS Digital) feedback could not be obtained regarding aspects of the taxonomy relating to health IT (functionality and utilisation). Despite the initial contact with one of the NHS Digital representatives, a workshop was not possible due to their unavailability and work schedule. Another challenge was achieving an acceptable balance between ensuring that the taxonomy is not too complicated (i.e., number of sub-categories for each system category) and being as comprehensive as possible. There was also the issue of determining if subcategories defined for each system category had similar meanings to prevent overlapping factors. However, the evaluation of the Medi-Socio AcciMap approach will assess this limitation.

Also, the methodology applied in the initial taxonomy development was considered an alternative to the development processes used in previous studies across different safety-critical domains. For example, part of the development process involves accessing data from incident reporting systems and extracting relevant themes. In this study, retrieving incident data from the relevant bodies in the NHS, especially related to health IT, was not possible to develop the proposed AcciMap taxonomy. However, access to this data can help to further refine the current Medi-Socio AcciMap taxonomy as part of the iteration process in a future study (Goode *et al.*, 2018). Finally, while this thesis does not focus on the usability evaluation of the proposed approach, it was essential to develop a taxonomy guideline defining each sub-category or nano code (Appendix D-9).

5.10 Conclusion

This chapter details the processes in developing the proposed Medi-Socio AcciMap taxonomy to address the second research question on reliability and the third question on validity assessments. These included reviewing existing taxonomies and selecting specific contributing factors and adapting them for the proposed AcciMap approach. System categories associated with each AcciMap level were extracted from existing socio-technical models that focused on the relevant aspects (as well as IT-related categories), including organisational and external elements of healthcare systems. Sub-categories related to each system category were also obtained from existing taxonomies/classification schemes and relevant literature. The initial Medi-Socio AcciMap taxonomy was reviewed by several human factors and patient safety practitioners, and changes were applied where necessary. Given the limitations in developing and revising the Medi-Socio AcciMap taxonomy, it is essential to test this proposed approach with professional participants and measure how reliable their outcomes are. This study will be covered in Chapter Six (reliability assessment) to address the second research question. Chapter Seven (validity assessment) will compare their results with safety expert outcomes to focus on the third research question.

6.0 CHAPTER SIX: Evaluation of the Reliability of the Medi-Socio AcciMap Approach – NHS Patient Safety Practitioners

6.1 Introduction

This chapter focuses on the reliability assessment study relating to the second research question of the thesis on the evaluation of the Medi-Socio AcciMap taxonomy approach. The specific focus of this chapter is on the reliability assessment based on its application by a set of participants comprising of NHS patient safety and human factors specialists designated as **"Professionals"**. The professional group was also divided into two, where each subgroup applied the standardised and the Medi-Socio AcciMap approaches, respectively. Contributing factors, causal relationships, and safety recommendations were compared between professional participants from each subgroup. A quantitative measurement using the Index of Concordance was applied for qualitative analysis to assess both AcciMap approaches.

6.2 Reliability

6.2.1 Overview

As the term was defined earlier in Chapter One, the definition has been argued to be flawed and used interchangeably with another word, "consistency", particularly when taxonomic coding is involved (Kozlowski and Hattrup, 1992). The authors defined reliability instead as the ability of raters to agree on the code for each causal/contributing factor rather than just its application on average the same number of factors across the entire data set (Kozlowski and Hattrup, 1992). Furthermore, for any accident analysis approach to be considered reliable, "*it must produce data that are independent of the measuring event, instrument or person*" (Kassarjian, 1977). Reliability assessment of accident analytical approaches, according to Cornelissen *et al.* (2014), consists of different metrics, including the Index of Concordance (IoC), test-retest paradigm (Baysari, Caponecchia and McIntosh, 2011), and Pearson's correlation (Stanton and Young, 2003; Cornelissen *et al.*, 2014). Also, other reliability measurements include the signal detection paradigm (Goode *et al.*, 2017). Each of these measurements has its respective strengths and limitations (Appendix E-1), but for the reliability studies in this chapter and the proceeding

chapter, the Index of Concordance (IoC) was applied to obtain per cent agreement scores (%) for quantitative analysis.

6.2.2 Types of Reliability

Reliability studies involve different assessment methods for determining the accident analytical approach's reliability. There are generally two ways of evaluating the reliability of an accident analysis model; *Intra-analyst agreement* and *the Inter-analyst agreement,* described in the following subsections:

6.2.2.1 Intra-analyst Reliability

This type of assessment focuses on the ability of the accident analysis approach to produce consistent outcomes by the same analysts at different times or "*comparison between judgements made by the same judge when presented with the same data on different occasions*" (Ross, Wallace and Davies, 2004; Branford, 2007; McHugh, 2012; Goode *et al.*, 2017). Also, the results produced from applying an accident approach on the same incident may vary from time to time (Goode *et al.*, 2017).

6.2.2.2 Inter-analyst Reliability

This type of assessment focuses on the accident analysis approach's ability to produce similar or consistent results (outcomes) between multiple analysts simultaneously (Ross, Wallace and Davies, 2004; Branford, 2007; McHugh, 2012; Goode *et al.*, 2017). This point also indicates that the classification scheme of the proposed model is logically organised, and causes/contributing factors can be classified in the appropriate categories by different users (Goode *et al.*, 2017). These reliability agreements have been used to evaluate and test classification schemes/taxonomies (Branford, 2007; Goode *et al.*, 2017; Salmon *et al.*, 2017). However, inter-rater reliability measurement is more commonly implemented as it saves time and resources for having multiple participants analyse multiple incident reports (Goode *et al.*, 2017).

6.2.3 Reliability Assessment

The ability of accident analysis methods/models to produce consistent outcomes from multiple analysts and repeatable results over time are fundamental attributes (Branford, 2007; Goode *et al.*, 2017, 2018). Based on Branford's

research (2007), two approaches have been used to consider different aspects of the application of the AcciMap approach, and these are discussed below:

6.2.3.1 Qualitative Assessment

This type of assessment of the model's reliability involves judging its application on a single or several case studies (Branford, 2007). Different approaches have been used when qualitatively assessing an approach's reliability include the assessment of the Human Factors Investigation Tool (HFIT) (Gordon, Flin and Mearns, 2005) and REASON Root Cause Analysis (RCA) method (Branford, 2007). In applying the qualitative assessment, the focus will be to visually determine the reliability of outcomes from multiple users using both the standard and Medi-Socio approaches. This process is achieved by observing the causal maps produced, comparing, and contrasting themes regarding factors and safety recommendations (Markóczy and Goldberg, 1995). However, while qualitative assessments require making judgements regarding similarities and differences in results produced, it also introduces different forms of bias, including subjective and researcher bias (Branford, 2007). Therefore, this study requires the need for including quantitative assessment as was applied in Branford's AcciMap evaluation.

6.2.3.2 Quantitative Assessment

Quantitative assessment is another option that allows for statistical analysis of contributing factors (nodes), causal links, and safety recommendations produced based on ratings from multiple analysts (Branford, 2007). The focus of quantitative reliability assessment is on calculating the percentage of agreement between different analysts in classifying discrete events in the appropriate categories (Hruschka *et al.*, 2004; Branford, 2007; Goode *et al.*, 2017, 2018). This type of assessment involves creating a coding template regarding contributing factors, causal relationships, and safety recommendations that will be reliable for multiple coders rather than having each coder utilise their method (Miles and Huberman, 1994; Hruschka *et al.*, 2004). Thus, this quantitative assessment can provide a fuller picture of the reliability difference between the standard and Medi-Socio AcciMap approaches.

6.3 Research Methodology

6.3.1 Methods

Based on Branford's thesis, content analysis was considered the appropriate method for qualitative assessment of both AcciMap approaches. Content analysis involves textual analysis for comparing, contrasting, and categorizing data (Hignett and McDermottt, 2015). This process also consists of quantitative (counting the number of instances that fall in a category for statistical analysis) and qualitative (understanding and describing these categories in contributing to the adverse event) approaches (Krippendorf, 2004; Bengtsson, 2016). However, with the development of the Medi-Socio AcciMap taxonomy, its reliability will also need to be categorised and analysed for statistical purposes (Branford, 2007; Goode *et al.*, 2017; Stanton *et al.*, 2019).

This study involved clinical safety practitioners with experience in incident/accident analysis from the National Health Service (NHS), United Kingdom. Each participant invited has experience conducting incident investigations using different accident analytical approaches. The participants were familiar with the AcciMap methodology but had never applied it in their practice for incident investigations.

6.3.2 Participants

A total number of six (n = 6) participants took part in this study after an initial invite and consent forms (Appendix E-2) were provided through email and skype correspondence. Five of these professionals were based in various NHS practices in the United Kingdom (Scotland and England). One was established in Greece but had collaborations with the NHS on Pharmacovigilance. The professional participants were divided into two subgroups, each comprising three professionals (n = 3). Table 6-1 provides a summary for each participant based on their roles and responsibility.

Table 6-1: Summary of professional participants and years of experience

Participant	Role/Responsibility	Years of Experience (General)	Years of Experience (Healthcare)
1	Pharmacovigilance (National Organisation for Medicines (EOF), Greece)	4	3
2	Patient Safety Manager (National Health Service (NHS))	11	11
3	E-health Pharmacy Adviser/Clinical Safety Officer (National Health Service (NHS))	6	6
4	Associate Director of Service Improvement (National Health Service (NHS))	2	1
5	Clinical Research Registrar (National Health Service (NHS))	3	3
6	Accident Investigator (Health and Safety Investigation Branch (HSIB))	N/A	N/A
N/A – Not available			

6.3.3 Training Provided

Each participant was given the two case incident reports and AcciMap guidelines via email and Skype correspondence. Unfortunately, due to location and time constraints, training could not be organised with all participants simultaneously. Each session was organised with each participant through Skype, lasting between 45 minutes to 1 hour. Training materials included Branford's AcciMap guidelines and a worked example of applying the AcciMap and Medi-Socio approaches. The professional users were also provided with materials relating to the Medi-Socio AcciMap approach and its associated documentation of contributing factor codes.

6.3.4 Training Procedures

The concept of the standardised AcciMap approach was during the training session, including applying Branford's guidelines for AcciMap analysis. An example case incident used was based on the AcciMap analysis of the CPOE case study (Horsky, Kuperman and Patel, 2005) previously used in Chapter Four. The Medi-Socio approach was then introduced to them using its application on the same case incident. Finally, each professional participant was provided with the documentation guideline describing each system category and sub-categories. They had never applied classification schemes in their respective practices.

6.3.5 Data Collection and Analysis

After the training, each participant independently analysed the incident, produced their AcciMap outputs and safety recommendations, and sent them via email to the principal researcher. Any areas identified in their outcomes that were unclear regarding contributing factors (semantics) were communicated to participants to enable them to make any necessary changes. The results obtained from the analysis are qualitatively and quantitatively compared to determine the reliability of both AcciMap versions. Safety recommendations made are also compared and contrasted.

6.4 Case Incident Three - Synopsis

The reliability study involved using two case incidents. The first (case incident three) was a health IT-related incident involving a patient who was administered an overdose ($38^{1/2}$ times) of Septra at the University of California San Franciso (UCSF) teaching hospital (Wachter, 2015). Appendix E-3 provides the incident details, with additional information shown in Appendix E-4. This incident offers a context in which clinical IT systems/medical devices contributed to patients' adverse effects (overdose). For this incident, the EPIC system is a "*UCSF based, Medical Record System (EMR) and electronic health record (EHR) system which puts increased emphasis on patient safety and medical error prevention by creating one electronic patient chart that's accessible across the institution, increasing the continuity of care"* (University of California, 2018). An additional incident (Incident 4) for the reliability study related to a patient receiving a fatal dose of Vincristine led to death at the Queens Medical Centre, Nottingham (Toft, 2001). The professional participants (groups A and B) were provided with the incident details as part of their AcciMap analysis in applying the standardised and the Medi-Socio AcciMap approaches.

6.5 AcciMap Analysis

After the training session, the first analysis round involved both subgroups (professionals A and B) applying the standard AcciMap approach on the two incidents. The process was then repeated in the second round of AcciMap analysis. Each subgroup then applied the Medi-Socio AcciMap approach but reversed the incidents used in the first round (see table 6-2). This process was applied to allow each participant to understand the AcciMap approach in the

first round, learn from their experience, and apply it when using the Medi-Socio AcciMap approach. Also, the standardised and Medi-Socio AcciMap templates were designed and provided for them to implement their analysis. However, some participants used their software tool to develop their respective outcomes and submitted them as images (jpeg format).

Table 6-2: AcciMap analysis rounds involving professional participants

Analysis One	
Professionals	**Activity 1**
1st Subgroup (Professional A)	Standardised AcciMap approach (Incident 3)
2nd Subgroup (Professional B)	Standardised AcciMap approach (Incident 4)
Analysis Two	
Professionals	**Activity 2**
1st Subgroup (Professional A)	Medi-Socio AcciMap approach (Incident 4)
2nd Subgroup (Professional B)	Medi-Socio AcciMap approach (Incident 3)

After their analyses, participants developed their respective safety recommendations based on step 9 of Branford's training manual. Next, AcciMap results submitted were re-created using the Microsoft Visio application to provide a more consistent design theme for the qualitative comparative study. Finally, the professional participants forwarded their safety recommendations separately for content analysis.

6.6 Qualitative Assessment

Results from applying the standardised AcciMap and Medi-Socio AcciMap approaches on the incidents were analysed using content analysis to extract common themes based on coding instructions (Appendix E-5). The content analysis involved identifying and extracting themes regarding contributing factors from the application of both AcciMap approaches by the professional participants based on contributing factor nodes (Branford's AcciMap) and classified nodes (Medi-Socio AcciMap approach) identified (Branford, 2007). In addition, safety recommendation themes were also extracted from both sets of outcomes relating to the standardised AcciMap, and Medi-Socio AcciMap approaches. The criteria used to compare findings after the analysis rounds were

based on Branford's assessment of the standard AcciMap approach, which includes:

1.) Similar and different (unique) contributing factors identified by each participant.
2.) Similar causal relationships between similar causal/contributing factors identified by each participant.
3.) Similar safety recommendations developed by each participant.

As previously mentioned in the methodology section, a qualitative content analysis was applied by both the principal researcher and human factors specialist to minimise biases and, where applicable, make a consensus regarding the similarity of outcomes.

6.7 Qualitative Results - Application of the Standardised and Medi-Socio AcciMap approaches

Professional participants produced standardised and Medi-Socio AcciMap outcomes based on their respective AcciMap results (Appendices F-1 and F-2). The qualitative assessment of findings obtained from professionals is shown in figure 6-1 and table 6-3. The first subgroup (A) applying the standardised AcciMap approach identified twenty-five (n = 25) causal/contributing factors divided into eight common contributing factors (CCFs) (C1 – C8) and five individual contributing factors (ICFs) (C9 – C13) at the physical/actor level, five CCFs (C14 – C18), and five ICFs (C19 – C23) (see table 6-3). No common factors were identified at the external level, but two ICFs were identified (C24 – C25).

Table 6-3: Contributing factors (Septra overdose) from applying the standardised AcciMap approach by professional participants (A)

Code	Contributing Factor(s) Themes
Physical/Actor Events, Processes, and Conditions	
Common Contributing Factor (CCF)	
C1	Trust between Lucca and Chan from prior relationship leading to complacency
C2	Pharmacist (Chan) is overloaded (busy) and overwhelmed
C3	Staff (pharmacist and paediatrician) ignoring software warning messages
C4	The Pharmacy office is very busy and noisy
C5	The patient was on different and complicated medications
C6	The Pharmacist ignored the error alert (clicked out of the alert screen)
C7	Alert fatigue due to previous alerts clicked out (dismissed) without consequence
C8	Paediatrician incorrectly inputs a high Septra dose value under mg/kg instead of mg

Code	Contributing Factor(s) Themes	
Individual Contributing Factor (ICF)		
C9	The added complexity of weight-based dose calculations	**Professional – 1A**
C10	The patient has a rare medical condition	
C11	Pharmacist authorised incorrect dose	
C12	The nurse administered 38.5 tablets	**Professional – 2A**
C13	The patient accepted and took 38.5 tablets	
Organisational		
Common Contributing Factor (CCF)		
C14	All overdose warnings (alerts) on the EPIC software system looked similar and unclear	
C15	The EPIC software system was not built with maximum dosage limits regarding dosage orders	
C16	The decision to impose weight-based dosing for children (<40kg) causing complications	
C17	The design of the alert screen was inefficient (poor design of error alert)	
C18	Translation of weight-based doses into pills (tablets) requiring confirmation	
Individual Contributing Factor (ICF)		
C19	The system allows ordering in mg and mg/kg	**Professional – 1A**
C20	Poor design of satellite pharmacy office – inadequate space, noisy, cluttered environment	
C21	There are many drug alerts	
C22	Tablets need to be ordered in mg (Not mg/kg)	**Professional – 2A**
C23	Screen for mg/kg not distinguished from the screen in mg only	
External		
Individual Contributing Factor (ICF)		
C24	EPIC and First Databank designed system and created rules that govern UCSF's alerts (no alert for mode – mg or mg/kg)	**Professional – 1A**
C25	Problems with previous software provider	**Professional – 2A**

The second group B of professionals, based on their application of the Medi-Socio AcciMap taxonomy, identified twenty-seven (n = 27) causal/contributing factors with seven CCFs (C1 – C7) and five ICFs (C8 – C12) at the physical/actor level. Three CCFs (C3, C6, and C7) identified from applying the Medi-Socio AcciMap approach were also found using the standardised AcciMap version. At the organisational level, they identified two CCFs (C13 – C14) and twelve ICFs (C15 – C26) (technical/operational and management levels) (see table 6-4). Only one ICF (C27) was identified at the external level.

Table 6-4: Contributing factors (Septra overdose) identified from applying the Medi-Socio AcciMap approach by professional participants (B)

Code	Contributing Factor(s) Themes	
Physical/Actor Events, Processes, and Conditions		
Commonly Contributing factor (CCF)		
C1	The nurse (Levitt) administers a wrong (high dose) order	
C2	Pharmacist (Chan) accepting an incorrect order	
C3	***Trust between Lucca and Chan from prior relationship leading to complacency in administering the dose – (C1)***	
C4	The dose order was returned as the variance was above 5%	
C5	The physician (Lucca) incorrectly amends the dosage order wrongly	
C6	***The Pharmacy office is very busy and noisy – (C4)***	
C7	***Pharmacist (Chan) is overloaded (busy) and overwhelmed – (C2)***	
Individually Contributing factor (ICF)		
C8	The patient received 15 different medications	**Professional – 1B**
C9	Admission process without Pharmacy	
C10	Doctor unfamiliar with paper prescribing	
C11	Existing relationship of trust between Physician and Pharmacist	**Professional – 2B**
C12	The physician made a first incorrect order	**Professional – 3B**
Organisational Level - Technical & Operational Management		
Common Contributing Factor (CCF)		
C13	Dosage calculation based on the weight of patients	
C14	Mode error relating to lack of feedback from the EPIC System on default settings	
Individual Contributing Factor (ICF)		
C15	Paper-based prescription in community	**Professional – 1B**
C16	Order entry module - Intelligence	
C17	Insufficient process for correcting incorrect drug dose entries	**Professional – 2B**
C18	The pharmacist receives multiple alerts from the EPIC system producing cognitive overload	
C19	Drug ordering screen calculated dose above available tablet strength	
C20	EPIC system – design of information screens poor. No visual clues to aid medical staff	
C21	Alert sign of the program was not the appropriate one	**Professional – 3B**
Organisational Level - Health Management		
Individual Contributing Factor (ICF)		
C22	The interface between care providers	**Professional – 1B**
C23	A poor decision relating to setting dosage limits in the system	**Professional – 2B**
C24	Implementation committee decision for weight-based dosing fo children < 40kg	
C25	EPIC – design and test policies and procedures	
C26	UCSF Management decided not to switch units on the dose of th program	**Professional – 3B**
External		
Individual Contributing Factor (ICF)		
C27	EPIC dose limits	**Professional – 1B**

6.7.1 Causal/Contributing Factors – Similarities and Variations

Based on the content analysis of factors identified after applying both AcciMap approaches, the summary of causal/contributing factors is designated as Common Contributing Factors (CCF) for each AcciMap level. Thus, tables 6-5 and 6-6 are based on the standardised AcciMap approach, and tables 6-7 and 6-8 are based on the Medi-Socio AcciMap taxonomy version.

Table 6-5: Matrix of CCFs identified by professional participants (A) from applying the standardised AcciMap approach – Physical/Actor-Process level

Code	Professional-1A	Professional-2A	Professional-3A
Common Contributing Factors (CCFs)			
Physical/Actor Events, Processes, and Conditions			
C1	X		
C2	X		
C3			
C4			
C5		X	
C6			
C7			X
C8		X	

KEY - Common Contributing Factor Theme	
C1	Trust between Lucca and Chan from prior relationship leading to complacency in administering the dose
C2	Pharmacist (Chan) is overloaded (busy) and overwhelmed
C3	Staff (Chan and Lucca) ignoring software warning messages
C4	The Pharmacy office is very busy and noisy
C5	The patient was on different and complicated medications
C6	The pharmacist ignored the error alert (clicked out of the alert screen)
C7	Alert fatigue due to previous alerts clicked out without consequence
C8	The paediatrician incorrectly inputs a high Septra dose value under mg/kg instead of mg

Table 6-6: Matrix of CCFs identified by professional participants (A) from applying the standardised AcciMap approach – Organisational and External levels

Code	Professional-1A	Professional-2A	Professional-3A
Common Contributing Factors (CCFs)			
Organisational			
C14			
C15			
C16			X
C17			X
C18	X		
External			
No Contributing factors identified			

KEY - Common Contributing Factor Theme	
C14	All overdose warnings (alerts) on the EPIC software system look similar and unclear
C15	The EPIC software system was not built with maximum dosage limits for dosage orders
C16	The design of the alert screen was inefficient (poor design of error alert)
C17	The decision to impose weight-based dosing for children (<40kg) causing complications
C18	Translation of weight-based doses into pills (tablets) requiring confirmation

Table 6-7: Matrix of CCFs identified by professional participants (B) from applying the Medi-Socio AcciMap approach – Physical/Actor-Process level

Code	Professional-1B	Professional-2B	Professional-3B
Common Contributing Factors (CCF)			
Physical Actor Events, Processes, and Conditions			
C1	X	P-SI3	P-SI7
C2	P-SI3	P-SI3	P-SI3
C3	X	P-SI6	P-SI6
C4	X	P-ST2	P-SI3
C5	X	P-SI3	P-SI6
C6	X	P-EN1	P-EN0
C7	P-EN5	P-EN5	P-EN3

KEY - Common Contributing Factor Theme	
C1	The nurse (Levitt) administers a wrong (high dose) order
C2	Pharmacist (Chan) accepting an incorrect order
C3	Trust between Lucca and Chan from prior relationship leading to complacency in administering the dose
C4	The dose order was returned as the variance was above 5%
C5	The physician (Lucca) incorrectly amends the dosage order wrongly
C6	The Pharmacy office is very busy and noisy
C7	Pharmacist (Chan) is overloaded (busy) and overwhelmed

Table 6-8: Matrix of CCFs identified by professional participants (B) from applying the Medi-Socio AcciMap approach – Organisational level

Code	Professional-1B	Professional-2B	Professional-3B
Common Contributing Factors (CCF)			
Organisational (Technical/Operational Management and Health Management)			
C13	O-IT2	O-IT2	X
C14	O-IT1	O-HC1	X
External			
No common contributing factors identified			

KEY - Common Contributing Factor Theme	
C13	Dosage calculation based on the weight of patients
C14	Mode error relating to lack of feedback from the EPIC System on default settings

The following subsections will elaborate further on the identification of CCFs and indicate each professional participant's individual contributing factors (ICFs).

6.7.1.1 Physical Actors, Events, Processes, and Conditions Level

Based on the application of Branford's AcciMap approach, out of the eight common contributing factors (CCFs) identified, all professional participants identified only three factors. These include C3 ("*staff ignoring software messages*"), C4 ("*the pharmacy office being very busy and noisy*") and C6 ("*the pharmacist ignoring an error alert*"). Two out of the three professionals identified the remaining common factors (C1, C2, C5, C7, C8) (see figure 6-1).

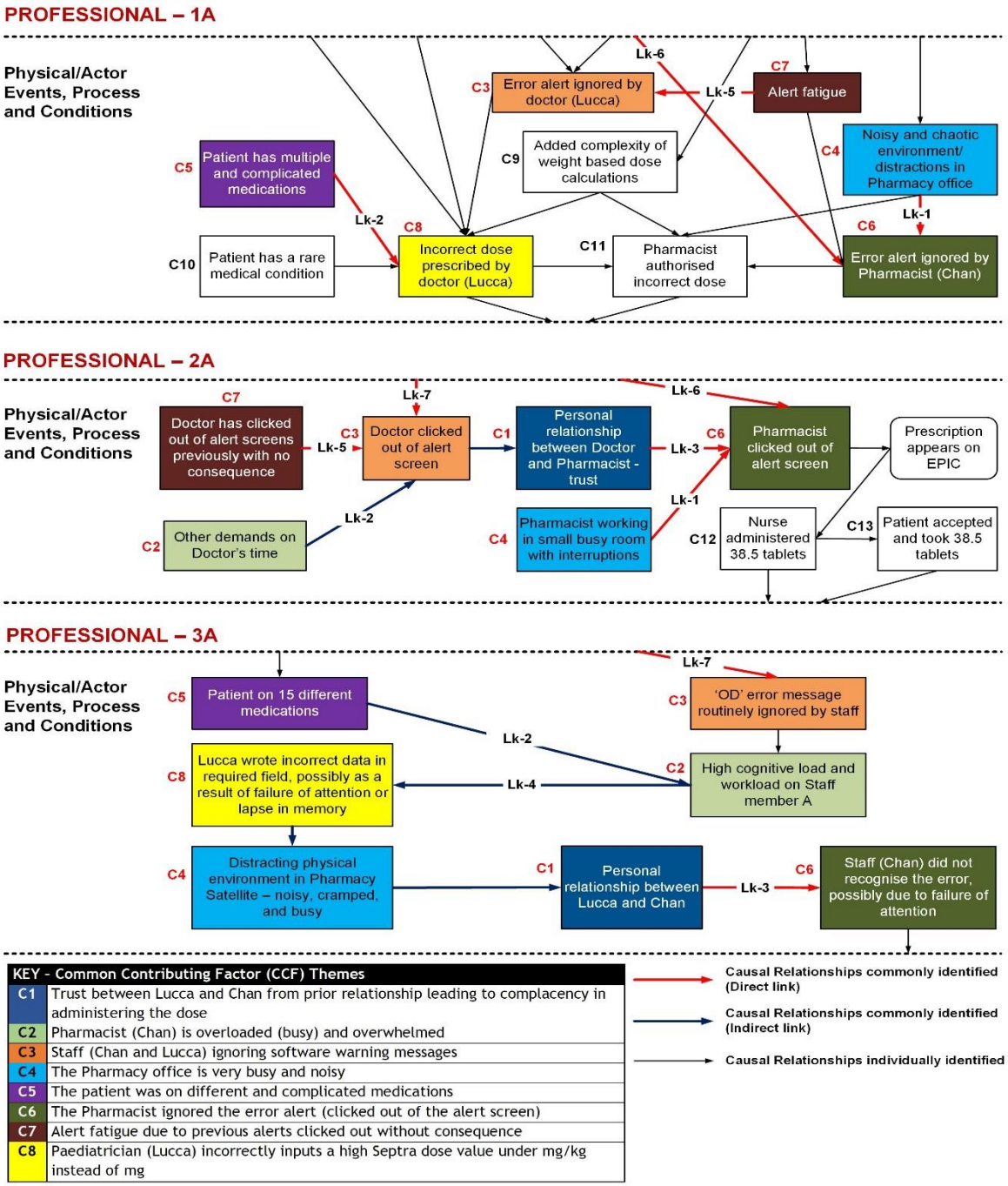


Figure 6-1: Comparison of contributing factors at the Physical/Actor and Process level using the Standardised AcciMap approach - Professional participants (A)

On the application of the Medi-Socio AcciMap approach, all professionals identified common factors relating to "*the pharmacist accepting an incorrect dosage order*" (C2) and "*the pharmacist being very busy*" (C7). From these factors, C2 was classified under the same sub-category (P-SI3: *unsafe acts*) and two out of three professionals classified C7 in the same sub-category (P-EN5: *time pressure*). Two out of three professionals identified the remaining 5 CCFs (C1, C3, C4, C5, and C6). However, each factor was classified under different sub-categories (figure 6-2).

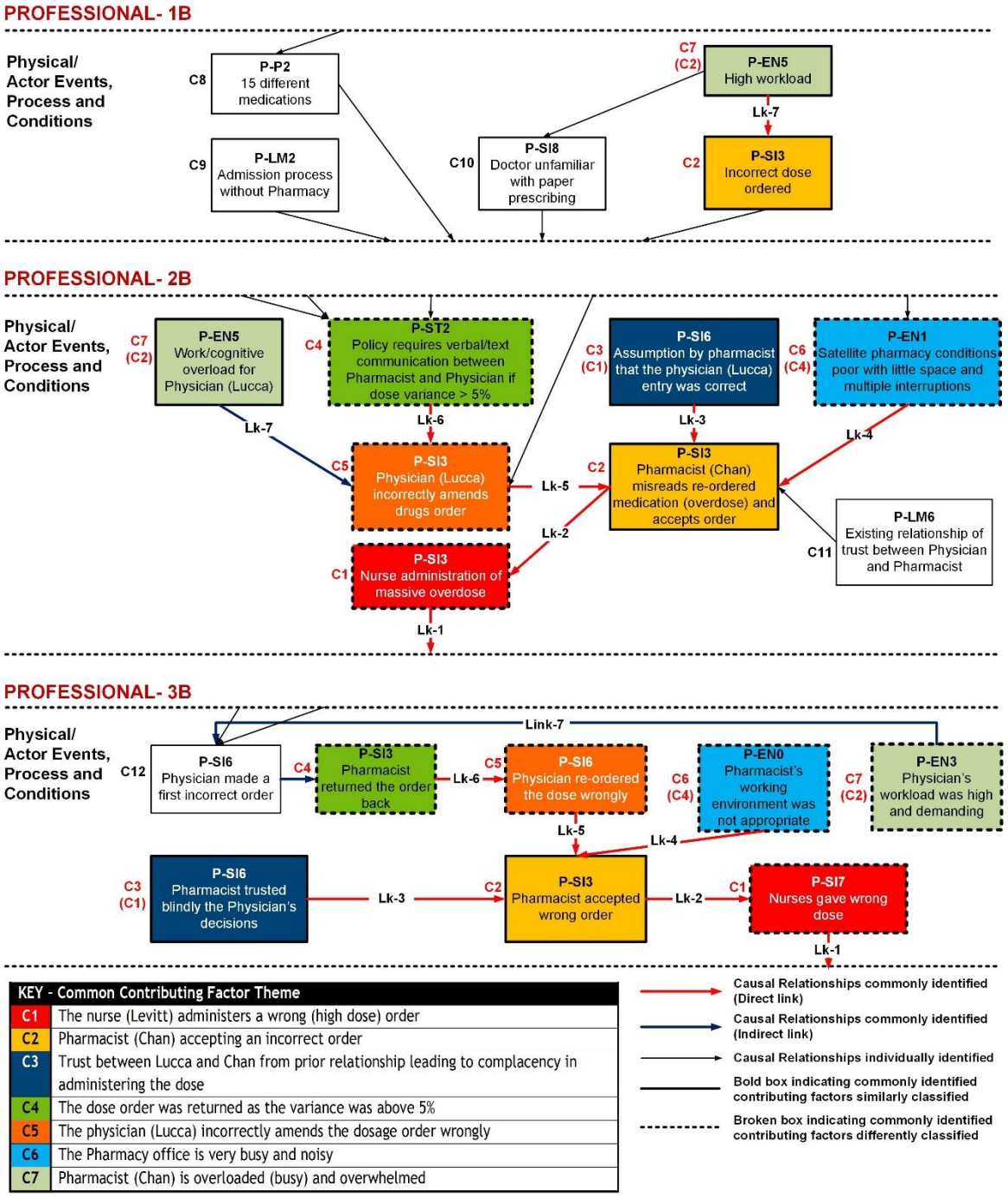


Figure 6-2: Comparison of contributing factors at the Physical/Actor and Process level using the Medi-Socio AcciMap approach - Professional participants (B)

6.7.1.2 Organisational Level

At this level, based on the summary of CCFs and ICFs from table 6-3 and the contributing factor matrix (table 6-6), CCFs identified by all three professionals were factors C14 ("*similarity of overdose alerts*") and C15 ("*the EPIC software not incorporating a maximum dose limit*"). The latter CCF identified by professional three was placed at the external level instead of the organisational level (indicated as a red bolded box). The other CCFs, C16 ("*weight-dosage*

policy for children causing complications"), C17 ("*the design of the error alert*"), and C18 ("*translation of weight-based doses to pills creating a risk*") was identified by two out of three professionals (see figure 6-3).

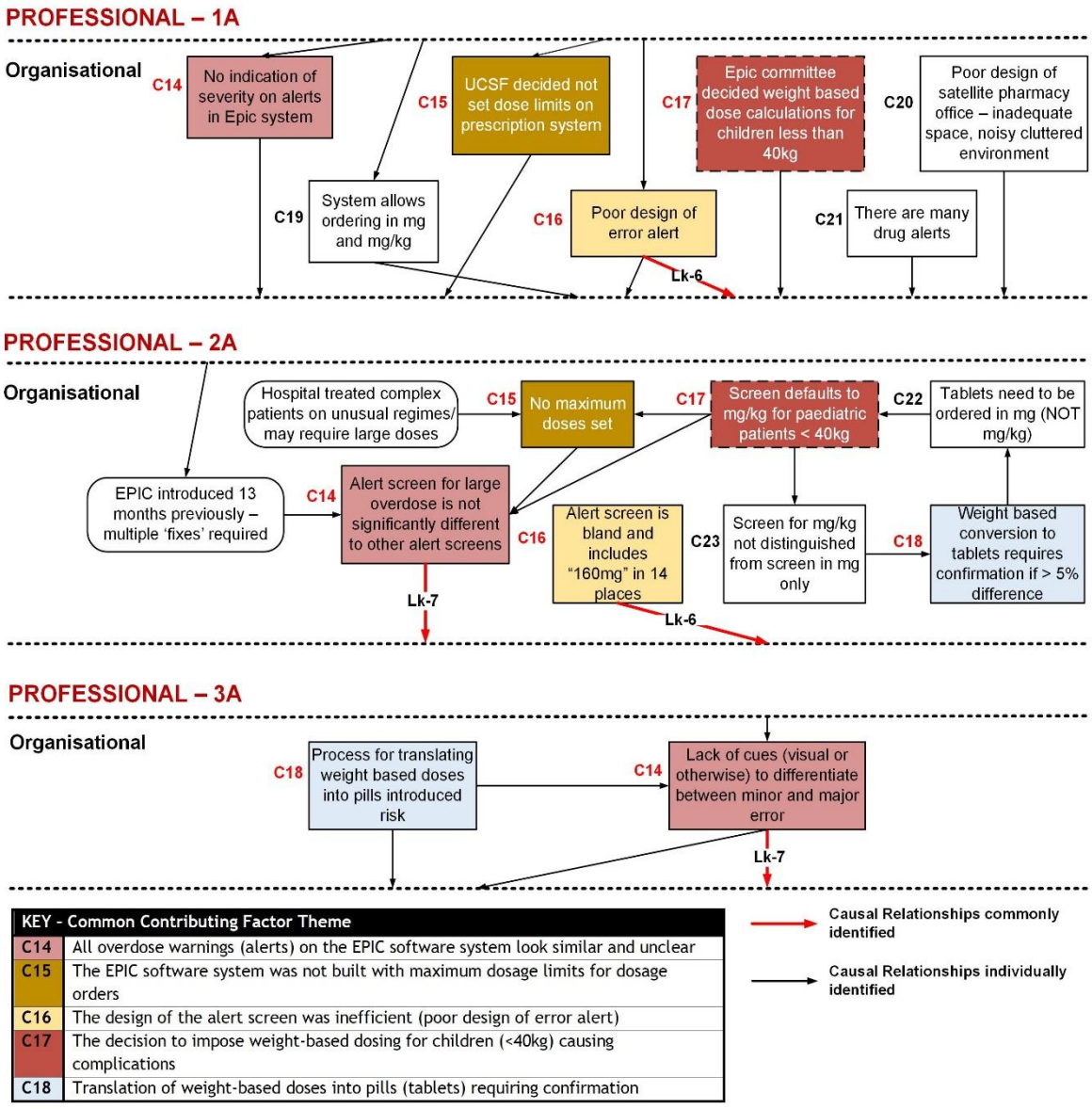


Figure 6-3: Comparison of contributing factors at the Organisational level using the Standardised AcciMap approach - Professional participants (A)

From applying the Medi-Socio AcciMap approach, two CCFs were identified with the only factor relating to C13 ("*dosage calculation based on patient's weight*") classified under the same sub-category (O-IT2: "software-configuration") by professionals 1B and 2B (see table 6-8). The remaining CCF C14 ("*lack of feedback from the EPIC system regarding its default settings*") were identified by professionals 1B and 2B. However, this factor (C14) was classified under

different sub-categories relating to O-HC1 (“*usability-information display/interpretation*”) and O-IT1 (“*software-functionality*”) (see figure 6-4).

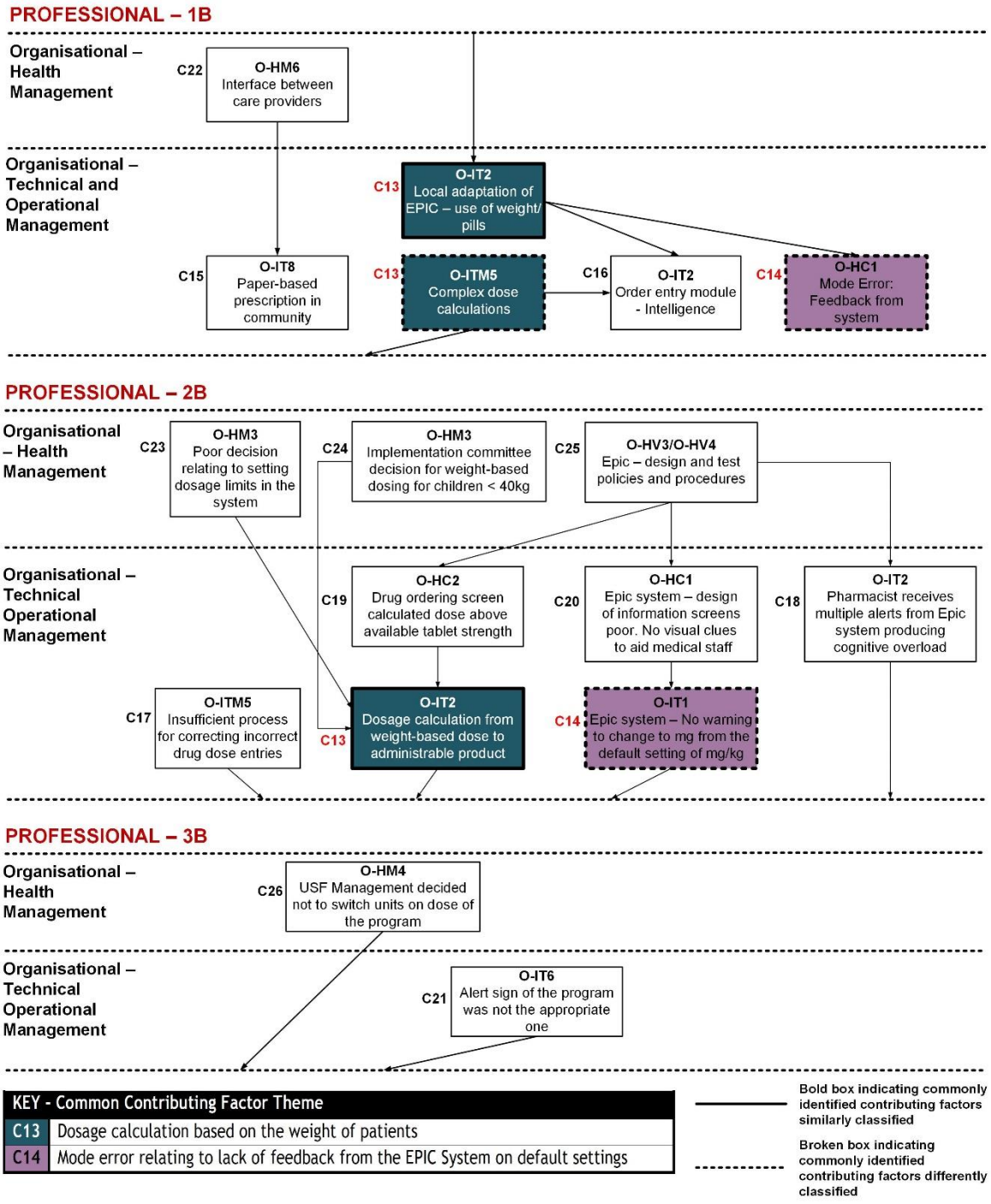


Figure 6-4: Comparison of contributing factors at the Organisational level using the Medi-Socio AcciMap approach - Professional participants (B)

6.7.1.3 External Level

There were no similarities to be determined after applying the standard and proposed AcciMap approaches at this level (see figure 6.5). Professional participants identified different factors using the standardised AcciMap. The only

factor identified by professional 3A at the external level was designated as a CCF (C15) regarding mode error of the EPIC software system. The second subgroup placed no factors at the external level after using the Medi-Socio AcciMap taxonomy approach.

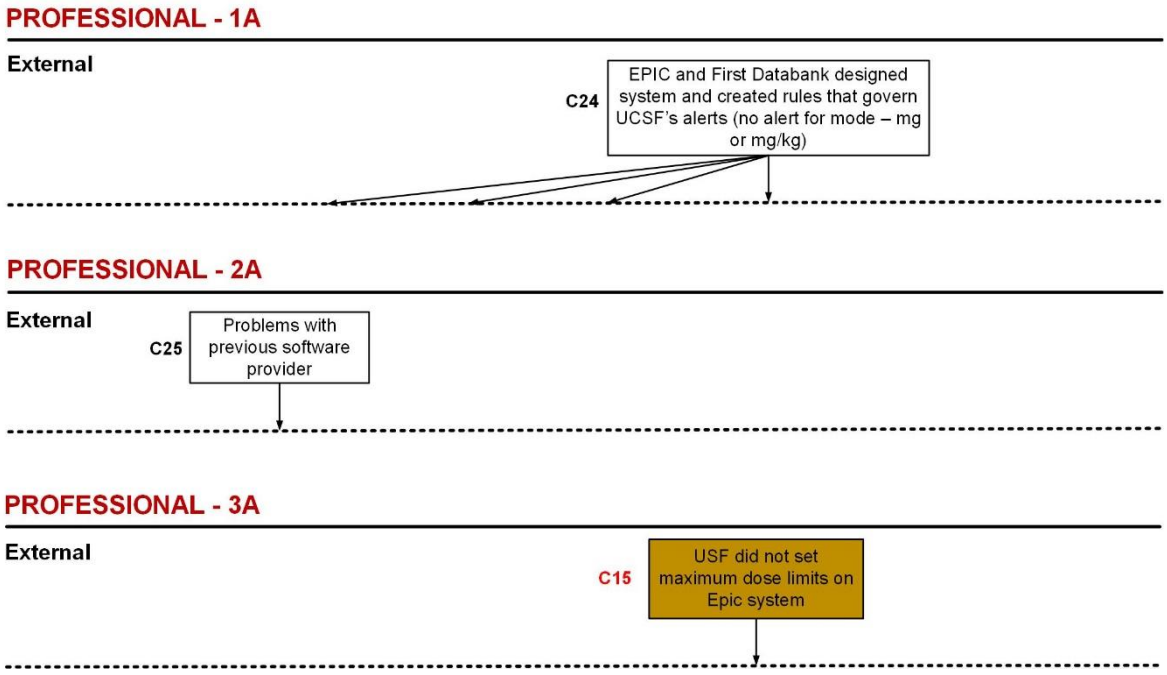


Figure 6-5: Comparison of contributing factors at the External level using the standardised AcciMap approach - Professional participants (A)

6.7.2 Causal Relationships (Links) – Similarities

Causal relationships between factors (CCFs) (marked as **red bolded** arrows indicating direct links and **blue bolded** arrows meaning indirect links from previous figures) within and between different AcciMap levels were identified and summarised based on the application of the standardised and Medi-Socio AcciMap taxonomy approaches (table 6-9). Based on the application of the standardised AcciMap, five causal links (greyed links indicate indirect causal relationships) within the physical/actor level. The relationship (Link-1) was the only link identified by all professional (A) users, which relates to the pharmacist clicking or "*ignoring error alerts (C4) due to the busyness, multiple activities, and distractions in his working environment (C6)*". Two professional participants identified the other two links (Link-6 (1, 2) and Link-7 (2, 3)) between the physical and organisational AcciMap levels. These links focused on the "*poor design of the alert screen (C19) leading to the pharmacist ignoring the error*

alert (C6)" and "*the lack of severity levels from the alerts (C18) leading to the paediatrician also ignoring warning alerts (C3)*". No other links were similarly identified within and between both organisational and external levels.

Table 6-9: Causal relationships (links) identified from the Septra overdose incident from applying both AcciMap approaches

Branford's AcciMap Approach		
Link Code	**Causal Relationships similarly Identified**	**Professional (A)**
Physical/Actor Events, Process, and Conditions		
Link-1	A causal relationship between contributing factors **C4** and **C6** *(contained intermediate factors between C4 and C6)*	1,2,3
Link-2	A causal relationship between contributing factors **C5** and **C8** *(contained intermediate factors between C5 and C8)*	1,3
Link-3	A causal relationship between contributing factors **C1** and **C6**	2,3
Link-4	A causal relationship between contributing factors **C3** and **C1** *(contained intermediate factors between C3 and C1)*	2,3
Link-5	A causal relationship between contributing factors **C7** and **C3**	1,3
Organisational		
Link-6	A causal relationship between contributing factors **C16** and **C6**	1,2
Link-7	A causal relationship between contributing factors **C14** and **C3**	2,3
Medi-Socio AcciMap Approach		
Link Code	**Causal Relationships similarly Identified**	**Professional (B)**
Physical/Actor Events, Process, and Conditions		
Link-1	A causal relationship between contributing factor **C1** and **outcome(s)**	2,3
Link-2	A causal relationship between contributing factors **C2** and **C1**	2,3
Link-3	A causal relationship between contributing factors **C3** and **C2**	2,3
Link-4	A causal relationship between contributing factors **C6** and **C2**	2,3
Link-5	A causal relationship between contributing factors **C5** and **C2**	2,3
Link-6	A causal relationship between contributing factors **C4** and **C5**	2,3
Link-7	A causal relationship between contributing factors **C7** and **C2** *(contained an intermediate factor between C7 and C2)*	1,2,3
Organisational (Technical & Operational and Health Management)		
	No similar causal relationships identified	

The second subgroup identified seven causal relationships within the physical/actor level after applying the Medi-Socio AcciMap version. Professionals 2 and 3 indicated similarities regarding all the relationships except for Link-7, which was similarly recognised by all the professionals (B). From the observation of the AcciMap results after qualitative content analysis, causal relationships between CCFs were virtually identical between professionals 2 and 3 at the

physical actor/process level. Other links that were not common were very few and were linked from the preceding AcciMap level (between levels rather than within each level). There were no other relationships identified at both the organisational and external levels that were similar.

6.7.3 Comparison of Safety Recommendations

Each subgroup also produced safety recommendations based on their application of both AcciMap approaches (Appendix F-3). Their safety measures were also qualitatively compared to determine themes using content analysis, with each recommendation theme designated as "Pr-R" (Professional – Recommendation) (see table 6-10). From the observation of safety measures from the first professional subgroup, there was higher reliability in safety recommendations after applying the standardised AcciMap than using the Medi-Socio AcciMap approach (see table 6-11). The only safety recommendation identified based on both AcciMap versions was Pr-R1 regarding reviewing the EPIC system's interface for data entry and introducing severity levels as applied to alerts.

Table 6-10: Safety recommendation themes based on the Septra overdose analysis after applying both AcciMap approaches by professional participants

Code	Safety Recommendation Themes	Parties Responsible
Standardised and Medi-Socio AcciMap approaches		
Pr-R1	Reviewing the EPIC software system to improve the design of alerts based on severity levels, system interfaces for data entry.	Hospital Management
Pr-R2	Reviewing of the EPIC software system to incorporate a maximum dose limit when administering drug medication	UCSF, Hospital Management
Pr-R3	Reviewing of the EPIC software system to incorporate clearly defined default settings regarding dosage units (e.g., mg/kg)	UCSF, Hospital Management
Pr-R4	Improving the working environment by the reduction of staff workload (tasks and responsibilities) and augmenting staff personnel (Pharmacy department) to prevent human error	Hospital Management
Pr-R5	Implementation of policies to encourage medical staff to challenge medication doses.	Hospital Management

Table 6-11: Summary of safety recommendations from applying of both AcciMap approaches by professional participants

Code	Safety Recommendation Themes	Professional (A)	Professional (B)
Standardised & Medi-Socio AcciMap Approaches			
Pr-R1	Reviewing of the EPIC software system in improving the design of alerts based on severity levels, system interfaces for data entry	1,2	1,2,3
Pr-R2	**Reviewing of the EPIC software system to incorporate a maximum dose limit when administering drug medication**	1,2,3	None
Pr-R3	**Reviewing of the EPIC software system to incorporate clearly defined default settings regarding dosage units (e.g., mg/kg)**	1,2	None
Pr-R4	**Improving the working environment by the reduction of staff workload (tasks and responsibilities) and augmenting staff personnel (Pharmacy department) to prevent human error**	1,2,3	None
Pr-R5	**Implementation of policies encouraging medical staff to challenge medication doses**	None	2,3
• Identified using the **Standardised AcciMap** approach only • Identified using the **Medi-Socio AcciMap** approach only			

Safety recommendation themes Pr-R2, Pr-R3, and Pr-R4 were formulated based on the use of the standardised AcciMap approach, while Pr-R1 and Pr-R5 were developed after applying the Medi-Socio AcciMap approach. However, regarding the safety recommendation theme (Pr-R1), only two out of the three professionals (A) indicated it while all three professionals (B) indicated this recommendation. Based on the qualitative assessment of both AcciMap approaches, the standardised AcciMap version was also visually more reliable than the Medi-Socio AcciMap version. The following subsection will quantify these results to obtain numeric values for each aspect of analyses in comparing both AcciMap approaches.

6.8 Quantitative Assessment

Quantitative measurements for analysing the reliability of outcomes produced after applying both AcciMap approaches after the qualitative assessment will provide a complete picture of the reliability regarding the Medi-Socio AcciMap approach. The coding rules (see Appendix E-6) used to code responses from professional participants as part of content analysis were mainly adapted from Branford (2007) and Goode *et al.* (2017) studies. These rules for both the standard and Medi-Socio AcciMap approaches were used to rate outcomes

produced relating to causal/contributing factors, causal relationships (links), and safety recommendations. The summary of the coding rules are:

1.) For any causal/contributing factor similarly identified between pairs (**Y:1**), partially identified between pairs (**1/2:0.5**), and not identified between pairs (**N:0**) (**Standardised AcciMap version**)
2.) For causal links and safety recommendations similarly identified between pairs of participants (**Y:1**) and not identified between pairs (**N:0**). (**Standardised and Medi-Socio AcciMap versions**)
3.) For any contributing factor classified in the same sub-category similarly identified between two pairs (**Y:1**), partially identified in the case of contributing factor identified similarly but classified under a different sub-category (**1/2:0.5**) and not identified between pairs (**N:0**). (**Medi-Socio AcciMap version**)

To achieve this process, two coders (principal researcher and a human factors specialist with Health Safety Investigation Branch (HSIB)) independently analysed the results to determine "agreements" and "disagreements" regarding causal factors, safety recommendations, and causal links. The purpose of using two coders (raters) was to reduce cognitive bias (e.g., subjective bias) and produce an agreed set of outcomes for further pair comparative analysis (Branford, 2007). The AcciMap results from professionals are compared in pairs of two. Since the participants were divided into two subgroups (three professionals per subgroup), the pairings for professionals constitute three pairs (AB, AC, and BC). Any items with disagreements regarding the three aspects of measurement were discussed, and a mutual consensus was reached regarding actual values.

Earlier in this chapter, different reliability metrics were introduced (Appendix E-1), where each approach has its respective strengths and weaknesses. The measurement chosen for the quantitative analysis is the Index of Concordance (IoC), which is one of the most commonly used statistical measurements for determining the per cent agreement rates regarding a tool of analysis (Olsen, 2011; Goode *et al.*, 2017). However, the limitation of this technique is that it does not account for "chance agreement" between multiple analysts (Landis and Koch, 1977; Branford, 2007). Another limitation of the IoC measurement is its overestimation of levels of agreement. A more stringent measurement option for

analysing classified data is Kappa's statistics, which considers *"chance agreement"* (Landis and Koch, 1977). This statistical technique can be applied to coding results between two raters (Cohen's Kappa) (Cohen, 1968) or multiple raters (Fleiss' Kappa) (Fleiss, 1971). Other options include Krippendorff's alpha which also takes chance agreement into account. The chance agreement essentially constitutes a situation where two or more independent coders select or classify an item based on a finite set of options and may agree by chance. In this instance, when applying the IoC measurement, the focus was on determining similarly identified factors between participants rather than if that factor was similarly "classified" (same sub-category) between users. These reliability measurements have a range of values indicating a tool's reliability, as shown in table 6-12. Table 6-13 shows the breakdown of the degree of agreement (kappa's statistics).

Table 6-12: Measures of reliability and associated values (Cohen, 2017)

Per cent Agreement		**Cohen's Kappa (K)/Fleiss' Kappa (K_F)**		**Krippendorff's Alpha (α)**		**Free-marginal Multi-rater Kappa ($K_{[free]}$)**	
Value	**Conclusion**	**Value**	**Conclusion**	**Value**	**Conclusion**	**Value**	**Conclusion**
70 - 100%	Reliable	> 0.80	Reliable	0.80 – 1.0	Reliable	> 0.80	Reliable
60% - 70%	Moderately Reliable	0.60 – 0.80	Substantially Reliable	0.667- 0.80	Tentatively Reliable	0.60 – 0.80	Substantially Reliable
0 – 60%	Unreliable	0.40 – 0.60	Moderately Reliable	0 – 0.667	Unreliable	0.40 – 0.60	Moderately Reliable

Table 6-13: Levels of Agreement using Cohen's Kappa Coefficients (Landis and Koch, 1977)

Cohen's Kappa	Degree of Agreement
< 0.20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Good
0.81 – 1.00	Very good

However, to compare reliability scores between both AcciMap approaches, the index of concordance metric was applied to both AcciMap approaches. The reason is that using an alternative measurement like kappa's statistics is only applicable to the Medi-Socio AcciMap approach, especially when analysing the reliability of contributing factors relating to classifying factors in the sub-

categories. The only instance where Kappa's statistics could be applied will be when considering the placement of contributing factors at AcciMap levels rather than their identification. While IoC offers a more simplistic approach in determining agreement and not taking "chance" into account, Ross *et al*. (2004) and Martin and Bateson (1993) argued that the use of this metric is considered an appropriate approach for calculating intercoder consensus. They cited benefits, including avoiding criticisms relating to Kappa's statistical measurement and agreement for each code being individualistic rather than agreeing on the code set (taxonomy) (Martin and Bateson, 1993; Ross, Wallace and Davies, 2004).

Finally, based on the "agreed ratings", the IoC metric was applied to calculate the reliability scores. The formula constitutes the *total number of "agreements"* divided by *the number of "agreements" and "disagreements"* (Appendix E-1). However, in using this formula, "partial agreements" (e.g., where the second participant partially identifies a factor identified by one participant) was considered to produce the actual reliability scores. Therefore, in calculating the scores, values were assigned for "agreement" (1), "partial agreement" (0.5) and "disagreement" (0).

6.9 Quantitative Results

The summary of reliability scores based on the application of both AcciMap approaches by the professional participants after applying the reliability coding procedures (Appendix E-6) are summarised in the following subsections.

6.9.1 Contributing Factors Results

Reliability scores using the IoC metric for contributing factors identified by professional participants are shown in tables 6-14 (standardised AcciMap version) and 6-15 (Medi-Socio AcciMap version), respectively. The mean reliability score based on the application of the standardised AcciMap resulted in 39%. In contrast, for the Medi-Socio AcciMap taxonomy, the result was 26% (34% regarding contributing factors not associated with sub-categories).

Table 6-14: Reliability scores of causal/contributing factors between professional participants (A) (n = 3) - Standardised AcciMap approach

Professional Pairing	Reliability Score (IoC) %
A and B	38%
A and C	41%
Mean Reliability	**40%**
B and C	38%
Grand Mean Reliability	**39%**

Table 6-15: Reliability scores of causal/contributing factors between professional participants (B) (n = 3) - Medi-Socio AcciMap approach

Professional Pairing	Reliability Score (IoC) % (Associated codes)	Reliability Score (IoC) % (No associated codes)
A and B	33%	38%
A and C	13%	17%
Mean Reliability	**23%**	**27%**
B and C	29%	41%
Grand Mean Reliability	**26%**	**34%**

6.9.2 Causal Relationship Results

Causal links identified between pairs of professional participants using the standardised AcciMap and Medi-Socio AcciMap versions are summarised in tables 6-16 and 6-17. The mean reliability scores resulted in the grand mean reliability score of 16% against the 26% score from applying the Medi-Socio AcciMap approach.

Table 6-16: Reliability scores of causal relationships (links) between professional participants (A) (n = 3) - Standardised AcciMap approach

Professional Pairing	Reliability Score (IoC) %
A and B	12%
A and C	28%
Mean Reliability	**20%**
A and E	12%
Grand Mean Reliability	**16%**

Table 6-17: Reliability scores of causal relationships (links) between professional participants (B) (n = 3) - Medi-Socio AcciMap approach

Professional Pairing	Reliability Score (IoC) % - Taxonomy
A and B	33%
A and C	13%
Mean Reliability	**23%**
B and C	29%
Grand Mean Reliability	**26%**

6.9.3 Safety Recommendation Results

Tables 6-18 and 6-19 summarise reliability scores regarding the safety recommendations produced using both AcciMap approaches. The grand mean reliability score of the standardised AcciMap resulted in 73%, with the Medi-Socio AcciMap approach having 45%.

Table 6-18: Reliability scores of safety recommendations between professional participants (A) (n = 3) - Standardised AcciMap approach

Professional Pairing	Reliability Score (IoC) %
A and B	100%
A and C	50%
Mean Reliability	**75%**
B and C	71%
Grand Mean Reliability	**73%**

Table 6-19: Reliability scores of safety recommendations between professional participants (B) (n = 3) - Medi-Socio AcciMap approach

Professional Pairing	Reliability Score (IoC) % - Taxonomy
A and B	100%
A and C	0%
Mean Reliability	**50%**
B and C	40%
Grand Mean Reliability	**45%**

6.10 Discussion

6.10.1 Comparison of Outcomes

Both qualitative and quantitative results from this reliability study involving professional participants indicated that despite the inclusion of the taxonomy, the reliability scores from applying the Medi-Socio AcciMap approach was less than the standardised AcciMap counterpart. A comparison between subgroups of professionals was also carried out to examine similarities and variations. The following subsections discuss the results from the reliability study.

6.10.1.1 Reliability – Causal/Contributing Factors

Associated codes with contributing factors identified using the Medi-Socio AcciMap approach indicated that the outcomes were less reliable than Branford's AcciMap version. At the physical/actor level, two out of three professionals (A) identified eight CCFs, where three (C3, C4, and C6) out of the CCFs were recognised by all professionals A. This observation indicated a higher reliability outcome compared to the results of the Medi-Socio AcciMap (professional subgroup B). However, visual observation of CCFs (C1 – C8) based on professional subgroup B's results at the physical/actor-level indicated that professionals 2B and 3B particularly have almost identical outputs in the CCFs identified. However, these factors were classified under different sub-categories. From these factors, only one out of the remaining six CCFs (excluding the CCF identified by all three professionals B) was categorised under the same sub-category (P-SI6 – *Judgement and Decision making*).

At the organisational level, the outcomes from subgroup A (standardised AcciMap) indicated that all three professionals identified two out of five CCFs except for CCFs (C16, C17, and C18) by two out of three professionals. For the second group B (Medi-Socio AcciMap), only two identified CCFs (C13 and C14) were identified by only two professionals, but only one was classified under the same category (O-IT2 – Software configuration). At the external level, no CCFs were identified from applying both AcciMap approaches by both professional subgroups. However, a CCF that was an organisational related factor (C15 – "*The EPIC software system was not built with maximum dosage limits regarding dosage orders*") was identified by professional 3A at that level based on the standardised AcciMap approach. From the quantitative results, the reliability

scores (IoC) from the use of the standardised AcciMap version was higher (39%) than the Medi-Socio AcciMap approach (26% with associated codes and 34% without the associated codes). The reliability result (Medi-Socio AcciMap) can be attributed partly to the outcome produced by professional 1B using the proposed approach. Aside from the two CCFs identified with the other professionals, the remaining ICFs (Individual Contributing factors) did not provide enough context, making coding the data (text) challenging.

6.10.1.2 Reliability – Causal Relationships/Links

From the quantitative results, the reliability score was higher based on the application of Medi-Socio AcciMap (26%) than the standardised version (16%). What was very interesting from the visual observation of relationships with the second subgroup of professionals (professionals 2B and 3B) that applied the Medi-Socio AcciMap was that there were very similar, especially at the physical/actor level. This observation also included CCFs identified and how they are causally linked to one another, although several links were seen as indirect (indicated as blue colour). However, no similar causal links were identified at both organisational and external levels after applying the Medi-Socio AcciMap approach. Two links identified by two out of three professionals were placed at the organisational level after using the standardised AcciMap method.

6.10.1.3 Reliability – Safety Recommendations

For the safety recommendations identified by professionals, the mean reliability scores using the standardised AcciMap were higher (73%) than for the Medi-Socio AcciMap approach (45%). From tables 6-10 and 6-11, the recommendation theme that was common from both AcciMap (Pr-R1) but the other recommendation theme (Pr-R5) relating to the *"implementation of policies to encourage medical staff to challenge decisions on high doses"* was formulated by two out of three professionals who used the proposed AcciMap. The remaining safety recommendations (Pr-R2 – Pr-R4) related to specific aspects of the EPIC software in setting the maximum dose allowed and improving the working environment were also not identified from the second group (Medi-Socio AcciMap approach).

6.10.2 Interpretation of the Case Incident

The Septra case incident presented a combination of factors at the physical and organisational level regarding using the EPIC software system and existing policies surrounding how medication doses were calculated, prescribed, and administered for paediatrics. However, the incident did not provide many systemic factors as to why there were safety concerns and how the patient eventually received such a high dose of Septra. Ideally, case reports giving further details, especially on any external or other organisational factors/decisions, would have allowed for in-depth clarity regarding decisions taken by different actors at both the physical and organisational levels. While participants were instructed to limit their findings and base them (contributing factors and safety recommendations) on what was available from the case report, it presents a study challenge. The purpose of accident analysis does not stop at just identifying or classifying causal/contributing factors or causal relationships between them.

Safety recommendations formulated will be considered adequate if they effectively address gaps relating to the safety of patients and the safe use of medical software products. One of the issues noted by one of the professional participants and one of the safety experts was the perceived lack of safety management systems or if such systems existed in the first place. These details were not available in the incident report. Also, while they were all based in different NHS establishments, their experiences in how they perceived a patient receiving such an overdose could have played a role in identifying causal/contributing factors. While it is acknowledged that healthcare systems from various countries operate differently, the purpose of analysing this incident was to gain new insights and provide safety recommendations not previously developed from the original analysis. However, no comparison could be made with any previous investigations due to lack of access to the information.

6.10.3 Application of AcciMap Guidelines and Taxonomy

Another reason for the reliability scores being low from both AcciMap approaches could be attributed to how the guidelines were applied. Particularly with the Medi-Socio AcciMap taxonomy, the additional taxonomy guideline given to participants regarding sub-category codes and examples was supposed to provide

further context on code definitions. However, there were situations as noted from the survey data on "overlapping categories" (discussed in the final chapter). Professional users and health safety practitioners who attended an AcciMap training workshop at the NHS, Durham (World Patient Safety Day) identified this issue. There were instances where some participants were confused regarding which sub-category best fitted the causal factor identified based on evidence from the report. Also, the number of codes, particularly sub-category codes associated with each category, may have contributed to some of the participants being confused about which subcategory to classify the causal/contributing factor.

From the AcciMap results, there were instances where a factor relating to either a "software configuration or functionality" issue (IT-related factors) was classified as a "human-computer" related factor. This scenario could be due to how participants interpreted the incident regarding contributing factors and, eventually, classified. Furthermore, regarding using both AcciMap approaches, some participants did not associate actions or events to specific "actors" involved in the system setting (i.e., nurse, pharmacist, and Paediatrician). For example, there were situations where a causal/contributing factor that the paediatrician committed was instead assigned either using a common term (e.g., clinician or medical staff) or to a wrong actor. This situation was one of the challenges experienced when comparing factors between pairs of participants which required making a judgement during discussions between coders.

6.11 Limitations of the Study

The reliability study presented limitations also reiterated in the final chapter regarding recommendations for future studies. While multiple clinical/human factors practitioners were invited to apply both AcciMap approaches, many were not available for the study due to their work schedules at their respective NHS practices. Even with the number of participants involved in the reliability study, the number of incidents for analysis was reduced to focus on the Septra overdose incident. The reliability study was initially supposed to apply the Medi-Socio AcciMap approach to a non-IT related case incident (*Queen's Medical Centre adverse incident*) (Toft, 2001) by professionals who had already used the standardised AcciMap version on the Septra incident. However, this chapter did

not include the outcomes from the incident because one of the participants could not complete the analysis, thus not having a complete set for subsequent reliability assessment.

An additional case analysis would have allowed for further evaluation of the Medi-Socio AcciMap approach. In addition, the number of participants for this study was considered very low. Goode *et al.* (2017)'s study generally recommended that the sample size of participants performing individual accident analysis be a minimum of eight participants. A larger sample size of professional participants would have allowed for further insights into similarities and variations. In addition, a larger sample size would also have allowed for a team-based AcciMap analysis rather than each participant conducting an individual evaluation. However, this approach would require each team member to correspond with their investigations before producing final results. This process further requires team discussions (similar to the study in Chapter Three) and could require more time and resources.

Another challenge was interpreting one of the professional participant's AcciMap results, mainly contributing factors when applying content analysis. For instance, professional 1B's AcciMap result after applying the Medi-Socio AcciMap approach indicated factors that were initially challenging to determine the context behind the factors identified, particularly at the organisational level. These included factors like "*Order entry module – intelligence*" classified under O-IT2 (software-configuration) and "*paper-based prescription in the community*" categorised under O-IT7 (accessibility of health IT systems). The participant was contacted to provide further context behind these factors selected. Another instance was in the causal factor at the physical level, "*incorrect dose entered*" causally linked (link 6) from "*High workload*", which was classified under P-EN5 (time pressure). This causal relationship between these grouped factors will relate to the paediatrician (rather than the pharmacist) based on the narration from the incident report. These issues brought up challenges during inter-rater coding and making judgement calls on what value to assign, which was one of the reasons why discussions with another independent rater were needed to reach a mutual consensus. The incident report used for the reliability study, while generally comprehensive, did not provide sufficient details regarding information,

particularly at the external, which led to most professional participants not being able to determine and classify any factors.

6.12 Conclusion

This chapter conducted a reliability assessment based on the AcciMap data produced by professional participants after applying both AcciMap approaches in determining and comparing the reliability of the Medi-Socio AcciMap approach. Based on the qualitative and quantitative analysis of the outcomes from the case incident, the reliability score (%) was lower with the proposed AcciMap version than the standardised AcciMap approach. However, this was explicitly about contributing factors and safety recommendations and for causal relationships (links), the reliability score was higher with the Medi-Socio AcciMap approach. In conclusion, and regardless of the analysis of a single incident, the reliability of the AcciMap method was not improved using a health-specific taxonomy. The reasons for this outcome will be discussed in the concluding chapter of the thesis (Chapter Eight) and potential recommendations for improving the taxonomy and methods for further evaluation. Regardless of the outcomes from this reliability assessment study between both AcciMap approaches, the validity assessment will be implemented and determined based on comparison with expert analysis of the same incident. This assessment will be covered in Chapter Seven to answer the third (final) research question.

7.0 CHAPTER SEVEN: Validity Assessment of the Medi-Socio AcciMap Taxonomy Approach – Clinical Safety Experts

7.1 Introduction

This chapter focuses on the validity assessment of the proposed Medi-Socio AcciMap taxonomy to answer the thesis's final research question. This study involves conducting a validity assessment by comparing the standardised AcciMap approach with the Medi-Socio AcciMap taxonomy based on its application on the Septra overdose incident. Regardless of the outcomes from the reliability study, it is important to also measure and determine the validity of the Medi-Socio AcciMap taxonomy approach compared with the standardised AcciMap method. In attempting to answer the third research question, a validity assessment was conducted by comparing both results from participants (professionals) with safety experts. Results including contributing factors, causal relationships, and safety recommendations from applying both AcciMap versions are compared quantitively. Findings and limitations from this study will also be discussed concerning the final research question.

7.2 Validity Overview

As briefly highlighted in Chapter One, Validity is another essential characteristic for determining the suitability of accident analysis approaches (Underwood and Waterson, 2013, 2014; Underwood, Waterson and Braithwaite, 2016). The standardised AcciMap approach's validity is considered from two perspectives, according to Branford (2007). The first relates to the validity of the accident analytical approach itself based on whether the method is developed in a way that carries out its intended purpose (Branford, 2007; Goncalves Filho, Jun and Waterson, 2019). The second aspect relates to the outcomes produced from applying the approach rather than the approach itself (Branford, 2007; Goncalves Filho, Jun and Waterson, 2019). In this case, the focus is not on whether the approach (standardised or Medi-Socio AcciMap version) and the process involved for producing results is considered appropriate, but on if the results produced are what they are intended to be. This latter process is called the "empirical validity", which is "*the degree to which an approach works with real cases in a real sample*" (Branford, 2007).

Four approaches to evaluating the validity of accident analysis approaches proposed by Branford (2007) are summarised below:

1.) Evaluation of outcomes against objective external criteria focuses on using a "gold standard" based on the results of a previously validated approach. The validity of results is determined by their agreement and disagreement with the standard available.
2.) Evaluation of outcomes relating to their internal logic which focuses on whether the results obtained have internal logic in ensuring that they are the correct answers.
3.) Evaluation of outcomes against those obtained by an expert analysis focusing on comparing results obtained from multiple users with those obtained by experts who applied the accident analytical approach (Gordon, Flin and Mearns, 2005).
4.) Evaluation of the degree of how similar the outcomes obtained are from different accident analysis approaches.

The third approach was considered most appropriate in assessing and comparing participants and experts results. The reason is that it's scarce to obtain such a gold standard of measurement based on the first approach because of its unavailability. The limitation with the second approach is that even the use of internal logic when evaluating results does not necessarily ensure that correct conclusions are reached (Goncalves Filho, Jun and Waterson, 2019). While Branford's study focused on comparing results obtained from her set of participants with those obtained through expert review, this study adopts a similar approach but with the inclusion of results also obtained from both groups applying the Medi-Socio AcciMap approach on the same incident (Branford, 2007). Results from standardised and Medi-Socio AcciMap versions implemented between the users and the experts are compared to determine any improvement in the validity of the outcomes using the proposed AcciMap version. However, in considering the validity of the Medi-Socio AcciMap, the sub-categories used to determine contributing factors and their classification will also need to be considered since the standard version does not consider categories.

7.3 Validity Measurement Approaches

According to studies implemented in Branford's thesis, Salmon *et al.* (2017), and Goode *et al.* (2017), there are different aspects or types when applying validity assessments. Referring to Chapter Six summarising reliability assessment measures (see Appendix E-1), they can be used for assessing the validity of both AcciMap approaches (quantitatively). The signal detection paradigm "*measures outcomes based on the number of hits, misses and false alarms and correct rejections"* (Stanton and Salmon, 2009; Cornelissen *et al.*, 2014). Hits refer to items (factors, recommendations) identified by both users and experts. Misses indicate items specified by experts but not by users, and false alarms represent items not identified by experts but selected by users. Correct rejections mean items that were not selected or indicated by both users and experts (Cornelissen *et al.*, 2014).

This approach has also been argued for its suitability regarding its application on taxonomy-based systems and theoretical maximum (Stanton and Stevenage, 1998; Baber and Stanton, 2002). However, Goode *et al.* (2018) indicated that the signal detection paradigm's advantages were preferable only for classification schemes with few *categories*. For this reason, the index of concordance (IoC) used in the previous chapter is a suitable measurement for systems with a large number of codes. This measurement applies to the Medi-Socio AcciMap taxonomy approach. While the Index of Concordance (IoC) and Signal detection paradigm are considered suitable based on a previous recent study (Goode *et al.*, 2017), the IoC metric is utilised for the validity assessment in determining per cent agreement based on reasons summarised in Appendix E-1.

7.4 Research Methodology

Experts' analysis will be used as an alternative in the absence of a "gold standard" to compare findings from the professional group based on causal/contributing factors, causal relationships, and safety recommendations. The following sections describe the methods applied in this study.

7.4.1 Recruitment of Experts

Different experts were contacted (via email correspondence) and provided with the details of the study. The number of participants that agreed to take part in

the study consisted of four (n = 4) safety experts; one based at the National Health Service (Nottinghamshire), two based in the Health and Safety Investigation Branch (HSIB), and one from the University of Glasgow (see table 7-1). The HSIB is an independent specialist branch under the NHS responsible for incident/accident investigation of major health cases. They also work in different trusts and specialist groups of the National Health Service, England. Each expert possessed extensive knowledge and experience not only in the application of the AcciMap approach but with other systemic (SAA) approaches, including STAMP and FRAM approaches both in clinical incident investigations and academics.

Table 7-1: Summary of Safety experts involved in the analysis of the Septra overdose incident

Expert	Role/Responsibility	Years of Experience (AcciMap Approach)
1	Patient Safety Lead (National Health Service, Nottinghamshire)	2
2	National Investigator (Health and Safety Investigation Branch)	3
3	National Investigator (Health and Safety Investigation Branch)	6
4	Professor (Department of Computing Science, University of Glasgow)	N/A
N/A – Not available		

7.4.2 Training Materials

Materials including the Septra overdose incident (used in the previous chapter), AcciMap guidelines, and Medi-Socio taxonomy notes was provided to the safety experts through email correspondence. Also, the guidelines on the standardised AcciMap approach adopted from Branford's work and the Medi-Socio AcciMap taxonomy were provided.

7.4.3 Study Design

An initial online correspondence was made with the experts before a formal field meeting was established, and this occurred at different times based on their location in the United Kingdom. During these field workshops, the Medi-Socio AcciMap taxonomy was presented alongside its taxonomy of contributing factors and how they were developed. In total, four expert participants excluding the principal researcher, where each set of two experts independently

analysed the Septra overdose incident. The first set applied the standardised AcciMap approach, while the second set applied the proposed approach to the incident. Any disagreements with safety experts regarding contributing factors, causal links, and safety recommendations were reviewed to reach a consensus. A discussion session also took place during the field meetings on the structure of the Medi-Socio AcciMap taxonomy and its application. A survey questionnaire link also was provided for them to give more feedback on their experiences after their analyses.

7.4.4 Analysis of Findings

Two independent raters will compare and code results obtained from professionals and safety experts to calculate the percentage agreement (using the index of concordance) to produce the validity results for each AcciMap version. For the proposed AcciMap version, a quantitative (criterion validity) assessment is applied to contributing factors classified into sub-categories by professional participants and determine if they matched with the experts. Then, each contributing factor, causal link, and safety recommendation identified by experts are compared with those identified by each professional to produce respective validity scores and determine the grand mean validity score.

7.5 Expert AcciMap Analysis

Standardised and Medi-Socio AcciMap results from their respective application and analysis of the Septra overdose incident were completed by both sets of safety experts as shown in Appendix G-1 and Appendix G-2, respectively. Disagreements or lack of clarity regarding wordings and classification of contributing factors themselves were discussed with safety experts and resolved where necessary. This process was achieved in a scenario where the second expert verified the first safety expert's initial analysis because both experts were not physically together. This process was similarly applied when producing the outcome for applying the Medi-Socio AcciMap (proposed), especially when using sub-categories from the taxonomy. There were few instances where a factor was classified under multiple sub-categories to describe it while classifying identified contributing factors. In such cases, a discussion took place with another safety expert on which sub-category is the most suitable for the identified contributing factor. Wordings (semantics) used to describe identified

factors were adjusted where necessary to improve clarity and understanding within the context of the incident scenario. This process was required to compare with the professionals' results on whether they conveyed similar meanings or not. This process was also applied when considering safety recommendations produced by expert analysts. In comparing standardised and proposed AcciMap results (models), there were similarities and several differences discussed in the following subsections.

7.5.1 Causal/Contributing Factors

Similar contributing factors were identified at each corresponding AcciMap level after applying both standardised and Medi-Socio AcciMap versions. For example, at the physical/actor level, factors including the "*physical environment where the Pharmacist was working*", "*multiple tasks and busyness of the pharmacy office*", "*high workload experienced by the Paediatrician*" were identified using both approaches. Other factors included "*trust between Pharmacist and Paediatrician based on their past relationship*", "*Paediatrician ignoring multiple alerts from the EPIC system*" and "*issues relating to how they both perceived the value "160" without cross-checking before the dose of approved*".

One notable factor identified using the proposed AcciMap version was the "*patient having multiple medications (15) and not questioning the dose given*". At the organisational level(s) (technical/operational and health management), contributing factors were identified using both AcciMap approaches. These include the EPIC system producing multiple alerts which did not make sense to the clinicians, the system not providing any guidance regarding which dosage mode it was operating, and the system's lack of clarity between small and large overdoses. Other factors included existing policies relating to calculated weights regarding children less than 40kg creating a complex situation and the EPIC system not setting a maximum or upper dose limit based on decisions made by the UCSF. Contributing factors uniquely identified using the standard approach included issues relating to EPIC system procurement and the transition from paper-based to a digital system. The application of the Medi-Socio AcciMap had an external contributing factor not identified using the standardised version, included "*a lack of evaluation of the EPIC system*" and "*tacit acceptance of the effectiveness of the digital system*". No external contributing factors were

identified using the standardised version. Still, factors relating to lack of safety management systems and lack of oversight on risks associated with the configuration of IT systems were identified using the proposed AcciMap version.

7.5.2 Causal Relationships (Links)

There were similarities between both model outcomes in observing causal relationships between contributing factors within and between corresponding AcciMap levels. Similar causal connections extracted from both AcciMap results include when the paediatrician administered the Septra overdose by typing "160" due to multiple contributing factors rather than a singular factor. This causal relationship had factors associated with the EPIC system's presentation of alerts indicating no difference in severity level, number of alerts, maximum dose limits and complexity regarding an existing policy of children's weights. Another similar causal relationship between the two outcomes includes factors leading to the paediatrician's prescribing error in typing "160". Both showed causal linkages stemming from factors relating to the paediatrician experiencing high workload, alert fatigue (receiving multiple alerts), and default unit settings of the EPIC system.

The other similar linkage was the direct relationship between the nurse administering a high Septra dose and the resulting massive overdose leading to seizure. The proposed AcciMap outcome indicated an additional factor as "*patient already being on fifteen different medications*". Notable differences between both results included causal relationships between the nurse administering an overdose (dispensing error) and a factor relating to trust between the pharmacist and paediatrician based on a past relationship. In the case of the standardised AcciMap application, the intermediate factor between these two factors was that "*Chan was very busy*", which, compared to the Medi-Socio AcciMap application, indicates "*Chan not noticing the mg/kg after seeing 160*". While the first factor appears straightforward, its meaning regarding context could be anything. However, other factors regarding why Chan was busy were similarly identified from the outcomes (e.g., Chan was busy due to multiple activities).

7.5.3 Safety Recommendations

Safety recommendations formulated by both groups of experts; four (standardised AcciMap) and seven (proposed AcciMap) recommendations are highlighted in tables 7-2 and 7-3, respectively. For each set of safety recommendations, the designed code for each safety proposal, for example, "S-R1" means *Standardised-Recommendation 1,* and the same applies for "P-R1", denoting "*Proposed-Recommendation 1*".

Table 7-2: Safety recommendations from applying the standardised AcciMap approach by safety experts (A)

Code	Safety Recommendations	Parties Responsible
S-R1	System review and redesign into prescribing of high-risk medications. Consideration of appropriate alarm limits to prevent alert fatigue and appropriate raising of alert and forcing functions to prevent incorrect medication dosage. Include alerting on drugs being prescribed and units (e.g., mg/kg).	UCSF and First Databank
S-R2	Local environment design and set up where prescribing/checking/administering to prevent contending cognitive demands and distractions	Hospital Management (UCSF)
S-R3	Including workload considerations around staff being required to attend multiple tasks simultaneously	Hospital Management (UCSF)
S-R4	Implementing standardised guidance on communication between pharmacy and clinicians around what to re-prescribe and how.	Hospital Management (UCSF)
S-R5	Implementing standards/usability assessment of electronic systems before installation to ensure as much safe environment as possible.	Hospital Management (UCSF)

Table 7-3: Safety recommendations from applying the Medi-Socio AcciMap approach by safety experts (B)

Code	Safety Recommendations	Parties Responsible
P-R1	Conduct a root and branch thorough analysis of the usability of the EPIC system focussing on displays and warnings on default values, which must be driven by user-centred design and appreciation of how staff uses the system in practice.	Hospital Management (UCSF) and First Databank
P-R2	The software should be developed and user-tested before being bought and mandated by local hospitals.	Hospital Management (UCSF) and First Databank
P-R3	Ensure that Safety Monitoring System (SMS) is in place, followed, and covering configuration of health IT systems (i.e., EPIC system).	Hospital Management (UCSF) and First

Code	Safety Recommendations	Parties Responsible
		Databank
P-R4	Ensure that there is an audit of workplace stress on staff and proper workload analysis, especially for key staff, e.g., pharmacy environment and design.	Hospital Management (UCSF)
P-R5	Ensuring that there is an analysis of noise and distraction from key pharmacy staff	Hospital Management (UCSF)
P-R6	Redesign continual training in IT systems to ensure all clinical staff are aware of medication errors common with IT systems such as EPIC. Appropriate training and evaluation on a system that has been designed from staff up to be effective	Hospital Management (UCSF) and First Databank
P-R7	Ensuring that appropriate legal/regulatory frameworks are in place to ensure that EMPA systems are fit for purpose and are procured on that basis, including the need for incorporating human factors/user-centred design into the process	Hospital Management (UCSF) and First Databank

In observing broad themes from both sets of safety recommendations, aspects regarding prevention of patient risks include training or improving existing training modules on awareness of medication risks relating to IT systems (P-R6). Other common themes from both results include "*the re-evaluation focusing on the implementation of appropriate alarm alerts and warnings*" (S-R1 and P-SR1) and "*usability testing focusing on user-centred design of IT systems before deployment*" (S-R4 and P-R2). An additional safety recommendation identified from both sets includes the need for "*reducing cognitive load and stress of medical personnel by improving their local environment (pharmacy)*" (S-R2 and P-R4). Safety recommendations uniquely identified after applying the standard AcciMap version include improving communication between medical staff (S-R3). For the proposed AcciMap approach, the inclusion of a safety management system (SMS) relating to the configuration of IT systems was formulated (P-R3). Finally, safety recommendation (P-R5) concerns the auditing of the workplace environment (P-R4). Based on the incident, the design of the pharmaceutical environment, noise and distractions impeded the pharmacist's effectiveness.

7.6 Validity Assessment Results

This section details the validity assessment outcomes from applying the standardised and Medi-Socio AcciMap versions by professional participants compared with safety expert results. Causal/contributing factors, causal relationships, and safety recommendations were compared between each

AcciMap approach. Index of concordance (IoC) measurement was applied after independent coding, and a mutual consensus was achieved by experienced human factors specialists based at the HSIB (UK) and Australia.

7.6.1 Quantitative Analysis – Criterion-Referenced Validity

Contributing factors, causal relationships, and safety recommendations were designated with alphanumeric values for each AcciMap result produced by the professional participants. Safety expert results were also labelled for comparison with both professional groups. For the validity assessment, each participant's outcomes were compared with each contributing factor, causal link, and safety recommendation of safety experts (Appendix E-6). Categorical values were then assigned for each result aspect based on the coding rules for validity assessment (standardised AcciMap approach) as follows:

1.) Any contributing factor similarly identified between pairs (expert and professional is indicated as (**Y:1**). Any partially identified factor between pairs is indicated as (**1/2:0.5**) and factors not identified between pairs (**N:0**)
2.) Any causal link and safety recommendation similarly identified between expert and participant is indicated as (**Y:1**) and not identified between pairs is indicated as (**N:0**).

For the Medi-Socio AcciMap taxonomy, the validity coding rules are summarised below:

1.) Any contributing factor similarly identified and classified in the same sub-category between pairs (expert and participant) is indicated (**Y:1**) (fully identified). Contributing factors similarly identified but classified under a different sub-category between safety experts and professionals are indicated (**1/2:0.5**) (partially identified). Finally, contributing factors not similarly identified and classified between pairs are indicated (**N:0**).
2.) Coding rules for causal relationships and safety recommendations are similarly applied for the proposed AcciMap version.

7.6.2 Quantitative Results

An additional rater independently analysed the AcciMap data to minimise bias regarding contributing factors, causal relationships, and safety recommendations. The second rater also had experience using the AcciMap method and quantitative coding involving the reliability of classification schemes. After mutual consensus regarding the data differently coded, validity assessment was applied to the participants' result set. The same set of values assigned for “agreement (1)”, “partial agreement (0.5)”, and disagreement (0)” from the reliability assessment was used to calculate the validity scores. The following subsections summarise the validity scores between the standardised and Medi-Socio AcciMap approaches for the professional participants.

7.6.2.1 Contributing Factors Results

The summary of validity scores for contributing factors identified by professional participants compared to expert findings are summarised in tables 7-4 and 7-5. The mean validity scores for the application of the standard AcciMap is 46%, and for the Medi-Socio AcciMap approach resulted in 32%.

Table 7-4: Validity scores of causal/contributing factors between professional participants (A) (n = 3) and safety experts (A) - Standardised AcciMap approach

Professional Pairing	Validity Score (IoC) %
Expert and A	43%
Expert and B	52%
Expert and C	43%
Mean Validity	**46%**

Table 7-5: Validity scores of causal/contributing factors between professional participants (B) (n = 3) and safety experts (B) - Medi-Socio AcciMap approach

Professional Pairing	Validity Score (IoC) %
Expert and A	16%
Expert and B	52%
Expert and C	28%
Mean Validity	**32%**

7.6.2.2 Causal Relationship Results

Causal relationships identified by professional participants were compared with those of the safety experts. The first subgroup compared with the experts’

standardised AcciMap application (27 links produced). The second group compared with 42 links identified by another set of experts who applied the Medi-Socio AcciMap approach. The summary of results is shown in tables 7-6 and 7-7 for each respective AcciMap method. The mean validity score was 6 % for the standardised AcciMap version and 10% for the Medi-Socio AcciMap approach.

Table 7-6: Validity scores of causal relationships between professional participants (A) (n = 3) and safety experts (A) - Standardised AcciMap approach

Professional Pairing	Validity Score (IoC) %
Expert and A	11%
Expert and B	4%
Expert and C	4%
Mean Validity	**6%**

Table 7-7: Validity scores of causal relationships between professional participants (B) (n = 3) and safety experts (B) - Medi-Socio AcciMap approach

Professional Pairing	Validity Score (IoC) %
Expert and A	5%
Expert and B	12%
Expert and C	12%
Mean Validity	**10%**

7.6.2.3 Safety Recommendation Results

Safety recommendations produced by professional participants indicated the mean validity score of 40% (uniform score from all professionals) was achieved using the standardised AcciMap by the first subgroup, as shown in table 7-8. The mean validity score based on the Medi-Socio AcciMap version produced 24% based on the average scores shown in table 7-9.

Table 7-8: Validity scores of safety recommendations between professional participants (A) (n = 3) and safety experts (A) - Standardised AcciMap approach

Professional Pairing	Validity Score (IoC) %
Expert and A	40%
Expert and B	40%
Expert and C	40%
Mean Validity	**40%**

Table 7-9: Validity scores of safety recommendations between professional participants (B) (n = 3) and safety experts (B) - Medi-Socio AcciMap approach

Professional Pairing	Validity Score (IoC) %
Expert and A	14%
Expert and B	29%
Expert and C	29%
Mean Validity	**24%**

7.7 Discussion

In understanding the differences in outcomes and recommendations produced by the professional participants compared to results produced by safety experts, the following subsections discuss the results from the analyses.

7.7.1 Validity - Contributing factors

There are several reasons for the low validity scores after applying the proposed AcciMap approach compared to the standardised version. First, identification and classification of causal/contributing factors into sub-categories showed differences where factors were similarly recognised by safety experts and professionals but classified differently. This observation is seen from the matrix tables 7-10 (standardised approach) and 7-11 (Medi-Socio AcciMap approach). For the standardised AcciMap version, the red boxes indicate "fully similar" factors, and the yellow boxes indicate "*partially similar*" factors. For the Medi-Socio AcciMap taxonomy, black bolded red boxes indicate "similarly identified and classified" factors with experts. The broken lighter coloured boxes indicate "similar but differently classified" factors from experts.

Generally, the visual representation of identified and classified factors between experts and professionals showed fewer instances of agreement using the Medi-Socio AcciMap version than the standardised version. For example, contributing factor E-7 ("*medical staff (pharmacist) working environment being busy and tight*") was classified under the sub-category P-EN1 (*"Physical layout"*) and two out of three professionals identified this factor. However, only one professional categorised this factor (E-7) in the same sub-category as the experts. Likewise, two out of three professionals identified contributing factor E-9 *("trust between Pharmacist and Paediatrician based on past relationships"*). However, none of them classified this factor in the same sub-category as the experts (P-SI0 –

"Other"). Another factor at the physical level was E-3 ("*Nurse administering a high dose of Septra*"). Only two out of three professionals identified this factor but were classified differently from experts (P-SI2 – *"Compliance with Procedures"*).

At the organisational level (both technical and health management), contributing factor E-13 *("Multiple alerts produced by the EPIC system not being sensible to clinicians"*) were identified by only two professionals (B) (none similarly classified). Other factors, including E-16 ("*EPIC system providing no guidance on its current mode (mg or mg/kg)"*), were identified by only one professional with no similar classification with experts (O-HC3 - *"Usability-Design Consistency"*). No professional participant identified contributing factors relating to E-17 ("*default settings for the EPIC system on children's weight less than 40k*g"). The contributing factor E-21 ("*UCSF's decision in having the EPIC system default to mg/kg for weights of children < 40kg based on weight policy*") was identified by all three professionals, with only one classifying similarly with safety experts. External contributing factors recognised by safety experts, like E-24 ("*Lack of regulatory oversight on risk management for configuration of health IT system*s") and E-25 ("*Lack of Safety Management Systems*"), were not identified by any professional participant. These two factors were also not found after applying the standardised AcciMap version by the first set of experts.

Table 7-10: Contributing factor matrix between safety experts (A) and professional participants (A) - Standardised AcciMap Approach

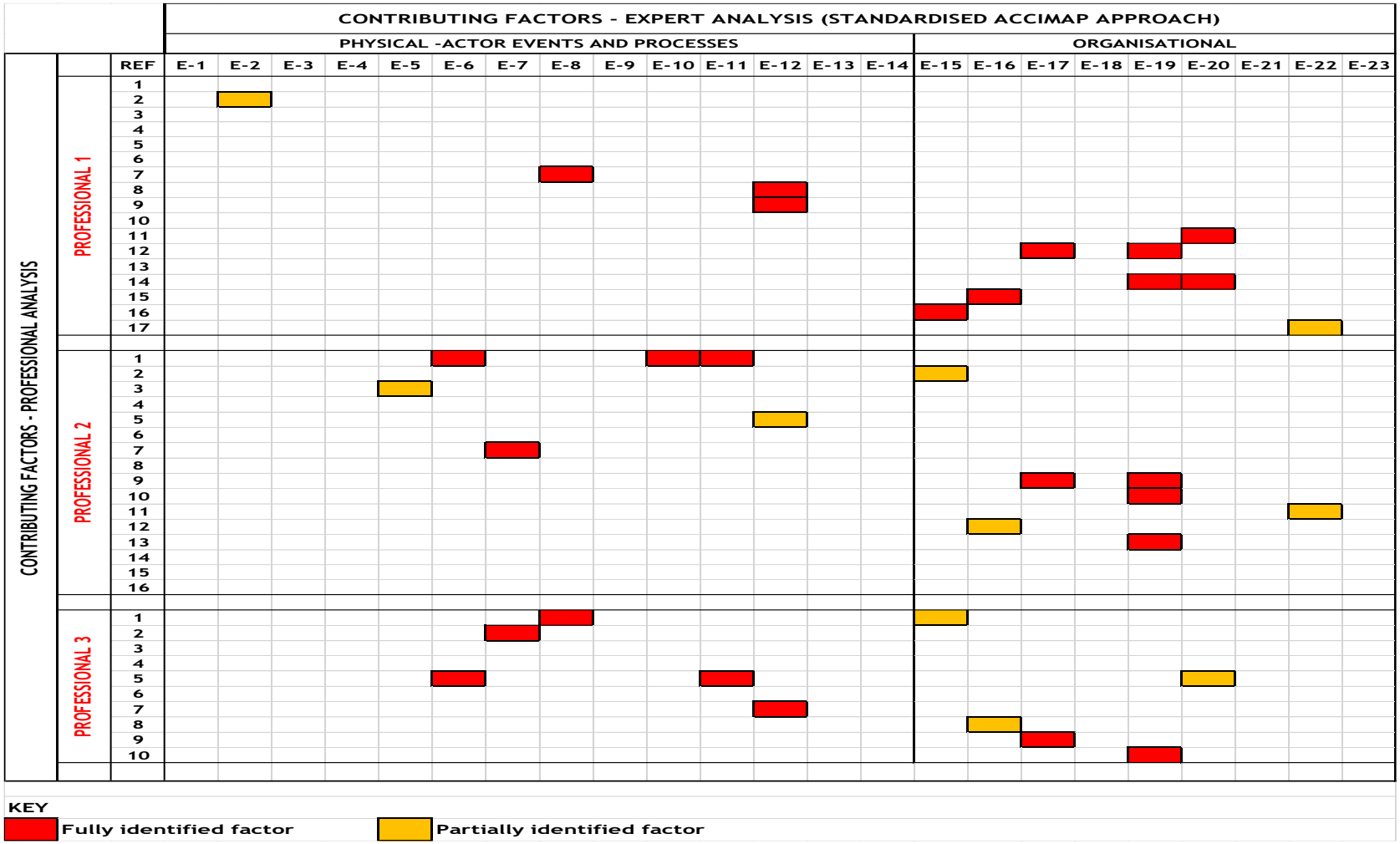
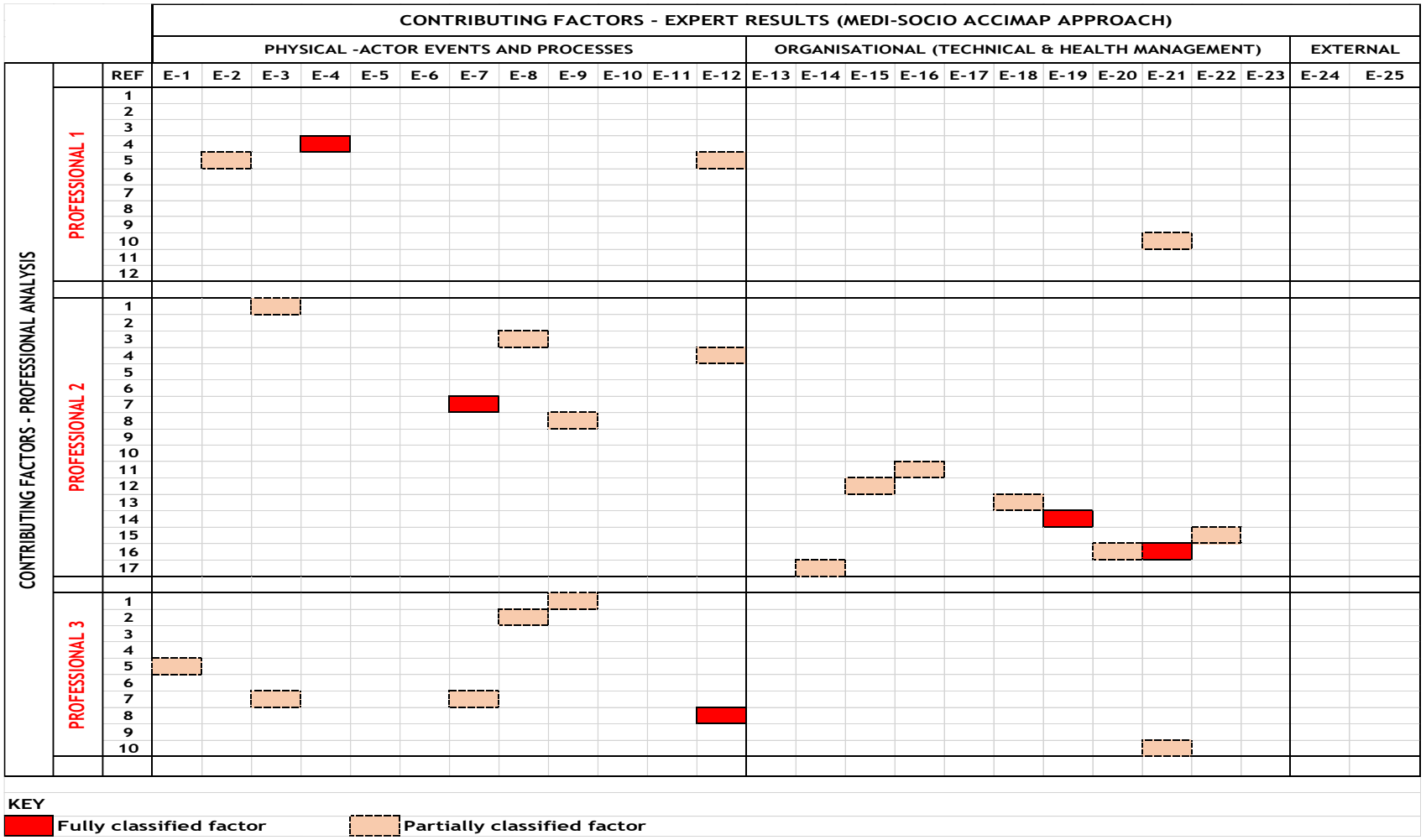


Table 7-11: Contributing factor matrix between safety experts (B) and professional participants (B) - Medi-Socio AcciMap Taxonomy Approach



These instances indicate that while multiple participants identified factors similar to what experts did, the use of the taxonomy to classify them showed differences. For example, there were instances where a contributing factor that may be classified as a system functional issue may then be categorised as a management or oversight issue regarding how the health IT system was utilised. Overall, validity scores were low regarding contributing factors, and the main reason for this can be attributed to their understanding and interpretation of the incident report's events. An additional reason for the low outcomes will be both professionals and safety experts understanding of the nano codes and how they applied them in classifying contributing factors. This second point relates to how they determined contributing factors within the context of the incident regarding what and why they occurred.

7.7.2 Validity - Causal Relationships

A closer observation of causal links from professional participants AcciMap models compared with safety experts generally indicated very few instances of causal link similarity from applying both AcciMap approaches. This observation corroborates the quantitative results where professional participants identified causal links between causal/contributing factors compared with experts' findings indicated the validity scores for the standardised AcciMap (6%) and Medi-Socio AcciMap (10%), respectively. Comparing causal relationships (direct and indirect) between standardised and Medi-Socio AcciMap versions showed more similar links for the latter than the former, particularly at the physical/actor activities level. Also, in cases where contributing factors identified by safety experts that were not found by any professional meant no causal relationships were identified. For example, in applying the proposed AcciMap version, contributing factor E-24 ("*lack of safety management systems*") linking to E-25 ("*lack of regulatory oversight for configuration of health IT systems*") at the external level was not identified in any of the professionals AcciMap models. Another instance includes E-23 ("*tacit acceptance that the EPIC system was effective*") linking to E-14 ("*lack of evaluation regarding the effectiveness of the EPIC system for any risks*") (Organisational levels). These examples were similar in the case of the standardised AcciMap version, where no participant identified contributing factors with their causal relationships with safety experts' outcomes.

7.7.3 Validity - Safety Recommendations

The matrix of safety recommendations by professional users compared with safety experts based on the observation of safety recommendation data between safety experts and professionals are shown in tables 7-12 and 7-13. Safety recommendations formulated after applying the standardised AcciMap version showed that all professionals agreed with experts regarding the systematic review of the health-IT system (EPIC). This recommendation denoted as "S-R1" (standardised - recommendation one) compared to professionals, shows that it encompassed multiple recommendations formulated by different participants that, if combined, will have a similar meaning to the expert's safety recommendation.

Table 7-12: Matrix of safety recommendations between safety experts (A) and professional participants (A) - Standardised AcciMap Approach

SAFETY RECOMMENDATIONS (STANDARDISED ACCIMAP APPROACH)												
	PROFESSIONAL - 1					PROFESSIONAL - 2				PROFESSIONAL - 3		
REF	1	2	3	4		1	2	3		1	2	3
S-R1												
S-R2												
S-R3												
S-R4												
S-R5												

KEY - Safety Recommendation Themes (Expert Analysis)	
S-R1	System review and redesign into prescribing of high-risk medications
S-R2	Local environment design and set up to prevent contending cognitive demands and distractions
S-R3	Workload considerations around staff being required to attend multiple tasks simultaneously
S-R4	Implementing standardised guidance on communication between pharmacy and clinicians on prescribing
S-R5	Implementing standards/usability assessment of electronic systems before installation for a safe environment

This scenario was also similar after applying the Medi-Socio AcciMap approach. All professional participants agreed with the first expert recommendation (P-R1), which focused on conducting a root and branch analysis on the health-IT system(s). This recommendation also encompassed the need for setting up dose limits, setting up appropriate alerts to avoid alert fatigue, re-designing screens based on human factors principles, and using colour codes to indicate dose severity. However, no professionals identified other safety recommendations, including S-R3 ("*workload considerations involving medical staff*"), S-R4

("*implementing standardised guidance on communication*"), and S-R5 ("*implementing standardised assessment of IT systems*"). However, relating to this recommendation (S-R3) was the second measure, S-R2 ("*prevention of contending cognitive demands and distractions through effective local environment design*"), which all three professionals also developed.

Safety recommendations were formulated after applying the Medi-Socio AcciMap approach (see table 7-13). Aside from the first recommendation (P-R1), only one professional developed each remaining measure P-R3 ("*Safety monitoring system is in place, followed and covering configuration of health IT systems*") and P-R6 ("*Redesigning continual training in using IT systems*"). The professional participants did not identify the remaining safety proposals, including P-R4 ("*Auditing workplace stress and workload analysis*"), which is similar to the safety recommendation (S-R3) from the standardised AcciMap analysis.

Table 7-13: Matrix of safety recommendations between safety experts (B) and professional participants (B) - Medi-Socio AcciMap Taxonomy Approach

SAFETY RECOMMENDATIONS (MEDI-SOCIO ACCIMAP TAXONOMY APPROACH)																	
	PROFESSIONAL - 1					PROFESSIONAL - 2						PROFESSIONAL - 3					
REF	1					1	2	3	4	5		1	2	3	4	5	6
P-R1																	
P-R2																	
P-R3																	
P-R4																	
P-R5																	
P-R6																	
P-R7																	

KEY - Safety Recommendation Themes (Expert Analysis)	
P-R1	Root and branch thorough analysis of the usability of the EPIC system
P-R2	The software developed and user-tested before being bought and mandated by local hospitals
P-R3	Safety Monitoring System (SMS) is in place, followed and covering configuration of health IT systems
P-R4	Audit of workplace stress on staff and proper workload analysis especially for key staff
P-R5	Ensuring that there is an analysis of noise and distraction from key pharmacy staff
P-R6	Redesign continual training in IT systems to ensure all clinical staff are aware of medication errors
P-R7	Ensuring that appropriate legal/regulatory frameworks are in place

Finally, the only safety proposal formulated by safety experts that no professional participant identified was P-R7 ("Ensuring appropriate legal/regulatory frameworks are in place"). This measure was based partly on the external contributing factor relating to E-24 ("Lack of regulatory oversight on risk management for configuration of health IT systems"), which was also not

similarly identified by either group. Overall, the difference between validity scores with each professional subgroup regarding safety recommendations, despite having low scores, showed a notable difference between them (40% vs 24%). One prominent reason was that the first professional participant identified only one safety recommendation related to reviewing and improving the health IT component.

Regardless of the AcciMap version used in this study, identifying contributing factors, including how they were classified, causal links between factors or classified factors and safety recommendations depend on participants' understanding and interpretation of the incident. In the case of applying the taxonomy guidance notes, this will also extend to how professional participants and safety experts interpreted each subcategory when determining and classifying causal/contributing factors. This process ultimately affects how they depict causal relationships and formulate safety recommendations from their analyses.

7.8 Limitations of the Study

Similar to limitations encountered in the reliability study in the previous chapter, only one incident could be used for the validity assessment. After one of the professional participants was unable to complete the QMC incident analysis, only the results from the Septra incident analysis were used to compare with safety experts' findings. Comparison with safety experts' AcciMap outcomes was based on comparing each result set, quantitatively determining its validity score, and obtaining the overall mean validity score. While Branford (2007) and Goode *et al*. (2017) applied this measure, its limitation is that each individual AcciMap result may not include contributing factors or factors classified under the same sub-categories from experts' results. An alternative approach would be to combine individual AcciMap outcomes, mainly contributing factors identified (standardised AcciMap version) and classified contributing factors (Medi-Socio AcciMap version) and compare them to safety experts' results.

However, combining causal links will not be practically feasible because it will require a team-based analysis. This process essentially means having a multi-disciplinary team where each AcciMap analysis (individual) can be cross-checked

and re-analysed to produce a final group AcciMap output. Nevertheless, this approach could potentially improve validity scores and must be considered for future research.

7.9 Conclusion

This chapter focused on the validity assessment of the application Medi-Socio AcciMap approach compared to the standardised AcciMap method in answering the final research question. Based on findings from comparing outcomes between professional participants with safety experts, the validity score (%) of the Medi-Socio AcciMap approach was lower than the standardised AcciMap approach. Furthermore, the validity score (%) was lower for the Medi-Socio AcciMap approach regarding contributing factors and safety recommendations but higher in causal relationships. Reasons were also discussed as to what could have contributed to the validity scores from the standardised AcciMap version being lower than the proposed version.

However, like the reliability study, the validity results are from a singular incident analysis. Therefore, it will require further studies applying and testing the Medi-Socio approach with other incidents. More importantly, this study also highlights the need to improve the current iteration of the Medi-Socio AcciMap taxonomy and subsequently re-evaluate the approach. This step requires a series of further iteration and evaluation cycles to achieve an acceptable validity score. Finally, this measure will require the involvement of clinical safety and health IT practitioners both at local and national levels as part of the overall objective of bridging the research-practice gap.

8.0 CHAPTER EIGHT: Conclusions, Discussion, and Future Work

8.1 Conclusions

As stated in the thesis, the overall objective is to compare the reliability and validity of Branford's standardised AcciMap and the Medi-Socio AcciMap taxonomy for health-IT analysis. The thesis statement made at the beginning of this research was that developing a health-specific taxonomy will enhance the reliability and validity of the AcciMap approach. However, results from both reliability and validity studies did not support this statement. The following table 8-1 summarises reliability and validity scores based on the outcomes produced by professional participants.

Table 8-1: Summary of the quantitative reliability and validity assessment based on the application of both AcciMap approaches on case incident (Septra overdose)

	Grand Mean Reliability (IoC) % - Professionals (6)	
Analysis Aspects	**Standardised AcciMap Approach**	**Medi-Socio AcciMap Approach**
Contributing Factors	39%	26%
Causal Relationships	16%	26%
Safety Recommendations	73%	45%
	Grand Mean Validity (IoC) % - Professionals (6)	
Analysis Aspects	**Standardised AcciMap Approach**	**Medi-Socio AcciMap Approach**
Contributing Factors	46%	32%
Causal Relationships	6%	10%
Safety Recommendations	40%	24%

Findings relating to each of the three research questions are also summarised in the following subsections.

8.1.1 Thesis research question one

Studies from Chapters Three and Four addressed the first research question, "*What is the perception of using the standardised AcciMap approach for accident investigation in the National Health Service (NHS)?*". Results based on quantitative (survey questionnaire) and qualitative (case study analysis) indicated a general acceptance of the AcciMap approach for accident analysis. However, neutral responses from the survey suggested that aspects like the time

allocated for the training and group analysis were insufficient to get a firmer opinion on the benefits of using the AcciMap approach. Chapter Four sought to address the limitations from Chapter Three by conducting a series of training workshops with an experienced clinical domain expert. Chapter Four mainly focused on a case study analysis of a health IT-related study (CPOE medication error) with findings compared between a clinical expert and the AcciMap expert who developed the standardised AcciMap method. Conclusions were drawn from the interview with the participant on the experiences, advantages, and demerits of applying a systemic approach compared to using RCA techniques.

8.1.2 Thesis research question two

The second research question, "*Does the application of a contributory factor AcciMap taxonomy improve the reliability of results from health IT analysis compared to Branford's AcciMap approach?*" The answer based on the results is no. Chapter Six addressed the reliability of the Medi-Socio AcciMap taxonomy involving clinical safety practitioners. The results were drawn after applying both AcciMap approaches and qualitatively (content analysis) and quantitatively (inter-rater reliability) analysed and compared. Findings from the reliability study indicated that the reliability score (%) of the Medi-Socio AcciMap was lower than the standardised AcciMap regarding contributing factors and safety recommendations. However, results regarding causal relationships indicated a moderately higher reliability score than the standardised AcciMap approach, although the scores were generally very low for both methods. Limitations from this study included an insufficient sample size of participants involved and short time relating to training and analysis, which only allowed a singular case incident to be used.

8.1.3 Thesis research question three

The third (final) research question, "*Does the application of a contributory factor AcciMap taxonomy improve the validity of results from health IT analysis compared to Branford's AcciMap approach?*" The answer based on the study results is no. Chapter Seven addressed the validity assessment of the Medi-Socio AcciMap approach compared to the standardised AcciMap version based on results from Chapter Six. This study mainly compared experts' analysis of the Septra overdose incident with results obtained from professional participants

after applying both AcciMap approaches. Outcomes from this study also indicated that the standardised AcciMap version was higher than those obtained from the Medi-Socio AcciMap approach regarding contributing factors and safety recommendations. However, causal relationships between experts and participants indicated a higher validity score for the Medi-Socio AcciMap approach than the standardised AcciMap version.

8.2 Discussion

The application of the Medi-Socio AcciMap approach based on feedback, practical benefits, and limitations in addition to research goals and study design are discussed in the following subsections.

8.2.1 Application of the Medi-Socio AcciMap Taxonomy Approach

Feedback on their experiences applying both standardised AcciMap and the Medi-Socio AcciMap versions are discussed based on the core usage characteristics; usability, reliability (research question 2), and validity (research question 3). It was also essential to ascertain the participants' perspectives (NHS patient safety practitioners) on their experiences in using the Medi-Socio AcciMap approach. Therefore, an evaluation questionnaire (Appendix H-1) was developed and distributed to professional participants regarded as "*intended end-users*" through email correspondence. Out of the six patient safety practitioners, only four responded to the survey questionnaire. This survey was also distributed to another set of participants; NHS attendants were involved in an AcciMap training workshop in NHS, Durham, and the safety experts (HSIB) engaged in the validity study. From the AcciMap seminar, only six attendants responded to the evaluation via email, out of the fourteen participants invited during the "*World Patient Day*" conference. Discussed in the following subsections are the characteristics.

8.2.1.1 Usability

The Medi-Socio AcciMap taxonomy's usability was not formally evaluated in this thesis. However, it is crucial to highlight users' experience using the proposed version during the reliability study. Regarding usability (ease of use), utility (provision of features needed) is usually considered, which constitutes the

usefulness of the Medi-Socio AcciMap taxonomy. Utility, in this case, will apply to the proposed AcciMap approach's applicability to not just health IT-related incidents but also to non-IT incidents. For instance, the AcciMap outcome seen in Appendix F-4 was from the QMC (Queens Medical Centre) adverse incident analysis, which indicates that the Medi-Socio AcciMap taxonomy is not limited to just health IT-related cases. However, their results were not analysed for the reasons stated in Chapter Six (see the limitation of the study in section 6.11). There were generally mixed opinions regarding its ease of use, similar to the first AcciMap training workshop (Chapter Three). One of the professionals noted from her experience using the HFACS approach in her practice that:

> *"Familiarity makes the tool easier to use. Initially, I was struggling with fitting the tool around my knowledge of HFACS, but it added more context in"* **(Professional-4)**

One of the attendants from the AcciMap workshop (NHS, Durham) also indicated an advantage of using the Medi-Socio AcciMap approach in terms of how suitable it can be in analysing complex socio-technical systems:

> *"This approach can be used to identify the cause of errors in a changing healthcare organisation where there is a complex socio-technical environment has"* **(Attendant-6)**

However, issues/limitations regarding its ease of use in analysing incidents were also noted by some other participants. Several factors may be attributed, including the clarity of guidelines regarding the taxonomy needed for the analysis and the restrictive nature of contributing factor categories. This last factor is a feature typically associated with taxonomy/classification schemes (e.g., HFACS) (Salmon, Cornelissen and Trotter, 2012). To further bolster these factors, another professional participant commented on the Medi-Socio AcciMap taxonomy:

> *"It could limit the number of factors identified if people stick with trying to fit factors into the available categories rather than having free reign"* **(Professional-3)**

This point supports using the standardised AcciMap approach over the Medi-Socio AcciMap version in allowing a free reign in analysing incidents. Two out of four

safety experts (Health Safety Investigation Branch) also responded to the questionnaire. Before the expert analysis, a field meeting took place at HSIB headquarters, where the Medi-Socio AcciMap taxonomy was presented. Relating to its structure, the first safety expert responded with the following:

> "*It provides a far more structured and comprehensive taxonomy for the creation of an AcciMap. Original AcciMap is less structured and therefore more difficult to apply without background knowledge; the prototype helps this.*" **(Safety Expert-1)**

This comment is considered a benefit, especially for beginners and those with knowledge of using taxonomies (i.e., HFACS) for incident analysis. However, both experts noted areas needed to improve the usability of the Medi-Socio AcciMap approach. One such aspect includes using a template or an example AcciMap as a guide in illustrating how it is applied. Also, the second expert commented on the guidance material associated with the proposed AcciMap version:

> "*The guidance document is lengthy. If this was incorporated into an e-system with prompts, it may reduce the burden on the user to identify and select the correct categorisation.*" **(Safety Expert-2)**

This point refers to an earlier comment from the Clinical Safety Officer (Chapter Four) on the need for developing a software toolkit specifically for AcciMap analysis. This idea also works in tandem with the need for refining the Medi-Socio AcciMap taxonomy, and any changes made will need to be reflected on any associated documentation.

8.2.1.2 Reliability

The Medi-Socio AcciMap approach's reliability was lower than the standardised AcciMap approach for contributing factors and safety recommendations but higher for causal relationships between factors. Reasons for why the reliability scores were low and lesser for the Medi-Socio AcciMap approach included the following:

1.) The number of sub-categories associated with each system category of the Medi-Socio AcciMap taxonomy (see subsection 8.2.3 for further explanation).
2.) The nature and interpretation of the incident report used for the AcciMap analysis. This point was discussed in Chapter Six (see subsection 6.10.2) regarding the professional group that analysed the Septra overdose incident. Despite their expertise and experience, their first-time application of both AcciMap approaches produced variations in contributing factors (including wordings and level of detail), causal links between them, and safety recommendations.
3.) The methodology of the AcciMap analysis on the incident. This point presents a scenario where no pre-determined number of causal/contributing factors was extracted from the incident report and used for classification for the reliability and validity studies. This process is usually the first step applied to determine taxonomy's reliability, where multiple analysts classify pre-determined factors under different categories (Goode *et al.*, 2017, 2018). However, each participant had the freedom to apply both AcciMap approaches to analyse the incident from scratch. As a result, their AcciMap outcomes were affected by their interpretation of the incident regarding similarities and variations.

Concerning the proposed AcciMap version's reliability in tandem with its usability, the first participant noted how reliable the proposed version could be compared to the standardised version:

> *"It reduces the subjectivity and would be helpful in codifying incidents across an organisation into specific themes"* **(Professional-1)**

However, despite professional participants having the taxonomy guidance notes on all sub-categories, causal/contributing factors were classified under different sub-categories despite having similar meanings. The main reason for differences in classification is their interpretation of factors from the incident report and understanding of causal relationships between those factors, as noted earlier. Another reason could be how participants applied Branford's AcciMap guidelines and the taxonomy code guidance in their analyses. For example, at the physical/actor level, the causal/contributing factor regarding the *"pharmacist's*

workload and busyness" was identified by all three professionals that applied the proposed AcciMap approach. However, while this factor was classified under the same system category (P-EN: "*Environmental factors"*), it was categorised into two different sub-categories (P-EN3*: "workload and shift patterns"*) and (P-EN5: "*time pressure"*).

Another similar instance was in system categories relating to the health-IT systems (e.g., EPIC software system) in identifying contributing factors. For example, factors relating to software's default settings on dosage mode (mg or mg/kg) were classified under different categories; Information technology (O-IT1: "*software functionality"* and O-IT2: "*software configuration"*), Human-Computer (O-HC1: *usability-information display*), and Health-IT vendor (O-HV3: "*software design processes"*). These differences are because of how participants interpreted that factor and associated it with the sub-category that best described it. From the evaluation survey data, the question on how the Medi-Socio AcciMap taxonomy's reliability could be enhanced was particularly informative. From two of the four safety experts, based in the Health Safety Investigation Branch (HSIB) who participated in the Septra incident analysis, the first expert opined that:

> *"For individual incident analyses, I don't worry about reliability too much as long as it is valid. It is more important if you are comparing themes across various incidents."* **(Safety Expert-1)**

The second expert user's comment was centred on the need for further reliability assessment based on multiple uses of the Medi-Socio AcciMap approach as stated below:

> *"This would need an evaluation from multiple users to determine the variability and improvements that could be made. I cannot say from my experience what would improve the reliability from a single-use".* **(Safety Expert-2)**

Comments from other professionals (patient safety practitioners) who participated in the AcciMap training workshop (NHS, Durham) generally indicated a need for further formal training and understanding of the approach to determine areas for further improvement. The reason was that some of them

considered the time allocated for training and applying both AcciMap versions insufficient to provide concrete feedback. However, comments from professional participants that took part in the reliability study also revealed the need for further testing. For example, based on one of the participants comments:

> *"It would have been helpful to have had another person to agree on the codes, in order to reduce bias"* **(Professional-4)**

This comment is considered very insightful concerning one of the limitations of the reliability study. In an ideal situation, a sufficient number of participants would have allowed for a team-based analysis using the Medi-Socio AcciMap approach on case incidents. Branford had argued in her thesis the benefits of adopting a team-based approach to accident analysis instead of individual-based analysis to reduce potential biases and enhance understanding of events that unfolded (Branford, 2007).

8.2.1.3 Validity

Similar to reasons identified regarding reliability, validity scores relating to causes/contributing factors and safety recommendations were lower using the Medi-Socio AcciMap than the standardised AcciMap version. From the Septra overdose case incident, the only factor that all professional participants agreed on was the need for a systematic review of the UCSF's EPIC software system. Aspects that multiple participants agreed with experts were from sub-categories associated with human-computer interactions on the system's usability and software configuration and functionality issues. Safety experts identified other factors that were not identified and classified by all professionals after applying the Medi-Socio AcciMap approach. These include factors recognised by experts at the external level (*implementation of a safety management system and risk assessment in configuring health-IT systems*). It is also important to reiterate that while there was no "gold standard" with which to use for the validity assessment, using safety expert analysis to compare with the findings of participants is not without drawbacks. As Branford noted, even experts may not identify causal/contributing factors that in reality played a role in the adverse outcome and include factors that did not contribute to it (Branford, 2007). Validity scores could be improved if this study were repeated by the same set of

participants and their outcomes compared again with experts' results (intra-reliability). However, the learning effect from such repeated studies would need to be considered for such research. Branford also opined that improving the validity of results will require setting up a multi-disciplinary team, implementing strict requirements regarding analysis especially around how conclusions are derived with supporting evidence. Additionally, full transparency must be provided regarding which contributing factors are known versus those that are inferred according to Branford.

On the flip side of this argument and despite the results from these studies, the fact that causal/contributing factors and safety recommendations may not be highly reliable may not necessarily mean the information is not useful. This view was argued in the study that compared safety recommendations by different accident investigators using a common methodology (Johnson, Oltedal and Holloway, 2013). Variations in identified contributing factors can potentially allow health organisations to identify other system weaknesses that may not have happened if the focus is solely on factors similarly identified between multiple users. This point is where the benefit of conducting a team-based AcciMap analysis becomes very important. Individual outcomes could be developed at an initial stage and then compared to determine similar factors and factors different from each AcciMap output. The results of discussions and mutual consensus reached can then produce a more refined AcciMap result. However, this process is potentially time-consuming and resource-intensive, and so it can only be best recommended for analysing significant incidents.

8.2.2 Benefits of the Medi-Socio AcciMap Approach

Despite the reliability and validity scores from applying the Medi-Socio AcciMap approach, there were merits from its use for incident analysis. Several professional participants from the AcciMap studies and the training workshop linked the benefits to its usability. Based on the evaluation survey, there were notable opinions regarding the advantages of applying the Medi-Socio AcciMap version. According to one of the attendants:

> *"This is a very descriptive analysis with a standardised approach, and the schematic approach gives you the opportunity to quantify the risks in*

> *relation to the system and re-introduce recommendations for their minimisation."* **(Attendant-1)**

While this proposed AcciMap version provides both quantitative and qualitative means of analysing a set of multiple incidents or a singular case incident, its taxonomy allows specific aspects of a healthcare system to be analysed and provides recommendations to address them effectively. Furthermore, although the Medi-Socio AcciMap approach is a retrospective approach, it's not limited to just health-IT analysis. The long-term benefit of adopting this approach based on the response of another safety expert from HSIB are as follows:

> *"I believe the greatest benefit is in post-incident analysis. The system offers a greater prompt to consider a variety of factors in the creation of the AcciMap. However, it then allows for coding and categorisation that can be used to identify broader themes and trends that may arise from a series of individual incidents."* **(Safety Expert-2)**

The Medi-Socio AcciMap taxonomy can be structured to suit speciality areas within healthcare, as illustrated in adopting the HFACS approach for the Acute Hospital in the NHS, Nottinghamshire (Woodier and Shale, 2017). A more recent example was the development of an investigation toolkit, the Patient Handling Injuries Review of Systems (PHIRES) in Australia (Newnam *et al.*, 2020). One way to improve and maintain the taxonomy will be to continuously test it with clinical safety practitioners (local and national levels) on a set of new incidents. This process will help determine categories or sub-categories that were either missed or existing ones that need clarification or combined to form a broader sub-category. In addition, feedback from practitioners can serve as a means of maintaining the Medi-Socio AcciMap approach.

8.2.3 Limitations of the Medi-Socio AcciMap Taxonomy Approach

The first reason why the proposed AcciMap version produced lower reliability scores than the standardised version may be regarding the number of subcategories associated with each system category. While the Medi-Socio AcciMap taxonomy may be comprehensive, it may come at the cost of applying the proposed AcciMap effectively when analysing an incident. In addition, despite the taxonomy guidance material briefly describing each subcategory, participants had different interpretations when identifying contributing factors

based on their background and experience. This limitation could also have led to a case of possible mental fatigue when trying to classify contributing factors.
From the feedback from participants (surveys and discussions) after the AcciMap workshop, there were scenarios where "overlaps" were encountered, particularly regarding which sub-category best identifies and classifies a contributing factor. For example, one attendant (AcciMap workshop, NHS, Durham) noted this from the AcciMap analysis exercise:

> *"Yes, sometimes it was hard to identify if the contributing factor lay from a technical issue or operational issue from not knowing the organisation too well."* **(Attendant-3)**

Several professionals confirmed this observation, particularly with the second professional based on the following comment:

> *"Yes, some things could be classified by a number of codes. I analysed the same as with Branford and then tried to code. Maybe others may use the codes to identify relevant factors so less overlap?"* **(Professional-2)**

However, while the professionals did not explicitly indicate any scenarios of overlapping categories in their analyses, there was an occurrence (professional 2B) where one contributing factor was classified under multiple categories. This scenario also presents another limitation in close relation to the overlapping of contributing factors. Regarding the current Medi-Socio AcciMap taxonomy, participants generally noted how they revised their initial outcomes to determine if they classified their factors in the appropriate system category and sub-category. Despite these limitations, there is still room for further improve the Medi-Socio AcciMap taxonomy approach regarding reliability, validity, and usefulness. The recommendation section addresses this (see section 8.4).

8.2.4 Research Design Challenges

The reliability and validity studies implemented in this thesis, results, and conclusions were based on analysing a singular narrative incident. Despite the qualitative and quantitative analysis outcomes, it was also imperative to acknowledge these studies' limitations in answering the second and third research questions. It's also essential to determine why results from these studies did not support the initial thesis statement. A close examination of the

reasons and limitations of the reliability and validity assessment will allow for recommendations for further studies. In terms of the research goals of this thesis, particularly the research questions, it would indicate that the inclusion of a domain-specific taxonomy synthesised with the AcciMap approach did not address the subjective nature associated with using the standardised AcciMap version.

When considering the Medi-Socio AcciMap taxonomy, including categories and sub-categories was supposed to help users systematically identify contributing factors when analysing factors. Also, in analysing incident reports, system categories and sub-categories incorporated at each AcciMap level were to help reduce producing subjective outcomes. However, when observing AcciMap output models from participants after applying the proposed AcciMap version, contributing factors were interpreted and classified differently despite the description provided for each sub-category (Appendix D-9). The differences in outcomes were particularly observable at the organisational level (both technical and management levels). However, two out of three professionals classified contributing factors were virtually identical at the physical/actor & processes level, as seen in the reliability study (Chapter Six). Time allocation must also be considered a factor in learning and understanding how to correctly apply the guidelines when using both AcciMap approaches. In addition, the development of the taxonomy guidance manual explaining each category and its sub-categories, while necessary, most likely contributed to participants' cognitive load when determining factors and where they felt was most appropriately classified.

Challenges were highlighted and discussed when considering the research methods in chapters relating to reliability and validity assessment. Regarding research design, the case study approach was considered the most appropriate method for conducting qualitative research. Although, it has been acknowledged that one of the disadvantages of using this method is the possibility of researcher bias when interpreting case study conclusions. Other disadvantages include difficulties in generalising findings from case analysis and the lack of objective criteria to compare with results from participants, especially relating to validity assessment (Branford, 2007). However, a notable advantage of using

the case study approach is that it allows for a thorough understanding, especially from safety practitioners who may not have had any prior knowledge or experience applying the AcciMap method.

Another challenge relating to applying the case study methodology was the sample size of professional participants involved in the reliability study. The number of professional participants was insufficient to perform group analyses (i.e., multiple teams) for the reliability assessment. Instead, individual AcciMap results were used for comparative purposes. According to Branford (2007), adopting a team approach when conducting a reliability assessment is beneficial. For example, if the sample size were sufficient, a group-based analysis, specifically where multiple teams are formed, would have been used in the reliability study. However, to fully realise this advantage, especially regarding health IT analysis in practical settings, it is essential to have a team composed of practitioners experienced in applying systemic accident methods and those with clinical IT safety backgrounds. Also, if the reliability is to be investigated in health practice, a *controlled* case study methodology can be applied, similar to the process implemented in Branford's thesis. In this setting, practitioners would be given the same incident information and time limit to analyse while their interactions are observed and audio-recorded. Thematic analysis is then applied to extract data and determine how members reached consensus on contributing factors, causal links and safety measures. Also, insights regarding the nature and significance of observed variations of outcomes can be gained to determine where and why they happened. Finally, the AcciMap approaches (standardised and Medi-Socio) in the first analysis stage would be randomised in the reliability study instead of the case incidents between the professional subgroups. This alternative approach could have influenced the reliability outcomes, especially when taking the learning effect into account.

8.2.5 Research Goals – Reflections

Previous sections have discussed the Medi-Socio AcciMap taxonomy, and while there were benefits, there were also limitations. This research presents the first comparative study between Branford's standardised AcciMap and a domain-specific taxonomy-based AcciMap version applying the methodology adapted from Branford (2007) and Goode *et al.* (2017). Also, the limitation section

(8.2.3) also explained why the proposed AcciMap taxonomy performed less than the standardised AcciMap version. In focusing on this research, it is clear that synthesising a taxonomy based on the AcciMap methodology did not enhance the reliability and validity of the AcciMap method. However, each chapter (particularly Chapters Six and Seven) highlighted its limitations and must be considered relating to the study outcomes, especially if this research is to be repeated in practice.

Regarding reliability and validity, particularly relating to the need for accident analysis methods to possess high or at least acceptable levels of these properties, there is still an ongoing need to address these aspects. This point was discussed in a recent paper comparing the criterion-referenced concurrent validity of AcciMap with other approaches (STAMP-CAST and AcciNet) (Hulme *et al.*, 2021). The study had initially noted the argument that the reliability and validity of SAA methods are less important, especially considering their ability to produce useful information when analysing isolated incidents (Waterson *et al.*, 2017; Hulme *et al.*, 2021). However, from a research standpoint, the authors firmly stated that these properties ultimately affects other aspects, including scientific processes (e.g., the internal validity of experiments) and confidence in their ability to provide meaningful results that impact practice (Hulme *et al.*, 2021). Another article provided perspectives on the reliability and validity of Human Factors and Ergonomics (HFE) methods by the paper's co-authors (Salmon, Read, *et al.*, 2020). The co-authors acknowledged the issue and agreed that the evidence of these attributes is a critical requirement for HFE system methods. They also largely agreed that the challenging nature of reliability and validity studies contributes to this problem requiring a considerable amount of resources and the existing barriers, including limited knowledge and guidance on implementing these studies (Salmon, Read, *et al.*, 2020). According to the co-authors, potential solutions included improving guidance for conducting reliability and validity studies and stricter requirements when assessing system methods (Salmon, Read, *et al.*, 2020).

While the thesis's outcomes would indicate that the AcciMap approach did not produce reliable and valid results, the findings will need to be shared with the professionals and even safety experts who participated in these studies. This

step will foster discussions to gain new insights regarding their experiences using the AcciMap method and where the taxonomy and guidelines need to be improved. If the reliability and validity studies are to be repeated, the first step will be to liaise with relevant clinical safety stakeholders at local and national levels (highlighted in the recommendations section). This measure will require sustained training and applying the AcciMap and iterated taxonomy versions, a considerable amount of time to implement them in their practices before retesting the approaches. While the inter-rater reliability testing was the reliability assessment, the intra-rater reliability assessment can also be applied where the same set of participants repeat their analyses after a considerable time from the initial evaluation. Again, however, this assessment type is potentially time-consuming and resource-intensive. Despite these study challenges and issues raised, there is an ongoing need for further research to improve the reliability and validity of the AcciMap method and, generally, other systemic accident analysis methods.

8.3 Study Limitations

Each chapter had its challenges and limitations in addressing the reliability and validity of the Medi-Socio AcciMap approach compared to Branford's standardised AcciMap version. While chapters regarding reliability and validity studies discussed differences between participants' AcciMap results (contributing factors, causal links, and safety recommendations), they did not explicitly judge the significance of any found variations. The concluding chapter of Branford's thesis discussed extensively regarding different types of variations that can exist when analysing AcciMap results summarised as follows:

1.) Insignificant and potentially avoidable variations
2.) Significant and potentially avoidable variations
3.) Insignificant and unavoidable variations
4.) Significant and unavoidable variations are further broken down into:
    a. Accidental omissions of relevant factors
    b. Interpretations of ambiguous data
    c. Selection of outcomes

A future research study can potentially consider these aspects in re-evaluating the Medi-Socio AcciMap taxonomy approach and involving a larger clinical safety

practitioners sample size. This process will further determine these aspects from the AcciMap results that could be of practical significance. During the research, one reoccurring issue was the unavailability of clinical risk/human factors practitioners for AcciMap training and analysis. A larger sample size of safety practitioners would have been beneficial and allowed for a broader range of outcomes for similarities and variations to be analysed from the case incident. As explained in Chapter Six, challenges regarding reliability assessment study included very few patient safety practitioners available to participate in the evaluation. Several attempts were made to organise an AcciMap workshop in an NHS trust (NHS Nottinghamshire) after invitations were sent. However, due to a major NHS alert, many of them had to withdraw from the exercise. The second workshop was subsequently organised following the incident, but very few practitioners (2) were available after over fifty (50) participants were invited by the NHS trust's patient safety Lead.

In addition, the time allocated for each workshop was insufficient for training and analysis processes. To circumvent this limitation, each participant who agreed to the study analysed the incidents separately to have enough time to investigate and formulate their safety recommendations adequately. This arrangement required that all six professionals apply both AcciMap approaches on the first incident (first round) to be able to learn and gain experience before applying them again on the second incident (second round). Five out of six participants completed both analysis rounds. However, the remaining professional could not complete the analysis on the second incident (QMC case report), so the second set of AcciMap results was exempted from evaluation.

8.4 Recommendations/Future Directions

Before any further evaluation of the Medi-Socio AcciMap approach, its taxonomy will need to be revised, and maintaining a balance between granularity and completeness is crucial. Nevertheless, based on findings after applying the Medi-Socio AcciMap taxonomy, several recommendations are proposed in improving the proposed AcciMap approach:

1.) A critical recommendation will be to collaborate with relevant healthcare authorities at the local and national levels in applying SAA methods for live

accident analysis in healthcare practices. This measure is particularly essential because there haven't been real-life applications of the AcciMap method to investigate severe healthcare incidents (Wheway, 2020; Wheway and Jun, 2021). Considering the thesis's results, safety practitioners, including those responsible for health IT systems, must be adequately trained in SAA approaches. In addition, collaboration and feedback need to be strengthened between practice and researchers (i.e., human factors) regarding health IT research and analysis. Implementing the AcciMap method for real-world accident analysis will provide valuable information on its reliability, validity, and utility, including applying strict testing requirements to help narrow the present gap (Salmon, Read, *et al.*, 2020).

2.) Refining the Medi-Socio AcciMap taxonomy approach through a continuous cycle of evaluation, reviewing, redesigning, and retesting until higher reliability rates are achieved (Goode *et al.*, 2018). This process can be implemented in two ways; the first is a continuous evaluation with frontline staff by providing feedback on sub-categories that may appear similar. The other way will be to reduce sub-categories by merging sub-items to form new and broader sub-categories, thus creating a lite version of the Medi-Socio AcciMap taxonomy. This step was applied in developing the lite version of the TRACEr (Technique for the Retrospective and Predictive Analysis of Cognitive Errors in Air Traffic Control) (Isaac, Shorrock and Kirwan, 2002; Shorrock and Kirwan, 2002; Shorrock, 2003) approach and is very applicable in this case. The lite version of the Medi-Socio AcciMap taxonomy could be used for analysing single significant incidents and could potentially improve reliability and validity. The full Medi-Socio AcciMap version can be applied to analysing multiple incident data.

3.) Developing an automated means of applying the AcciMap approach for incident analysis. This measure is in response to the outcomes from Chapter Four and a crucial step in incorporating and encouraging more health organisations to apply systems thinking for accident analysis. Developing a software-based AcciMap tool incorporating an improved Medi-Socio AcciMap taxonomy could also enhance usability. In general,

developing and implementing an incident reporting database system based on the AcciMap methodology can benefit NHS practices and NHS Digital to analyse incidents relating to using Health IT systems. This measure has already been practically implemented for Led Outdoor Activities (Salmon *et al.*, 2017) and most recently for analysing patient injuries (Newnam *et al.*, 2020), both based in Australia.

4.) Closely related to the first proposal, the final recommendation will be developing a new profession within local healthcare systems that support SAA approaches on major incidents (including those relating to health IT). While the Health Safety Investigation Branch (HSIB), as a national body, uses SAA approaches, local safety groups working in tandem with resident health practices can help with applying these systemic methods for incident analysis. This measure also includes supporting safety recommendations in a structured manner that is open to challenge regarding practical significance in reducing risks and preventing reoccurrence.

8.5 Research Contributions

This research presented the development of the Medi-Socio AcciMap taxonomy, a health-specific classification scheme based on Branford's standardised AcciMap method. This proposed taxonomy consists of socio-technical aspects, including clinical software systems and interactions with medical practitioners in healthcare organisations. The approach is applicable for analysing software-related (IT) and non-IT related incidents in healthcare. Therefore, the continual development and evaluation of the Medi-Socio AcciMap approach can benefit health organisations, including providing a systematic and socio-technical analysis of systemic factors associated with IT systems utilised in healthcare.

More importantly, this thesis also demonstrated the adoption of Branford's methodology involving measuring the reliability and validity to evaluate and compare both standardised and the Medi-Socio AcciMap versions. Also, the proposed AcciMap approach was presented and discussed in a field meeting with safety practitioners at the Health Safety Investigation Branch (HSIB) headquarters, Farnborough, United Kingdom. Throughout the PhD research

journey, the following papers (journals and conferences) published in addition to the study cited in this thesis (Igene and Johnson, 2019), include:

1.) **Igene, O.O.**, Johnson, C.W., and Long, J. (2021). 'An evaluation of the formalised AcciMap approach for accident analysis in healthcare'. *Cognition, Technology & Work*, pp 1-21.
2.) **Igene, O.O.**, and Johnson, C.W. (2018). 'Comparing HFACS and AcciMaps in a Health Informatics Case Study – The Analysis of a Medication dosing error'. *Safety and Reliability – Safe societies in a changing world: Proceedings of European Safety and Reliability (ESREL 2018)*, pp 3-10.
3.) **Igene, O.O.**, Johnson, C.W., Long, J., Yinuo, L. (2017). 'Is the AcciMap Method an effective approach for analysing adverse events in the National Health Service, Scotland?' *Proceedings in the 12th International Symposium on Human Factors in Organisational Design and Management*, pp 447-457.

8.6 Closing Remarks

Beyond the objectives and research questions regarding assessing the reliability and validity of the proposed AcciMap approach, its taxonomy will require refinement to make it more intuitive and less time-consuming. This process requires further collaboration with health-based stakeholders, including human factors specialists, IT specialists, and clinical risk managers within the NHS system. In addition, this will require improving training workshops and specifically applying rigorous requirements for testing the proposed AcciMap during live incident investigations. Valuable feedback can be obtained from clinical safety practitioners using the approach in live accident investigations and could help improve its reliability and validity.

Finally, while national regulatory bodies (i.e., HSIB and the NHS Digital) apply various SAA approaches for investigating significant incidents across NHS, there is a need for firmer collaborations with clinical risk management teams at local NHS practices. Their experience and access to incident data, including data relating to software/IT-related incidents, will further help improve the Medi Socio AcciMap taxonomy and potentially adopt it across different NHS trusts and boards in the United Kingdom. This process is crucial in increasing the awareness of the unintended consequences that health-IT systems can introduce and how they can significantly impact the safety of patients and health organisations.

Appendix A: Accident Analytical Techniques and Causation Models (Appendix to Chapter Two)

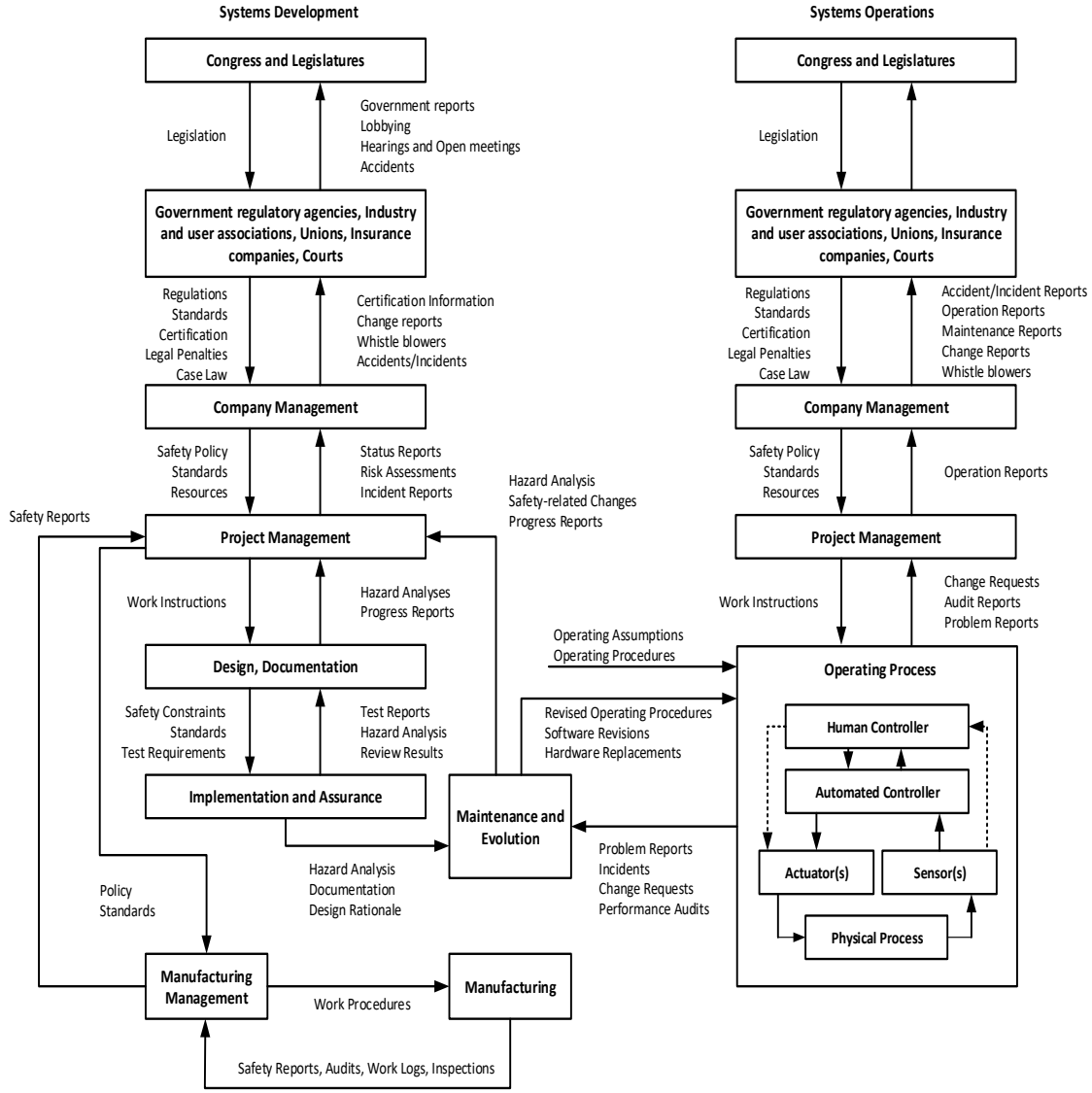
A-1 Accident Analysis Approaches

Approach Type	Approach Sub-type	Methods
Sequential	Events-based Reconstruction Techniques	• Accident Evolution and Barrier Function (AEB) • Cause-Consequence Diagram Method (CCDM) • Causal Tree Method (CTM) • Deviation Analysis (Integrated Safety Investigation methodology (OARU)) • Event Trees • Failure Tree Analysis (FTA) • Multilinear Events Sequencing (MES) • Root Cause Analysis (RCA) • Sequential Timed event Plotting (STEP) • Why-Because Analysis (WBA)
	Flow Charts and Taxonomies	• Management Oversight and Risk Trees (MORT) • Prevention and Recovery Information System for Monitoring and Analysis (PRISMA) • Human factors and Classification System (HFACS)
	Elicitation and Analysis Techniques	• Barrier Analysis • Change Analysis
Epidemiological		• Control Change Cause Analysis (3CA) • Australian Transport Safety Board (ATSB) • Casualty Analysis Methodology for Maritime Operations (CASMET) • Cognitive Reliability and Error Analysis Method (CREAM) • IPICA (Integrated Procedure for Incident Cause Analysis) • Integrated Safety Investigation Methodology (ISIM) • PG Diagram • PHARM-2E • Reason/Swiss Cheese Model (SCM) • SCAT (Systemic Cause Analysis Technique) • SOL (Safety through Organisational Learning) • STEP (Sequentially Timed Events Plotting) • TEM (Threat and Error Management) • Tripod β
	Argumentation Techniques	• Why-Because Analysis (WBA) • Conclusion, Analysis and Evidence (CAE) Network
Other		• 3D-Analysis • Critical Incident Technique • Elementary Event Analysis Method • Multi-Incident Analysis (MIA) • Performance Shaping Factor (PSF) • Software, Hardware, Environment, Livewire (SHEL) • Variation Tree • Viable Systems Model (VSM) • Work Accidents Investigation Technique (WAIT)

A-2 Accident Causation Model classification

Accident Causation Models		
Linear Accident Models	• Heinrich Domino Theory • Bird's Model • Kitagawa's Model • Orbit Intersecting Theory • Swiss Cheese Model • Stewart's Model • Occupational Accident Model • Offshore Oil and Gas Process Model • System Hazard Identification, Prediction, and Prevention (SHIPP) • 24Model	
Nonlinear Accident Models	• Human-based Accident Models	• Accident Prone Tendency (APT) • Accident Liability (AL) • Surry's Model • Hale's Model • Wigglesworth's Model • Lawrence's Model
	• Statistics-based Accident Models	• Accident Pyramid Model
	• Energy-based Accident Models	• Energy Transfer Theory (ETT)/Energy Accident Release Model (EARM) • Tripod Beta Model • Bow-Tie Model
	• Systems-based Accident Models	• Accident Epidemiology Model (AEM) • 3M and 5M • Socio-technical System and AcciMap • Systems-Theoretic Accident Model and Processes (STAMP) • Cognitive Reliability and Error Analysis Method (CREAM) • Integrated Procedure for Incident Cause Analysis (IPICA) • Functional Resonance Analysis Method (FRAM) • Teleo – Centric System Model for analysing Risks and Threats (TeCSMART) Framework

A-3 Generic Complex Sociotechnical Safety Control Structure (STAMP model) (Adapted from Leveson, 2011)



A-4 AcciMap Studies between 2000 to 2015 (Adapted from Waterson *et al.*, 2017)

No.	Title of Paper	Author(s)
1	Lessons From Longford: The Esso Gas Plant Explosion	Hopkins (2000)
2	Sociotechnical systems, risk management, and public health: comparing the North Battleford and Walkerton outbreaks	Woo and Vicente (2003)
3	Why-Because analysis of the Glenbrook, NSW rail accident and comparison with Hopkin's AcciMap	Ladkin (2005)
4	The Walkerton E. coli outbreak: a test of Rasmussen's framework for risk management in a dynamic society	Vicente and Christophsen (2006)
5	An investigation into the loss of the Brazilian space programme's launch vehicle VLS-1 V03	Johnson and de Almeida (2008)
6	Cassano-Piche *et al.* (2009) A test of Rasmussen's risk management framework in the food safety domain: BSE in the UK	Cassano-Piche *et al.* (2009)
7	A systems ergonomics analysis of the Maidstone and Tunbridge Wells	Waterson (2009)

No.	Title of Paper	Author(s)
	infection outbreaks	
8	Systems-based accident analysis in the led outdoor activity domain: application and evaluation of a risk management framework	Salmon *et al.* (2010)
9	Systems-based analysis methods: a comparison of Accimap, HFACS and STAMP	Salmon *et al.* (2012)
10	A systemic approach to accident analysis: A case study of the Stockwell shooting	Jenkins *et al.* (2010)
11	What could they have been thinking? How sociotechnical system design influences cognition: a case study of the Stockwell shooting	Jenkins *et al.* (2011)
12	Accident in a French dynamite factory: An example of an organisational investigation	Le Coze (2010)
13	Using Accimaps to describe the emergence of critical work situations e a systemic approach to analyse evaluation	Andersson (2010)
14	Seeing the big picture of mishaps e applying the AcciMap approach to analyse system accidents	Branford (2011)
15	Assessing organisational factors in aircraft accidents using a hybrid Reason and AcciMap model	Debrincat *et al.* (2013)
16	The crash at Kerang: Investigating systemic and psychological factors leading to unintentional non-compliance at rail level crossings	Salmon *et al.* (2013)
17	Systems thinking, the Swiss Cheese model and accident analysis: a comparative systems analysis of the Grayrigg train derailment using the ATSB, Accimap and STAMP models	Underwood and Waterson (2014)
18	The driver, the road, the rules … and the rest? A systems-based approach to young driver road safety	Scott-Parker *et al.* (2015)
19	An integrated graphic taxonomic associative approach to analyse human factors in aviation accidents	Lei *et al.* (2014)
20	Impromaps: Applying Rasmussen's Risk Management Framework to improvisation incidents	Trotter *et al.* (2014)
21	A systems approach to examining disaster response: Using Accimap to describe the factors influencing bushfire response	Salmon *et al.* (2014)
22	Safety in System-of-Systems: Ten key challenges	Harvey and Stanton (2014)
23	Applying the AcciMap methodology to investigate a major accident in offshore drilling: a systematic risk management framework for oil and gas industry	Tabibzadeh and Meshkati (2015)
24	Analysis for Yangmingtan bridge collapse	Fan *et al.* (2015)
25	Do not blame the driver: a systems analysis of the causes of road freight crashes	Newman and Goode (2015)
26	Systems-based approach to investigate unsafe pedestrian behaviour at level crossings	Stefanova *et al.* (2015)
27	An AcciMap analysis on the China-Yongwen railway accident	Chen *et al.* (2015)

Appendix B: Survey and AcciMap Results from Case Incident One (Wrong Patient) (Appendix to Chapter Three)

B-1 AcciMap Training Manual (Branford, 2007)

INSTRUCTIONS TO ACCIMAP ANALYSIS

AcciMaps can be developed using a whiteboard, large sheet of paper, sticky notes, or electronically using Microsoft Visio, depending on the analyst's preference. The following steps are included:

Step 1 - Create a blank AcciMap format on which to arrange the causes: Separate the file in Visio or on any large sheet of paper into the four sections of the AcciMap, with the heading s of the four levels on the left–hand side and horizontal lines separating each level.

Step 2 - Identify the Outcome (Accident): (1) From the accident data, identify the negative outcome(s) to be analysed: and (2) insert the outcome(s) into the "Outcomes" level of the AcciMap.

Step 3 - Identify the causal factors: On a separate page, make a list of all causes in the accident data, that is, all the factors for which you can say, "*had this been otherwise, the accident would (probably) not have occurred*". If you are unsure as to whether or not a factor is a cause, include it in the list – it can always be eliminated at a later stage.

Step 4 - Identify the appropriate AcciMap level for each cause: Next to each cause, write down the name of the AcciMap level to which it belongs. Then, refer to table 1 to determine the correct level. The first column in Table 1 defines the levels of an AcciMap and the second provide examples of the types of causes that may be found at each level.

<table>
<tr><th>I. Level Definitions</th><th colspan="3">II. Categories of Causes</th></tr>
<tr><td>The EXTERNAL level includes causes that are beyond the control of the organisation(s). this level includes factors relating to</td><td>GOVERNMENT, for example:
Budgeting issues government, cost-cutting
Inadequate legislation
Privatisation, outsourcing
Inadequate provision of services</td><td>REGULATORY BODIES, for example, inadequate:
Regulations, communication of regulations
Certification, permits
Safety standards
Enforcement of regulations
Auditing</td><td>SOCIETY, for example:
Market forces
Societal values, priorities (such as the public's requirement for quality, efficiency, comfort, affordability).
Historical events.
Global politics.</td></tr>
<tr><td>The ORGANISATIONAL level incorporates causes relating to organisational processes. Factors are placed in this level if they are within the control of the organisation(s) involved, for example</td><td colspan="2">FINANCIAL ISSUES, for example:
Organisational budgeting, cost-cutting.
Resource allocation problems.
EQUIPMENT AND DESIGN, for example:
Design problems (such as ergonomic issues, inaccessibility).
Equipment problems (such as poor quality, defective, ageing, untidy, missing or poorly maintained equipment or tools)
Equipment not used as</td><td>ORGANISATIONAL CULTURE, for example:
Incompatible goals (between safety and production or safety and budget, etc.).
Organisational acceptance or encouragement of shortcuts, non-compliance, etc.
RISK MANAGEMENT, for example, inadequate:
Hazard identification or risk assessment.
Hazard or defects reporting.
Processes for learning from past mistakes.</td></tr>
</table>

I. Level Definitions	II. Categories of Causes	
	designed. **DEFENCES**, for example, inadequate, insufficient, or missing: • Proactive system defences (such as alarms, warnings, barriers, personal protective equipment). • Reactive system defences (such as hazard containment, protection, escape and rescue systems). **COMMUNICATION AND INFORMATION**, for example, inadequate: • Information or knowledge. • Flow or organisation of information. • Communication of instructions, hazards, priorities, objectives, etc. **AUDITING AND RULE ENFORCEMENT**, for example, inadequate: • Implementation and enforcement of rules, regulations, or procedures. • Internal auditing, inspection.	• Awareness of risks. • Security (such as protection from unauthorised access). **MANUALS AND PROCEDURES**, for example: • Inadequate, ambiguous, conflicting, outdated, absent or difficult to follow procedures, rules, regulations or manuals. **HUMAN RESOURCES**, for example, inadequate or insufficient: • Supervision, management, coordination, staff numbers. • Delegation, accountability. • Staff selection procedures or criteria **TRAINING**, for example, inadequate or insufficient: • Training, training equipment, training exercise. • Training needs analysis
PHYSICAL/ACTOR EVENTS, PROCESSES AND CONDITIONS are the immediate precursors to the outcome(s) and should include factors relating to	**PHYSICAL EVENTS, PROCESSES AND CONDITIONS**, for example: • The physical sequence of events (including technical failures). • Environmental conditions and factors relating to physical surroundings which are necessary for making sense of the sequence of events	**ACTOR ACTIVITIES AND CONDITIONS, for example:** • Human errors, mistakes, violations, actions, activities, etc. • False perceptions, misinterpretations, misunderstandings, loss of situational awareness, etc. • The physical and mental status of actors (such as fatigue, ill health, inattention, unconsciousness, intoxication).

Step 5 - Prepare the causes: Write each identified cause on a sticky note (or equivalent), making sure that you:

1.) Keep it brief
2.) Use wording that makes it clear how things might have been different, that is, don't just say "training" or "operator actions", say "inadequate training" or "operator failed to monitor temperature" so that what went wrong is clear; and

3.) Use wording that suits the level that the cause is located in:
    a. Causes at the "Physical/actor events, processes and conditions" level should be phrased in terms of the actual errors, failures, conditions and

events that led to the accident (for example, “life raft failed to inflate” or “pilot failed to adjust heading”); and

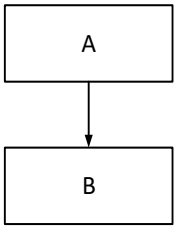
b. Causes at the “Organisational” level and above should not focus on the particular individuals involved (for example, say “Inadequate pilot training”, not “Pete Smith had not been adequately trained”).

Insert each sticky note (cause) into its appropriate level in the AcciMap.

If you have identified any causes which are not of practical significance but which need to be included so that the AcciMap make sense, draw an oval around these factors to distinguish them from the other causes.

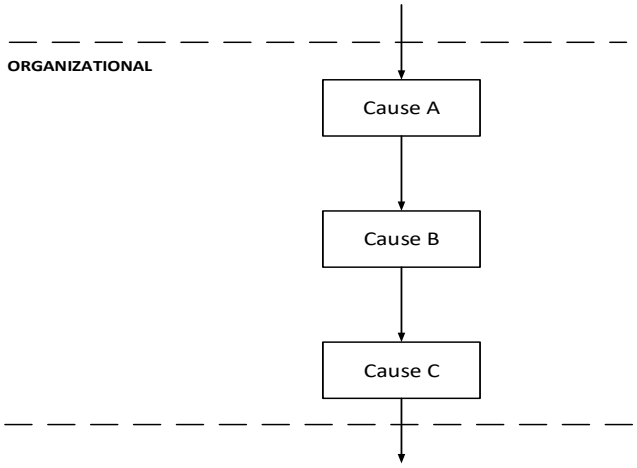
Step 6: Insert the causal links: Rearrange the causes in the AcciMap so that the causes lie directly above their effects (whether the effects are in the same level or in the level(s) below).

Consider each cause in the diagram and insert ca causal link between a cause and its effects if the following criteria are met:

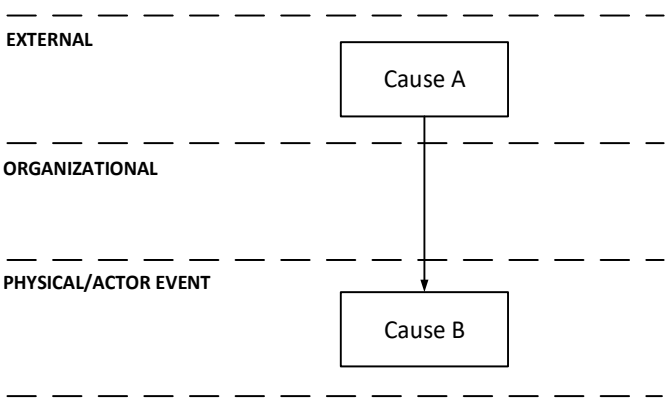


If one cause does not obviously lead on to the next, leave a space where the missing information can be inserted later.

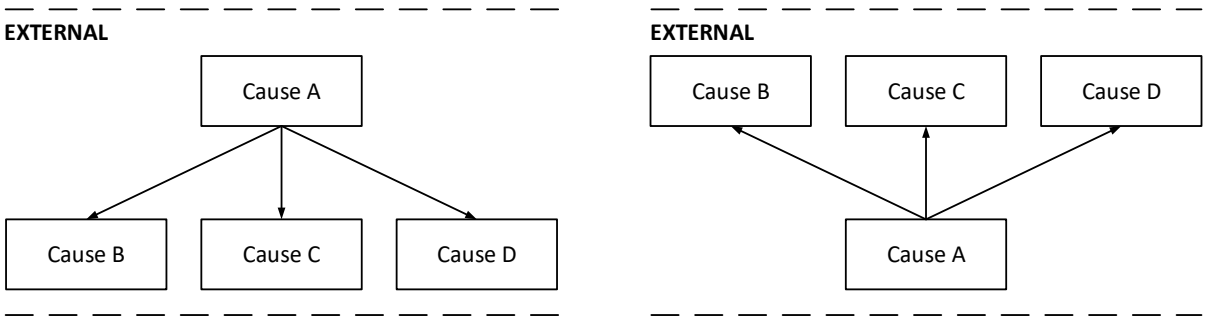
There is no limit to the number of causes to be included in any causal chain, and there may be multiple linked causes within the same level of the AcciMap:



Causes do not have to be linked to effects in the same level or in the level immediately below – they may be linked to factors several levels below:



Some causes may be linked with more than one effect. Conversely, several causes may be linked to one common effect. This means that no cause ever needs to be listed more than once in an AcciMap:



Step 7: Fill in the gaps: At this point, there may be gaps left in the causal chains where information is missing. These gaps must be filled so that the causal chains are unbroken from the earliest identified causes in each chain all the way down to the outcome(s) and so that every cause relevant to the accident is included in the AcciMap.

In order to uncover any missing causes, look at each cause on the AcciMap and ask why it occurred. Your AcciMap must include all factors which caused its occurrence or which failed to prevent it from occurring. Refer to Table 1 for help at this point. Table 1 is not an exhaustive list, but it will serve as a guide to the types of factors that may be relevant.

Aim to follow each causal chain as far as possible. Each chain should extend at least to the "Organisational" level (with the exception of the oval-shaped causes).

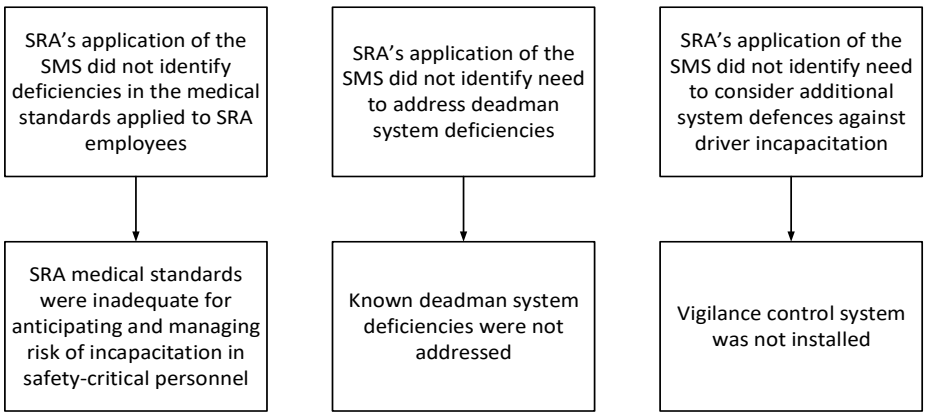
Be sure to include as many (but only as many) factors as are necessary so that someone reading your AcciMap will be able to understand the sequence of events and conditions without difficulty.

Step 8 - Check the causal logic: Go through each cause in the diagram and make sure that, had it not occurred, the factor(s) it is linked to (and the accident itself) would probably not have occurred.

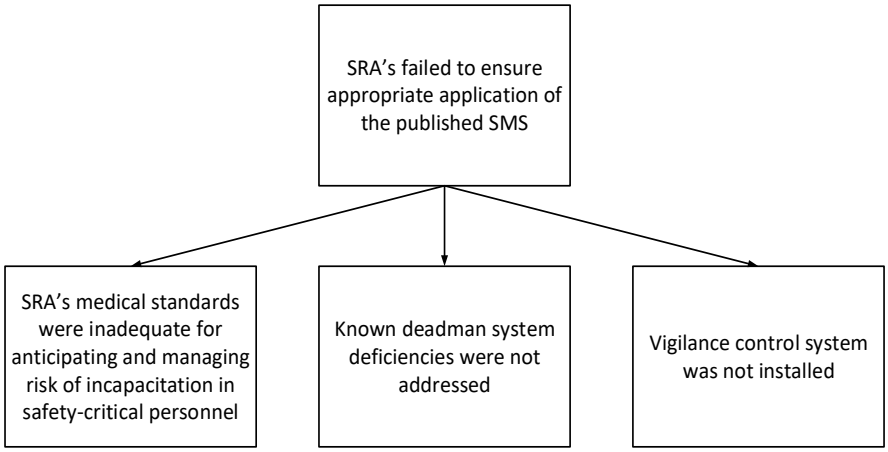
Go through each causal chain in the diagram and make sure that:

1.) Anyone reading the AcciMap will have no difficulty in making sense of the sequence of events;
2.) All of the arrows are facing downwards, towards the outcome(s); and
3.) No cause is listed more than once. If you have two or more similar causes, see if they can sensibly be combined into one more general cause. For instance, the following causes can be combined as follows (as they are in the sample

AcciMap), to simplify the diagram and to highlight that the SRA's application of the published SMS was inadequate in a number of respects and is therefore a problem area that should be addressed.



Can be combined as follows (as they are in the sample AcciMap), to simplify the diagram and to highlight that the SRA's application of the published SMS was inadequate in a number of respects and is therefore, a problem area that should be addressed.



Step 9 - Formulate safety recommendations: Go through each of the causal factors in your AcciMap and identify those which could potentially be changed, controlled or compensated for so that a similar outcome could not occur again. Safety recommendations must also be practical to implement:

- Formulate safety recommendations that identify what specifically should be done to change, control or compensate for each cause.
- Consider whether or not there is a more general problem area that should also be addressed (for example, if there are one or more problems relating to a certain part of a manual, it may be beneficial to recommend that the manual be reviewed, as well as the particular problem parts, to ensure that any inadequacies are addressed); and
- Identify the party responsible for making the required changes.

Note: Recommendations should aim to prevent similar accidents from occurring regardless of the individuals involved or the particular circumstances.
Compile a list of recommendations, grouped according to the partiers for carrying out the actions (as in figure 3). Each recommendation should be numbered and should identify the party responsible for making the change. Finally, check that every cause

you identified in the first part of step 9 has been addressed by one or more recommendations, if appropriate.

Note: Not all recommendations will necessarily be accepted by those responsible for implementing them. Issues of practicality, redundancy and cost-effectiveness may be relevant, and alternate solutions may be taken into consideration.

B-2 Summary of Events (Wrong Patient)

Time	Event (s)
6:15 am	The electrophysiology nurse (RN1) logged into the laboratory computer to check on morning schedules, called in the Telemetry unit to request for the patient (Jane Morrison) but was incorrectly told that the patient was moved to the Oncology floor.
6:20 am	RN called the Oncology floor (Joan Morris was transferred after her cerebral angiography) and was mistakenly notified that the patient was to be transferred to the electrophysiology laboratory).
6:30 am	The second nurse (RN2) agreed to transport the patient for the procedure but was informed about the plan by the charge nurse or Joan Morris's nurse from the previous evening. RN2 also informed the patient that she could refuse the procedure.
6:45 a.m.	The doctor spoke with the patient (Ms Morris), who was brought in by RN2. The patient expressed reluctance in undergoing the procedure due to feeling nauseated and general unwellness. The doctor (the attending) was surprised due to having met with the patient the night before. After speaking with the patient, intravenous prochlorperazine was administered to the patient to help reduce nausea.
6:45a.m. - 7:00 a.m.	RN1 noticed no consent indicated in the patient's chart even though it was stated in the daily schedule that the consent was obtained. The nurse also paged the electrophysiology fellow regarding the procedure.
7:00 a.m. - 7:15 a.m.	The electrophysiology fellow then reviewed the patient's chart and was surprised regarding the lack of important information. The fellow then discussed the nature of the procedure, and the patient then signed the consent for the EP study with both possible ICD (Implantable cardiac defibrillator) and PM (Pacemaker) replacements.
7:10 a.m.	RN1 informed the electrophysiology charge nurse that an earlier patient had arrived without mentioning the patient's name in the conversation.
7:15 a.m. - 7:30 a.m.	RN3 proceeded to attach the devices, including monitors on the patient, while also explaining the procedure. The patient (Ms Morris) indicated fainting to the nurse, who surmised it as a reason for the electrophysiology procedure.
7:30 a.m.	The resident (neurosurgery team) came in for morning rounds and discovered that the patient (Ms Morris) was not available in the room. The resident then learned about the procedure and enquired to know why it was the case. However, the patient's name was not used. RN1 then informed the resident

Time	Event (s)
	that the patient was being taken as the first case after being bumped twice. The resident then left, assuming that the attending had ordered the EP study without his knowledge.
8:00 a.m.	RN4 (an additional nurse) and the electrophysiology attending arrived. The latter could not see the patient's face at the computer console due to her head being draped. The fellow then initiated the procedure by inserting femoral sheaths and commencing the heart simulation via an intracardiac electrophysiology catheter.
8:30 a.m. - 8: 45 a.m.	RN5 from the telemetry floor then telephoned the electrophysiology laboratory to enquire why the patient (Jane Morrison, who was the correct patient) was not called. After consultation with RN4 regarding the expected completion time for Joan Morris, RN5 was then advised to send Ms Morrison by 10 a.m.
8:30 a.m. - 8: 45 a.m.	The electrophysiology charge nurse took note of "Joan Morris" not matching any of the five names listed in the morning log. She queried the fellow regarding the patient names in the electrophysiology laboratory. However, due to the state of the procedure, further conversations did not occur as the charge nurse assumed that the patient (Joan Morris) had been added after the advanced schedule.
9:00 a.m. - 9: 15 a.m.	An interventional radiology attending went into Ms Morris' room and was surprised to find it empty. A call was then made to the electrophysiology laboratory to find out why the patient was undergoing the procedure. The electrophysiology attending indicated to the nurse that the call was concerning the patient named Morris, but instead, Jane Morrison was currently on the table. However, the electrophysiology charge nurse corrected him that it was Jane Morris who was on the table. The attending (electrophysiology) then examined the patient's chart and noticed the error.
9:15 a.m. - 9:30 a.m.	The procedure was then aborted, and the patient was subsequently returned in a stable condition back to the oncology unit. The patient was then kept under observation and was discharged the following day. The error detected was also explained to the patient and the family. Outpatient neurosurgical follow-up was then arranged for the patient, and surgery was also scheduled for her aneurysm.

B-3 AcciMap Evaluation Questionnaire

Your Name (Optional):
Your Participant Number:
Your Team Number:
Before attending the introductory AcciMap training workshop

Q1.) Were you familiar with "systems thinking"?	Yes [ ]	No [ ]
Q2.) Where you aware of the AcciMap method?	Yes [ ]	No [ ]
Q3.) Had you previously used the AcciMap method in your NHS board before?	Yes [ ]	No [ ]

Questions on the use of the AcciMap Approach
The following is a set of statements about using the AcciMap method. For each statement, please say whether you:

[6] – Strongly agree
[5] – Agree
[4] – Slightly agree
[3] – Neutral
[2] – Slightly disagree
[1] – Disagree
[0] – Strongly disagree

Put a tick in the appropriate box

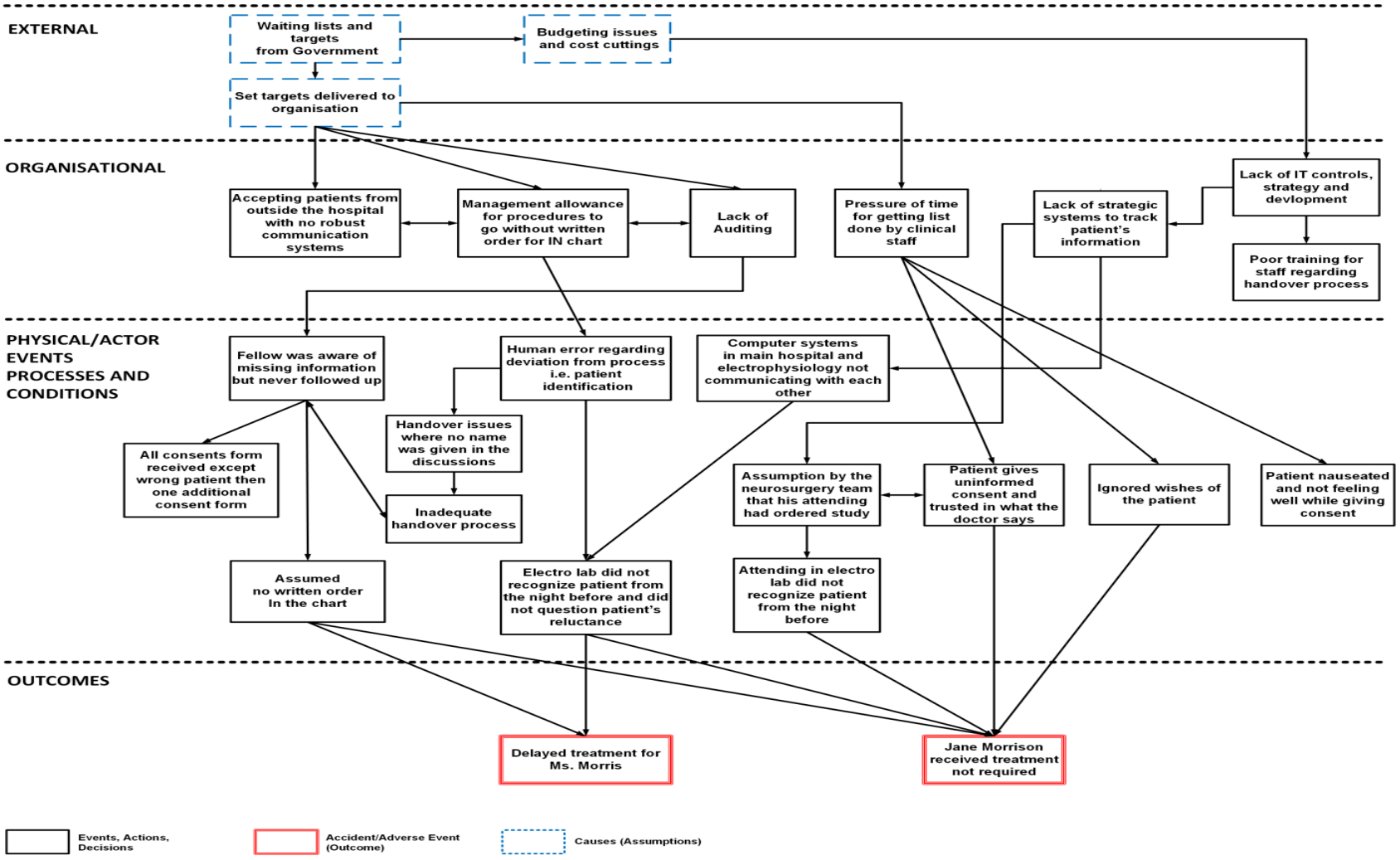
	Strongly Disagree			**Neutral**			**Strongly Agree**
Q4.) AcciMap is a suitable method for analysing accidents	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q5.) AcciMap effectively describes the timeline of events leading to the accident	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q6.) AcciMap effectively analyses the contributing factors to an accident from:							
a) Technical components, e.g., hardware, software	[0]	[1]	[2]	[3]	[4]	[5]	[6]
b) Human factors issues, e.g., workload, fatigue	[0]	[1]	[2]	[3]	[4]	[5]	[6]
c) Organisational issues, e.g., policies and procedures	[0]	[1]	[2]	[3]	[4]	[5]	[6]
d)Environmental issues, e.g., climate and noise levels	[0]	[1]	[2]	[3]	[4]	[5]	[6]
e) External issues, e.g., lack of oversight, budget allocation	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q7.) AcciMap provides a comprehensive description of an accident	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q8.) AcciMap effectively represents causal relationships between each level	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q9.) AcciMap accurately identifies	[0]	[1]	[2]	[3]	[4]	[5]	[6]

Put a tick in the appropriate box

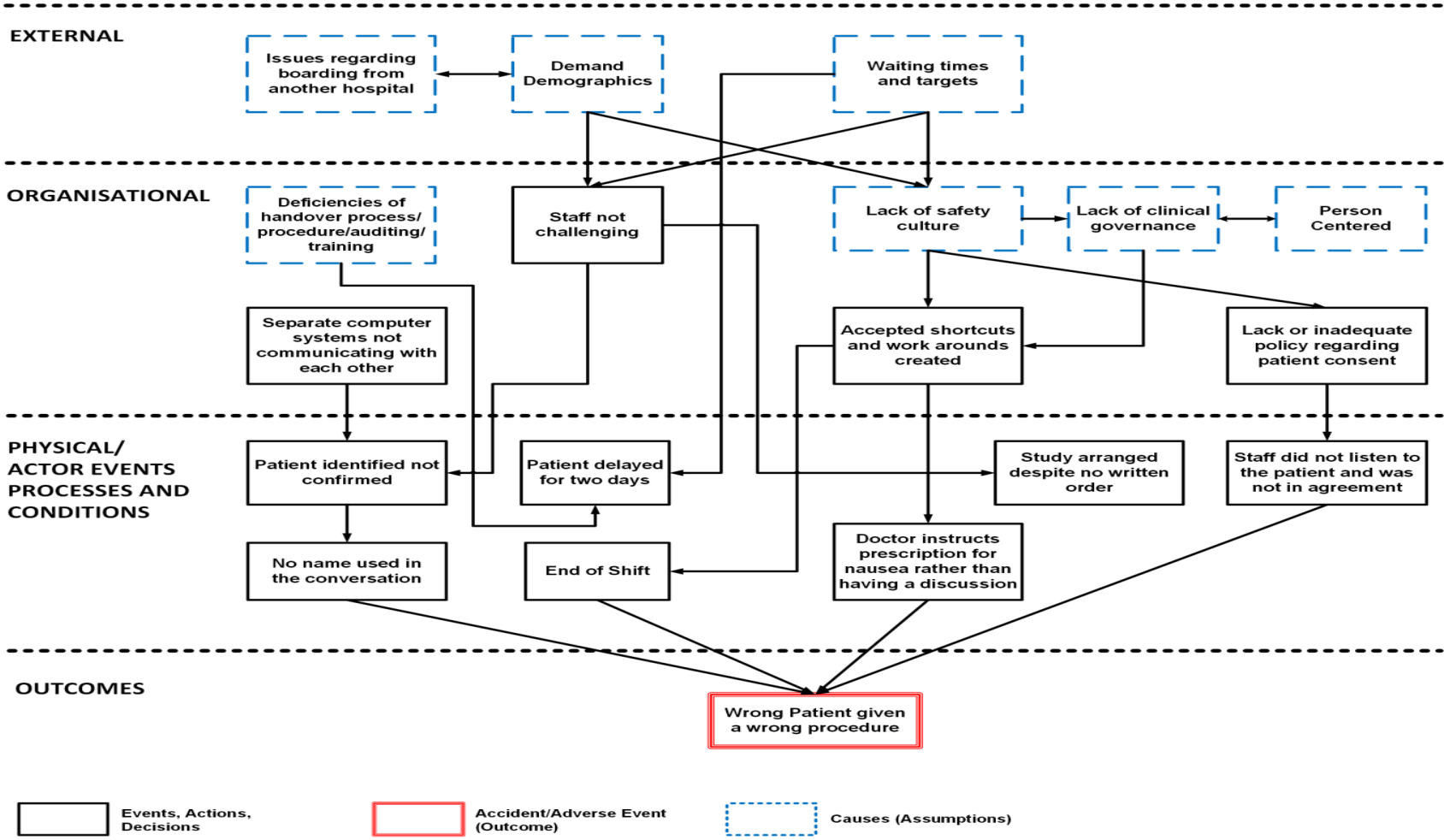
	Strongly Disagree			**Neutral**			**Strongly Agree**
the causes of an accident							
Q10.) AcciMap can be applied to analyse any type of accident in NHS trust	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q11.) AcciMap is an easy method to understand	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q12.) The terms and concepts used in the AcciMap method are clear and unambiguous	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q13.) It is easy to identify contributing factors that led to the accident	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q14.) It is easy to identify unsafe decisions that led to the accident	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q15.) AcciMap is an easy method to use for accident analysis	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q16.) AcciMap is easy to use in a team-based analysis	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q17.) AcciMap promotes team collaboration during analysis	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q18.) AcciMap's graphical diagram is a useful communication tool	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q19.) It would be easy for me to become skilled at using the AcciMap method	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q20.) AcciMap analysis can be completed in an acceptable timescale (within a few hours of the training workshop)	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q21.) AcciMap method is time-consuming	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q22.) I received sufficient introductory training in the use of the AcciMap method to effectively use this method.	[0]	[1]	[2]	[3]	[4]	[5]	[6]

Any other comments

B-4 Team B - AcciMap Output of Case Study



B-5 Team C - AcciMap Output of Case Study



Appendix C: Case Incident Two (CPOE Medication dosing error) (Appendix to Chapter Four)

C-1 Case Description: CPOE Medication Error

The patient was initially hypokalemic and was examined by the first physician (Provider A). A decision was then made to immediately replete the potassium by administering an intravenous (IV) bolus injection. As the events unfolded, the physician realised that the patient already had an IV and administered the KCl as an additional treatment. Several events took place that resulted in the patient receiving a higher KCl dosage than what was intended. A new dosage order was written after an initial dosage order was detected to be higher than what the hospital policy allowed and so was discontinued. However, this new dosage order was entered correctly into the CPOE system, and it did not contain the maximum volume of the fluid to be administered (Horsky, Kuperman and Patel, 2005).

On the next day, there was a changeover between the first physician and the incoming one (Provider B). The second provider was already notified to check the patient's KCl levels from the system but did not realize that the laboratory results were from before the last potassium repletion. As a result, the second provider thought that the KCl levels of the patient was low and so ordered an additional IV injection even when the KCl from the previous delivery had not finished running. The case was subsequently analysed within the health organisation, and safety recommendations were developed for their continuous learning process.

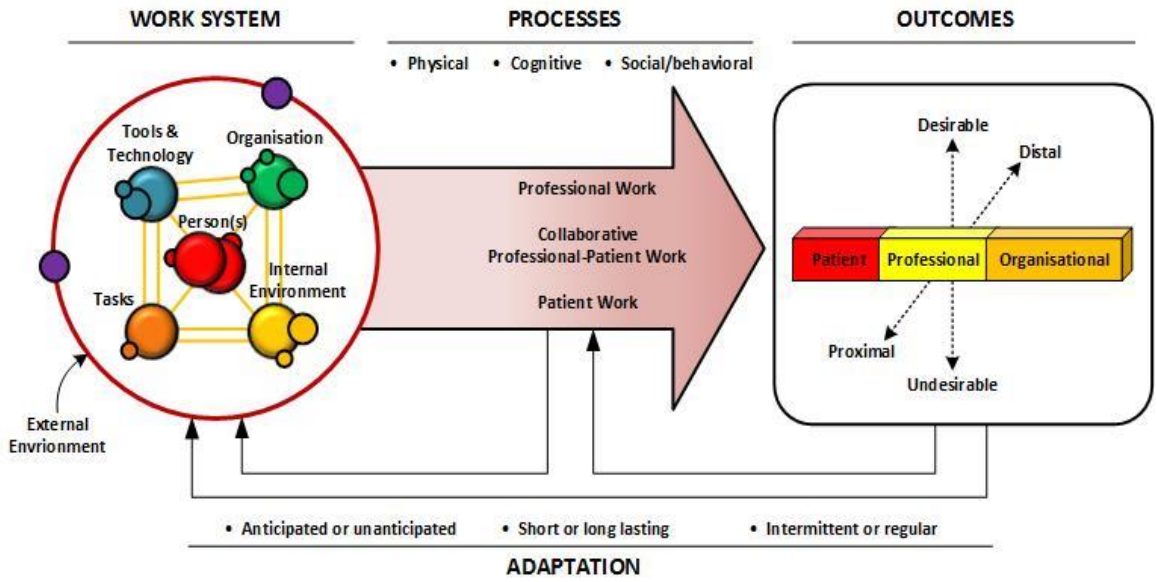
Time	Provider	Action	Type	Description	Notes/Findings	Order No.
Saturday 13.30 (7 min)	A	ACT	IV Injection	40 mEq KCl IV injection over 4 hr Decision	Correct order The provider wants to change IV injection of KCl to a medicated drip to avoid pain administration	1
		DC	Drip	D5W non-medicated fluid	Discontinues an older standing order (not in table)	2
		ACT	Drip	D5W with 40 mEq KCl 1,000 mL @ 75 mL/hr	Intended for 1 L of fluid only; free text volume limit, auto-stop in 7 days	3
		DC	Drip	Preceding order discontinued	Realizes the preceding order [3] was incorrect and discontinues	4
		ACT	Drip	D5W non-medicated fluid	Enters order identical to the one just discontinued [2]	5
		ACT	Drip	D5W with 100 mEq KCl 1,000 mL @ 75 mL/hr	Second attempt to enter drip order, similar to order [3]; now with a higher dose (100 mEq)	6

Time	Provider	Action	Type	Description	Notes/Findings	Order No.
		DC	IV Injection	KCl 20 mEq	Meant to discontinue order [1] but discontinued an expired order from 2 days before (not in table)	7
time lag				**49-min**	Pharmacy calls to warn about the order [6], which has dose over the limit (100 mEq, max allowed 80 mEq)	
Saturday 14: 26 (16 min)	**A**	DC	Drip	D5W non-medicated fluid	Discontinues non-medicated fluid order [5] in response to the call from the pharmacy	8
		DC	Drip	D5W with 100 mEq KCl 1,000 mL @ 75 mL/hr	Discontinues erroneous drip order [6] in response to the call from the pharmacy	9
		ACT	Drip	D5W with 80 mEq KCl 1,000 mL @ 75 mL/hr	Enters recommended 80 mEq. Intended for 1 L only, but no stop time entered; auto stop in 7 days	10
52-min time lag						
Saturday 15:34	**A**	DC	Drip	D5W with 80 mEq KCl 1,000 mL @ 75 mL/hr	The preceding order [10] discontinued	11
		ACT	Drip	D5W with 80 mEq KCl 1,000 mL @ 75 mL/hr	The same order [cf 10, 11] re-entered, runs for 36 hr and delivers 216 mEq KCl	12
27-hr time lag **Change of Providers**						
Sunday 18:36	**B**	ACT	IV Injection	40 mEq KCl IV injection	Misperceived older potassium laboratory values as current; did not notice running KCl drip [12]	13
34-min time lag						
Sunday 19:10	**B**	DC	IV Injection	40 mEq KCl IV injection	The preceding order [13] discontinued	14
		ACT	IV Injection	60 mEq KCl IV injection	Increased IV injection dose to 60 mEq	15
27-min time lag						
Sunday 19:37	**B**	ACT	IV Injection	40 mEq KCl IV injection	Another IV injection of KCl ordered; however, no clear evidence that it was	16

Time	Provider	Action	Type	Description	Notes/Findings	Order No.
					administered	
	ACT – Activate DC – Discontinue KCl – Potassium Chloride					

Appendix D: Development of the Medi-Socio AcciMap Taxonomy (Appendix to Chapter Five)

D-1 Systems Engineering Initiative for Patient Safety (SEIPS) Model (version 2.0)



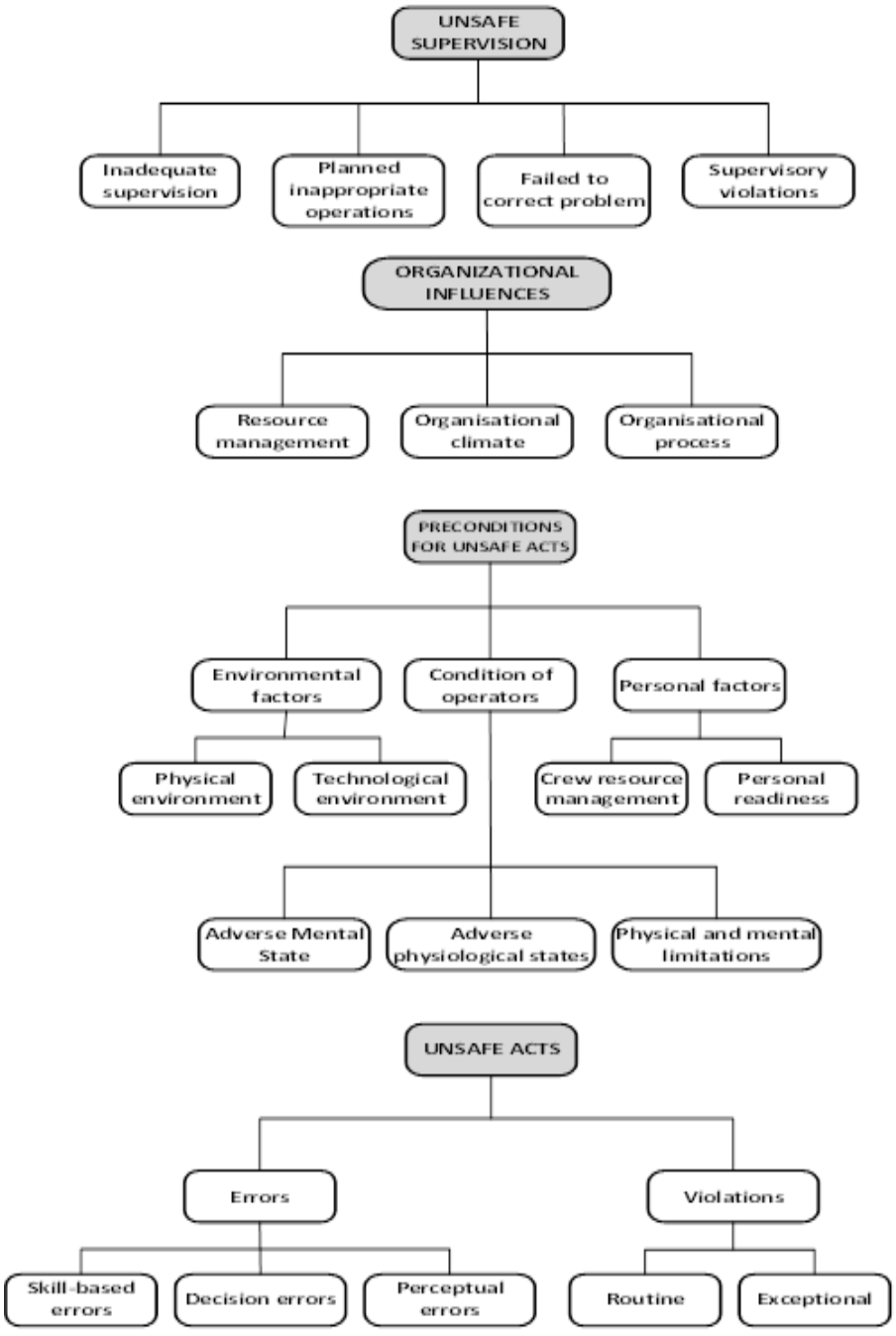
D-2 The Eight-Dimensional Socio-technical Model

Dimension	Description
Hardware and Software	Computing infrastructure used to support and operate clinical applications and devices
Clinical content	Includes text, numeric data and images that constitute 'language' of clinical applications, including clinical decision support
Human-Computer Interface	Includes all aspects of technology that users can see, touch or hear as they interact with it
People	Comprises of persons involved with patient care and interacts in some way with healthcare delivery (including technology). This includes patients, clinicians and other healthcare personnel, IT developers and other IT personnel, informaticians.
Workflow and Communication	Processes to ensure that patient care is carried out effectively, efficiently and safely
Internal organisational features	Policies, procedures, the physical work environment and the organisational culture that govern how the system is configured, who uses it, where and how it is used
External rules and regulations	Federal or state rules and billing requirements that facilitate or constrain the other dimensions
Measurement and Monitoring	Evaluating both intended and unintended consequences through a variety of prospective and retrospective, quantitative and qualitative methods.

D-3 The framework of Contributory Factors influencing Clinical Practice

FACTOR TYPES	CONTRIBUTORY INFLUENCING FACTOR
Patient Factors	• Condition (complexity and seriousness) • Language and Communication • Personality and social factors
Task and Technology Factors	• Task design and clarity of structure • Availability and use of protocols • Availability and accuracy of test results • Decision-making aids
Individual (staff) Factors	• Knowledge and skills • Competence • Physical and mental health
Team Factors	• Verbal communication • Written communication • Supervision and seeking help • Team structure (congruence, consistency, leadership)
Work Environmental Factors	• Staffing levels and skills mix • Workload and shift patterns • Design, availability and maintenance of equipment • Administrative and managerial support • Environment • Physical
Organisational and Management Factors	• Financial resources and constraints • Organisational structure • Policy, standards and goals • Safety culture and priorities
Institutional Context Factors	• Economic and regulatory context • National health service executive • Links with external organisations

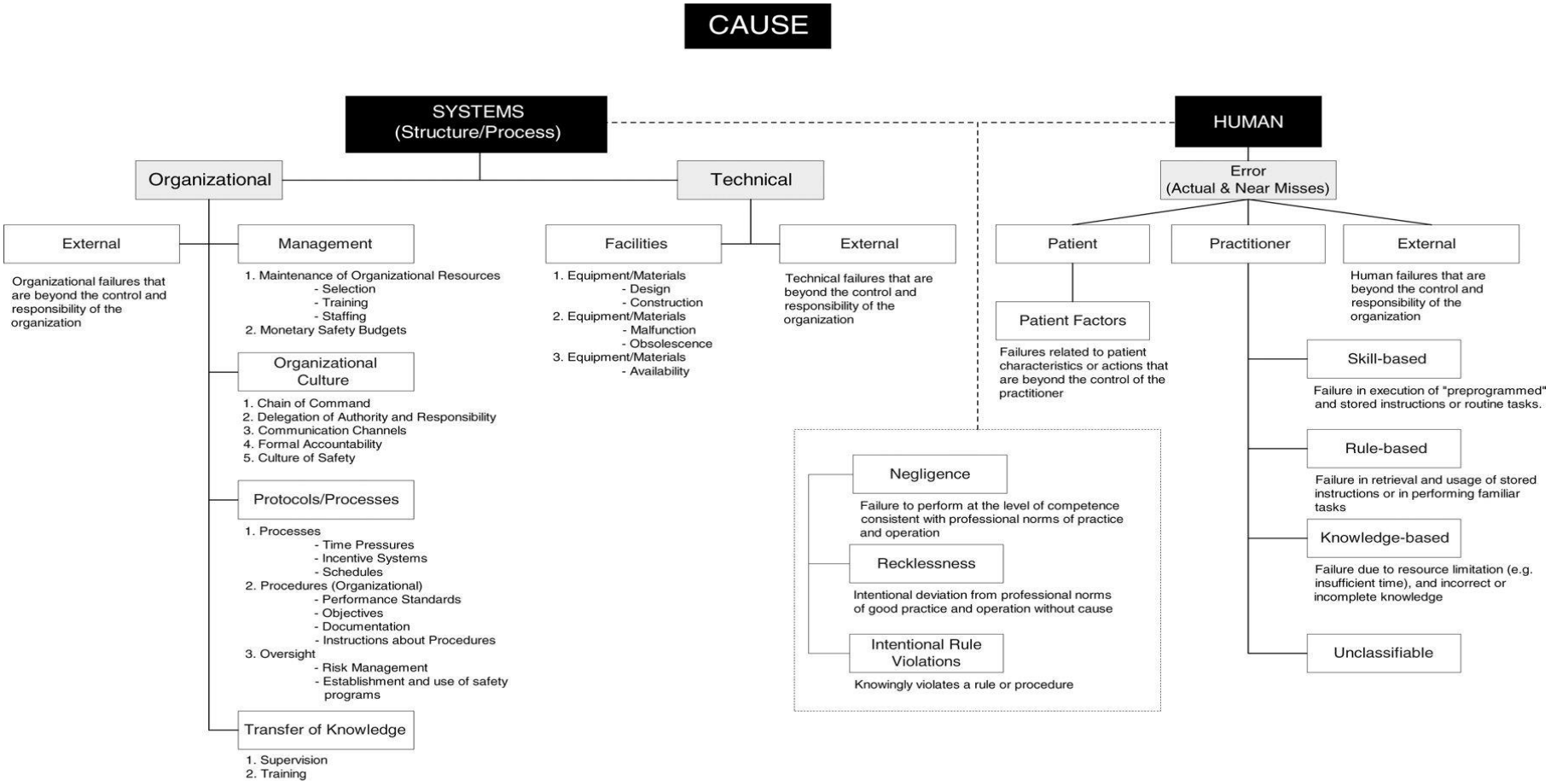
D-4 The Human Factors and Classification System (HFACS)



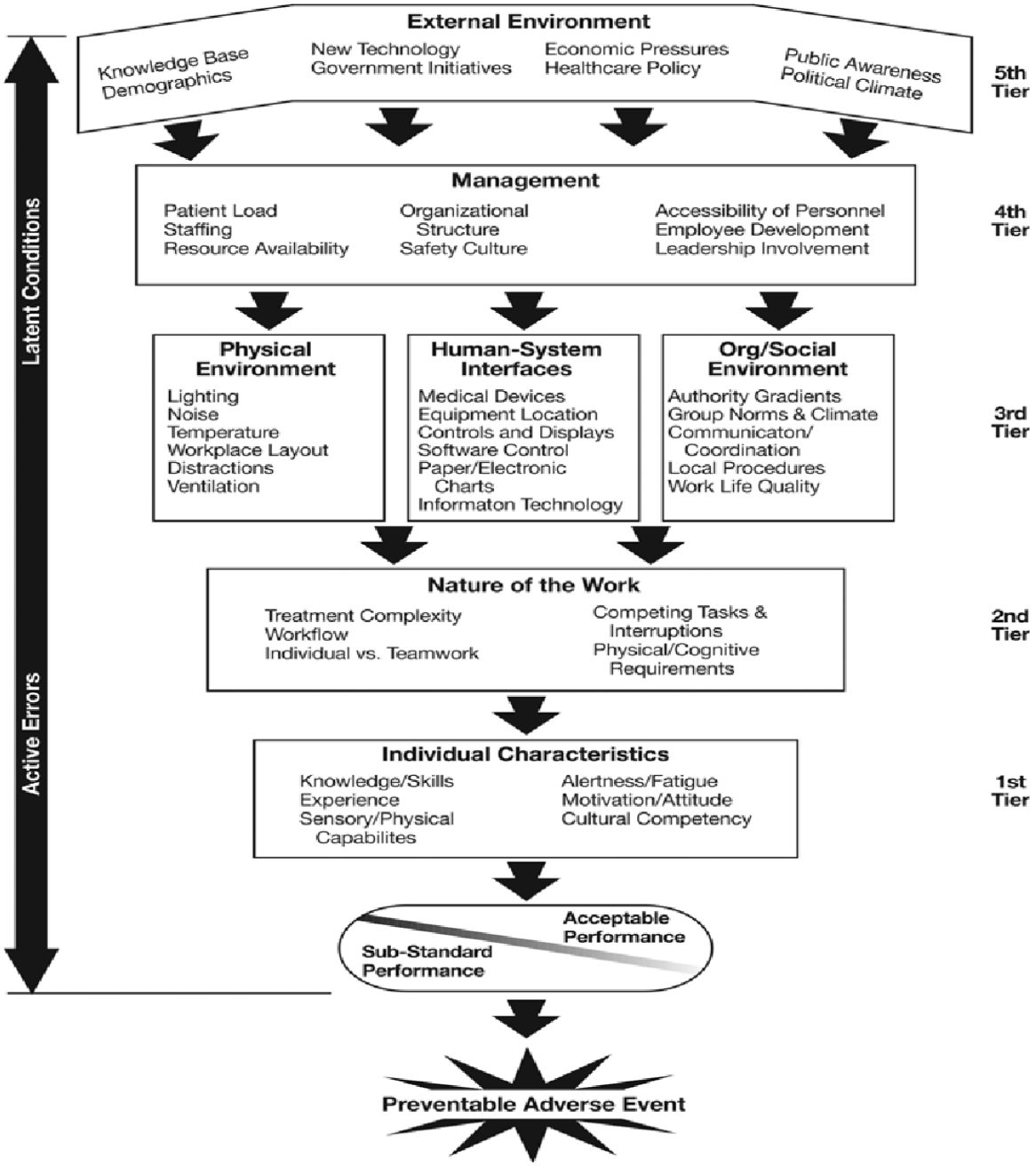
D-5 Human Factors Classification Framework (HFCF)

Contributing Factor Categories	Sub-categories
Medical equipment	• Lack of equipment
	• Medical equipment failure – design
	• Medical equipment failure or breakage
	• Medical equipment (not classified elsewhere)
	• Non-medical equipment or medical supplies
Work environment	• Light
	• Noise
	• Physical layout
	• Work environment (not classified elsewhere)
Staff action factors	• Communication or documentation issues
	• Medical task failure
	• Monitoring
	• Delay
	• Misdiagnosis
	• Medication issue
	• Staff action (not classified elsewhere)
Patient	• Physical health-pre-existing
	• Health state
	• Communication issues
	• Medication
	• Toxicology
	• Patient (not classified elsewhere)
Organisational factors	• Work practices, policies or guidelines
	• Supervision
	• Organisational resources
	• Work pressure
Individual factors	• Experience
	• Training
	• Fatigue
	• Stress
	• Individual factors (not classified elsewhere)
Other factors	

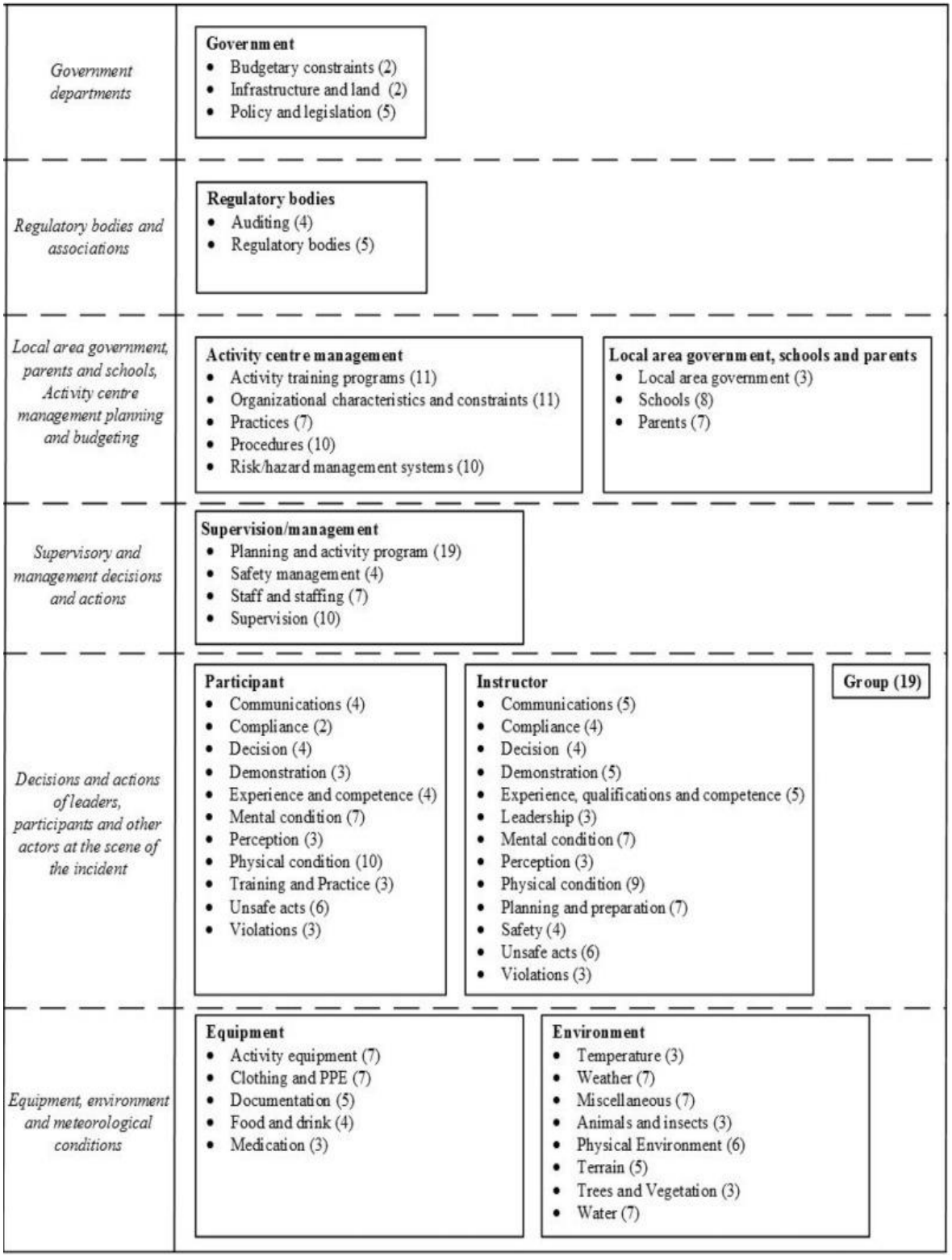
D-6 The Joint Commission on Accreditation of Healthcare Organisations (JCAHO) Patient Event Taxonomy



D-7 The Human Factors Framework – Contributing factors to Adverse events in healthcare



D-8 The Understanding, Prevention and Learning Outdoor Activities System (UPLOADS) Classification Scheme



D-9 Taxonomy guidance notes/description for each AcciMap level (Citations from existing taxonomies/frameworks)

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
Physical/Actor activities, Events, Processes and Conditions	**Patient-related Factors** *Comprises of actions, decisions and contributing factors that played a role in combination with other factors leading to increased risk and adverse outcomes.*	**Communication** ❖ *This consists of verbal or written communication between patients and medical staff, including doctors, nurses, etc.* ❖ *Contributing factors include non-existing, inefficient, inadequate communication or miscommunication with medical staff.*
		Medical condition (Complexity and seriousness) ❖ *This describes the medical and physical condition of the patient and how severe the condition is.*
		Unsafe acts ❖ *This refers to actions, slips committed by the patient that resulted in an undesired outcome.*
		Unsafe acts - Violations (Non-concordance) ❖ *This refers to any evidence of any form of deviation from existing rules or standards of practice by the patient that directly led to an adverse outcome.*
		Other ❖ *It consists of causes/contributing factors that were not captured under the "Patient" element.*
	Staff – Individual-related Factors *Comprises of actions, decisions and contributing factors that directly or indirectly affected patient safety. This*	**Communication and feedback** ❖ *Includes both verbal and written communication between clinicians and patients, between other medical colleagues and management.* ❖ *It also consists of a lack of communication, ineffective/inadequate feedback or miscommunication that resulted or contributed to the adverse event.*
		Compliance with procedures

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
	element focuses on individual decisions taken by different medical personnel.	❖ *This describes existing clinical procedures that medical personnel are required to adhere.* ❖ *Causes/contributing factors may include individual personnel not complying with existing safety-related procedures or not being carried out ineffectively, which led to patient harm.* ❖ *Non-compliance could be unintentional or intentional.*
		Unsafe acts ❖ *Describes actions taken by individual medical staff that directly or indirectly led to the adverse outcome.* ❖ *These are acts that cause adverse events could either be intentional acts that do not yield a positive outcome or unintentional acts that unwittingly deviates from planned intentions*
		Unsafe acts - Violations (Non-concordance) ❖ *Describes any evidence of wilful deviation from existing rules or standards of practice by individual staff members which directly caused an adverse outcome.* ❖ *These violations could either be **routine** (creating workarounds due to time pressure and that is tolerated by management) or **exceptional** violations (isolated departure from rules and not tolerated by management).*
		Physical and mental condition ❖ *Refers to the individual staff's physical and mental state that directly resulted or contributed to a negative outcome.* ❖ *Contributing factors include issues relating to cognitive resources involving working memory involved in, for example, learning and using health IT systems. Relying on memory could cause unintentional errors to be made.*
		Judgement and Decision making ❖ *Refers to clinical decisions taken by individual clinicians/medical persons that directly led to an adverse outcome.*
		Situation awareness ❖ *Refers to the awareness of the staff (individual personnel) of their surroundings and how they contributed or affected the patient's safety.*
		Experience and competence ❖ *Refers to acquiring basic skills, knowledge and applicability of skills in carrying out clinical tasks and using clinical IT systems*

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		as designed. ❖ *Contributing factors include inadequate knowledge of medical tasks and health IT mechanisms and unfamiliarity with IT systems.*
		Other ❖ *Refers to causes or contributing factors that could not be classified under the "Staff-Individual" element.*
	Staff – Team-related Factors *Comprises of actions, decisions and contributing factors that are directly or indirectly affecting patient safety. This element focuses on decisions taken by a group of medical personnel.*	**Communication and feedback** ❖ *This consists of both verbal and written communication between different staff members and management.* ❖ *Contributing factors can include miscommunication, lack of feedback, and ineffective feedback mechanisms within teams and higher authorities.*
		Compliance with procedures ❖ *Describes existing clinical procedures that medical teams are required to adhere to.* ❖ *Causes/contributing factors may include a team of medical staff not complying with existing safety-related procedures or procedures carried out ineffectively, which led to patient harm.* ❖ *Non-compliance could be unintentional or intentional.*
		Unsafe acts ❖ *Describes actions taken by medical staff in teams or groups that directly or indirectly led to the adverse outcome.* ❖ *These acts could be intentional acts that do not yield a positive outcome or unintentional acts that unwittingly deviates from planned intentions.*
		Team structure ❖ *Refers to the number of staff members assigned to handle clinical tasks. This also can include the adequacy of the team composition and their experience/competence.*

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		Teamwork and coordination ❖ *Refers to a range of coordinated team-based activities that impact performances and how they directly contribute to the patient's safety.*
		Other ❖ *Refers to causes/contributing factors that could not be classified under the "Staff-team" element.*
	Staff – Local Management related factors *Comprises of actions, decisions and contributing factors that are directly or indirectly affecting patient safety. This element focuses on decisions taken by supervisors who coordinate other staff where the adverse event occurred.*	**Communication and feedback** ❖ *Communication (both verbal and written) between staff supervisors/clinical heads and subordinates that directly and indirectly contributed to the adverse outcome.* ❖ *Contributing factors can include miscommunication, lack of feedback and ineffective feedback mechanism between supervisors, clinical staff and higher authorities.*
		Compliance with procedures ❖ *Describes existing clinical procedures that are required to be adhered to by supervisors/clinical heads.* ❖ *Causes/contributing factors may include supervisors not complying with existing safety-related procedures or ineffectively carrying out the processes, which led to patient harm.* ❖ *Non-compliance could be unintentional or intentional.*
		Unsafe acts ❖ *Refers to local clinical management's actions, events, and errors that directly contributed to the adverse outcome.*
		Unsafe acts - Violations (Non-concordance) ❖ *Describes supervisors' actions of departure from existing rules or standards of practice that directly caused an adverse outcome. These violations could either be routine or exceptional.*
		Physical and mental condition ❖ *Refers to the physical and psychological state of the local management personnel (supervisors) that contributed directly to*

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		the adverse outcome. ❖ *Contributing factors include issues relating to cognitive resources involving working memory involved in, for example, learning and using health IT systems.*
		Judgement and decision making ❖ *Refers to clinical decisions taken by the local (clinical) management that directly led to the accident.*
		Situation awareness ❖ *Refers to the awareness of the staff (supervisors/clinical) of their surroundings and how they contributed or affected the patient's safety.*
		Experience and competence ❖ *This describes the experience and competence of the local management personnel (supervising staff) involved with either patient, individual staff or teams.* ❖ *Contributing factors can include inadequate knowledge on medical tasks and health It mechanism as unfamiliarity with IT systems.*
		Supervision ❖ *Refers to how individual staff/teams are monitored by local management to ensure compliance and achieving safety standards. This includes factors relating to oversight of staff.*
		Other ❖ *Other categories associated with the staff-local management that could not be classified in the categories.*
	Environment-related factors *Consists of contributing factors relating to both the physical characteristics of the*	**Physical layout** ❖ *Describes physical and structural settings (e.g., ICU rooms, surgical rooms) where medical staff work and use Health software systems and other equipment.* ❖ *Contributing factors include issues relating to the design of facilities, ambient environment features, noise, lighting, temperature etc.*

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
	workplace where health practitioners perform both clinical and other related tasks and work conditions of the environment. This also includes the state and availability of equipment used for clinical purposes.	**Staffing levels and skill mix** ❖ *This describes both the number of available staff and level, the relevance of skill and experience applying those skills for different tasks.* ❖ *Contributing factors include lack of staff experienced in using health IT systems, inadequate staff for clinical activities, and inadequately experienced staff etc.*
		Workload and shift patterns ❖ *This refers to the amount of work carried out by staff and how they work to achieve the organisation's productivity and patient safety needs.* ❖ *Contributing factors include work overload can cause stress and fatigue for health practitioners.*
		Administrative/managerial support ❖ *This refers to how supportive the management is with medical personnel in promoting a safety culture within the organisation.*
		Time Pressure ❖ *Refers to the pace of work (clinical activities) and time associated with those tasks that need to be completed to achieve expected safety performance standards and productivity.* ❖ *Time pressure is considered a major contributing factor associated with demands created by the hospital management, which could lead to consistent errors.*
		Clinical equipment and IT systems availability ❖ *Refers to existing systems and equipment that are available for health practitioners to carry out their activities.* ❖ *Contributing factors include equipment and systems not available due to defects, lack of real-time information.*
		Other ❖ *Other categories associated with the "Environment" element that could not be mapped in the preceding categories.*
Organisational	**Information Technology**	**Software – functionality**

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
Level – Technical Operational Management	**related factors** *Comprises of contributing factors relating to the design, implementation and use of Health IT systems (software/hardware) for clinical purposes. This element is also within the control of the health organisation that provides them.*	❖ *Refers to the software component of the health IT system operating as designed and intended for clinical operations.* ❖ *Contributing factors in this category include software malfunction, bugs, programming errors (e.g., patch installation), and slow response times.* ❖ *The functionality of software systems could also be too complex and not intuitive enough, especially for new/inexperienced users.*
		Software - configuration ❖ *Refers to the ability to alter the settings of the clinical software by end-users to improve their tasks, e.g., setting alerts.* ❖ *Contributing factors in this category can include limited settings or difficulties in changing operational settings of clinical software.*
		Hardware - functionality ❖ *Refers to the hardware component of the health IT system operating as designed and intended for clinical operations.* ❖ *Contributing factors include*
		Hardware – configuration ❖ *Refers to the hardware component of the health IT system operating as designed and intended for clinical operations.*
		Network configuration and availability ❖ *This refers to contributing factors relating to network communication devices.* ❖ *Contributing factors can include, e.g., network temporarily unavailable, slow network, inadequate IT network, limited security, configuration issues, etc.*
		Health IT system workflow integration ❖ *Refers to the ability of health IT systems to integrate within real-world clinical workflow without compromising patient safety.* ❖ *Contributing factors can include, for example, existing clinical workflows being affected in unanticipated ways when IT systems are implemented.*
		Accessibility of health IT systems

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		❖ *This refers to the features/functions of Health IT systems being available and ready for clinical use.* ❖ *Contributing factors can include functions not being easily accessible or difficulty in implementing specific functions of Health IT systems.*
		Interoperability of health IT systems ❖ *Refers to its ability to seamlessly work with other health IT systems from different health units/departments.* ❖ *It also includes the ability to exchange relevant health information between health IT products and across organisational boundaries.* ❖ *Contributing actors would include ineffective, inadequate or non-existing interoperability between existing IT systems, independently developed computer systems and non-transfer between IT systems etc.*
		Other ❖ *Other categories associated with the "Information Technology" element that could not be classified in the preceding categories.*
	Clinical IT Management-related factors *Comprising of contributing factors relating to the management of new and existing health IT infrastructure by health IT professionals and hospital management.*	**Communication and feedback** ❖ *Refers to both verbal and written (electronic) communication issues between Health IT vendors, health IT professionals (within the clinical practice), hospital management and clinicians who use these systems.* ❖ *Contributing factors include gaps in communication, miscommunication between IT management and staff that utilises health IT systems, inefficient feedback mechanisms.*
		Delivery of IT training and services ❖ *Refers to the provision and effectiveness of training and services (e.g., repairs and updates) for clinicians in effectively using Health IT systems for clinical purposes.* ❖ *Contributing factors relating to inadequate delivery of IT systems that fit with existing clinical workflows and quality of training regarding the use of new IT systems.*
		Selection of Health IT systems ❖ *Refers to identifying health IT systems that appropriately fit staff's tasks, workflow, and clinical activities in different*

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		medical units. ❖ *Contributing factors include issues relating to the selection of appropriate IT systems that are useful for medical staff.*
		Evaluation of Health IT systems ❖ *Refers to activities for measuring the reliability of health IT systems, e.g., system usability, system functionality.* ❖ *Contributing factors include, for example, inadequate or non-existing tools for evaluating IT systems.*
		Safety and risk management processes ❖ *Refers to clinical risk management activities, including risk identification, risk analysis (potential hazard identification and estimation), risk evaluation and risk control* ❖ *Contributing factors include, for example, issues relating to non-implementation of risk management activities during the life cycle of health IT systems deployed and the inadequate or inconsistent application of these activities.*
		Maintenance of Health IT systems ❖ *Refers to activities including ensuring that health IT systems are functional, up-to-date and improving clinical efficiency and workflow.* ❖ *Lack of implementation or inadequate maintenance activities including not having efficient and timely updates, especially in situations where IT systems crash, not adapting to ever-changing user environments and technologies*
		Health IT implementation processes ❖ *Refers to a set of interrelated activities regarding implementing Health IT systems that potentially contributed to increased patient harm.* ❖ *This section also includes inadequate, inefficient or existing processes not correctly carried out, for example, when implementing new IT systems.*
		Procurement of health IT systems ❖ *Refers to the management ensuring that Health IT systems and manufacturers comply with existing policies regarding the availability of clinical safety case reports in aiding risk analysis.* ❖ *Contributing factors potentially include*
		Other

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		❖ *Other categories associated with the "clinical IT management" element that could not be classified in the preceding categories.*
	Human-Computer related factors *This system element constitutes contributing factors relating to the interactions between users (clinical staff) and health IT systems.*	**Usability – Information display/interpretation** ❖ *Refers to the ease of how information is processed, displayed and interpreted by clinical staff.* ❖ *Contributing factors, e.g., staff missing critical results due to the structure of table list (long) or the options menu, poor data display, poor alert display, use of abbreviations (or truncated items), etc.*
		Usability – Data entry and selection ❖ *Refers to how data is entered by clinical staff and the ease of carrying out this function.* ❖ *Contributing factors include issues relating to the selection of items from menus, difficulties in entering appropriate data due to inconsistent measurements.*
		Usability – Design Consistency ❖ *Contributing factors can include inconsistency of expressions (e.g., metrics for patient's height), inappropriate button names, unclear label names, inconsistent user interface component placement etc.*
		Usability – Interface design ❖ *Refers to the design and feel of clinical software systems.* ❖ *Contributing factors can potentially include inflexibility of health IT systems, poorly designed scope and content of IT systems, and information displayed across different screens, increasing the cognitive load on staff.*
		Other ❖ *Other categories associated with the "Human-Computer "element that could not be mapped in the preceding categories.*
	Equipment-related	**Maintenance of clinical equipment**

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
	factors (Non-IT) *Comprises of contributing factors relating to non-IT equipment, including its design and functionality.*	❖ *Refers to maintenance activities in place to keep medical equipment operational for clinical purposes.* ❖ *Lack of implementation or inadequate maintenance activities, including efficient and timely updates, not adapting to ever-changing user environments and technologies*
		Suitability of clinical equipment ❖ *Refers to how suitable and applicable medical equipment is for staff to use in clinical settings.* ❖ *Contributing factors include existing equipment not practicable or not fitting in with clinical procedures or workflow of medical units.*
		Functionality of clinical equipment ❖ *Refers to how efficient and well the equipment performs its given operations as designed.* ❖ *Contributing factors potentially include parts or the whole equipment not operating properly or as it should be operated.*
		Access/availability of clinical Equipment ❖ *Refers to how accessible the equipment is and if they are available for operations.* ❖ *Contributing factors can include equipment not being available when needed.*
		Design of clinical equipment ❖ *Refers to how the equipment is designed and if it fulfils its operation.* ❖ *Contributing factors can include, for example, poor equipment design, defective equipment etc.*
		Other ❖ *Other categories associated with the patient that could not be mapped in the preceding categories.*
Organisational Level – Company Management and Local Area	**Hospital (High-level) Management related factors** *Comprising contributing*	**Communication and feedback** ❖ *This refers to the flow (both verbal and written) of information (for example, communication of instructions) with clinical staff.* ❖ *This also includes receiving feedback from frontline staff in the form of incident reports.*

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
Planning	*factors indicating latent conditions regarding decisions and existing policies on clinical risk management and safety practices that are within their control.*	❖ *Contributing factors include gaps in communication, miscommunication between management and staff, inefficient feedback mechanisms.*
		Staff supervision ❖ *Refers to how clinical personnel are monitored by management to ensure compliance and achieving safety standards.* ❖ *Examples of potential contributing factors can include inadequate oversight of staff, lack or inadequate provision of training, appropriate orientation, and safety information regarding clinical tasks, including using IT systems.*
		Judgement and decision making ❖ *This refers to clinical and safety decisions taken by hospital management in conjunction with different stakeholders.* ❖ *This can include decisions on if the implementation of Health IT fits in with existing clinical workflow, appropriate training regarding their use and recruitment of experienced staff, e.g., people who may have extensive IT knowledge in addition to their medical expertise.*
		Internal auditing and inspection ❖ *Refers to internal processes/activities to assess, evaluate, and improve the care and safety of patients. This also includes evaluating the performance of medical personnel and the IT systems used by them. This forms part of clinical governance.* ❖ *Contributing factors can include ineffective auditing or none existing procedures regarding staff periodic inspection and IT performance.*
		Enforcement of rules and procedures ❖ *Refers to a set of activities carried in ensuring that rules and procedures are effectively carried out by staff as part of enhancing patient safety.* ❖ *Contributing factors may include issues relating to the lack of enforcement of procedures for maintaining safety in the health environment and patient safety.*
		Organisational processes ❖ *Refers to processes both within and between other organisations to get things done (e.g., safety and quality programs) and identify any systemic issues.* ❖ *Contributing factors may include inadequate or non-rigorous processes (existing) for identification of systemic issues, processes not addressing safety concerns or identifying potential hazards.*

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		Financial Constraints ❖ *This includes contributing factors relating to limited funding and a constrained budget, leading to limited staff recruitment, availability of clinical IT systems and training in their safe use.*
		Policies, protocols and procedures ❖ *Describes existing management policies/procedures that are meant to guide and promote patient and system safety and governance in clinical practice.*
		Safety culture and priorities ❖ *Describes the "way safety processes are carried out" in health organisations.* ❖ *This also includes what areas need to be improved upon to enhance the safety of patients, systems, and assets. This can be from incident reporting.* ❖ *Contributing factors potentially include culture allowing staff to create "workarounds" when using IT systems which could put patients at risk. Lack of incident reporting is also a reflection on the state of the safety culture of the health organisation.*
		Staff training and evaluation ❖ *This subcategory relates to the quality of training and can include the following:* *1.) Applicability of Training* *2.) Recency of Training* *3.) Level of Training* *4.) Applicable operational experience* 5.) *Language or cultural barriers to training* ❖ *Contributing factors include quality of training regarding the use of IT systems and executing clinical tasks.*
		Other ❖ *Other categories associated with the hospital (high-level) management element that could not be mapped in the categories.*
	Health Information	**Communication and feedback**

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
	Technology (IT) Vendor related Factors *Comprises of contributing factors relating to the design, manufacture, implementation, and software/hardware for clinical purposes. This element is also within the control of health organisations in collaboration with Health IT vendors/manufacturers.*	❖ *This refers to communication (both verbal and written) and feedback based on the clinical software system's operation, including the system's design for its intended purpose.* ❖ *Contributing factors include communication issues between hospital management, clinical IT management, Health IT vendors/manufacturers and stakeholders.*
		Knowledge of clinical processes ❖ *This relates to the adequacy and knowledge of the clinical processes in the development of clinical IT systems.* ❖ *Contributing factors potentially include, for example, inadequate transference of existing or new clinical processes into the designing and updating of health IT systems.*
		Software design processes ❖ *This describes the processes involved in the programming and development of the clinical software for its intended purpose.* ❖ *Activities include requirement activities, software development and designing of user interface activities.* ❖ *Contributing factors include, for example, issues relating to software requirement analyses (e.g., performance), lack or insufficient prototype testing and safety analyses.*
		Health IT system testing processes ❖ *Relates to testing activities for the clinical software system developed for any errors and bugs that may exist and operating as expected.* ❖ *Contributing factors include, for example, issues relating to testing protocols for new health IT systems before deployment and during the system's life cycle.* ❖ *This also includes insufficient failsafe mechanisms and systems testing not being extensive enough, especially when dealing with actual data under realistic conditions.*
		Health IT implementation processes ❖ *This relates to activities relating to software deployment, maintenance and upgrade.* ❖ *Contributing factors include issues relating to lack of participation with clinical users before deployment, inadequate mechanisms for identifying areas for needed maintenance*
		Quality management processes

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		❖ *Relates to activities in ensuring that Health IT systems (Software and hardware) and other medical equipment are up to the standard required for clinical operations.* ❖ *Contributing factors can include, for example, issues relating to adherence to standards and best practices in developing IT systems that are useful for medical staff.* ❖ *Other examples include inadequate quality measures for assessing the reliability of health IT systems.*
		Legal responsibilities ❖ *This relates to legal issues regarding the development of clinical IT systems.* ❖ *Contributing factors in this category include legal obligations on health IT vendors facilitating the lack of information sharing with health organisations.*
		Other ❖ *Other categories associated with the health IT vendor element that could not be mapped in the defined categories.*
External	**Government-related Factors** *Consists of contributing factors, including actions, decisions, and policies from government-based entities that affect the system and patient safety. These factors and beyond the control of the health organisation.*	**Communication** ❖ *This includes Communication (both verbal and written) between government entities and healthcare stakeholders regarding patient and system safety.* ❖ *It also includes contributing factors relating to inadequate or lack of communication between these entities regarding policies and guidelines, etc.*
		Policies and legislation ❖ *This refers to existing policies and legislation from the government regarding promoting safety practices in health organisations.* ❖ *Contributing factors include, for example, existing policies on testing, deployment and safe use of health IT systems throughout its life cycle. This also includes policies regarding risk assessment and incident reporting.*
		Funding and budgeting ❖ *This relates to financial resources budgeted for health organisations, including hiring and training of existing staff and the development of new health IT systems.*

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		❖ *Contributing factors include limited resources for staff recruitment, budget priorities that could potentially compromise quality in the development of technologies and risk management.*
		Operational oversight (via certification) ❖ *This consists of regulations and certifications to ensure clinical software systems meet specific standards in their operation.* ❖ *Contributing factors include a lack of oversight from government stakeholders on patient safety and safe use of Health IT systems.*
		Standardisation (via guidelines) ❖ *This includes existing standard guidelines relating to clinical operations and risk management practices.* ❖ *Contributing factors may include, for example, issues relating to safety standards not rigorously applied in the design of health IT systems.*
		Other ❖ *Other categories associated with government element that could not be mapped in the defined categories.*
	Regulatory-related Factors *Consists of contributing factors relating to decisions and influences from regulatory bodies responsible for ensuring acceptable levels of patient safety and continuous monitoring and improvement of safety standards.*	**Communication and feedback** ❖ *This refers to verbal and written (electronic) communication between regulators and health management.* ❖ *Contributing factors can include gaps in communication, miscommunication between stakeholders and management, lack of clarity, etc.*
		Auditing ❖ *Refers to processes used by health professional bodies to assess, evaluate, and improve the care and safety of patients. This forms part of clinical governance.* ❖ *Contributing factors include inadequate auditing procedures from regulatory bodies on safety and performance from medical staff and management.*
		Regulation on health IT systems

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
		❖ *This refers to rules/directives relating to the safety and effective use of clinical IT systems by staff and management.* ❖ *Contributing factors may include, for example, a lack of enforcement regarding regulations on the safe use of health IT systems.*
		Safety monitoring measures ❖ *This refers to the process of measuring patient and system safety. This can also include measuring how safely Health IT is used for delivering care and its effects on the patient.* ❖ *Contributing factors can include ineffective safety monitoring measures and a lack of appropriate regulations regarding implementing safety and incident reporting tools.*
		Clinical risk management processes ❖ *This includes all risk management activities, including risk analysis, risk evaluation and risk control. These activities are also applied to health IT systems used.* ❖ *Contributing factors include the inadequate, inefficient or inconsistent application of these activities in identifying potential hazards associated with health IT systems and the health environment.*
		Other ❖ *Other categories associated with the patient that could not be mapped in the preceding categories.*
	Professional Bodies/Association Factors *Consists of contributing factors relating to various health bodies/associations in implementing guidance and best practices for continuous safety improvement and*	**Communication and feedback** ❖ *This refers to verbal and written (electronic) communication between professional bodies/associations, healthcare management, and medical staff.* ❖ *Contributing factors can consist of gaps in communication and feedback mechanism, lack of clarity, etc.*
		Current best practices ❖ *Refers to implementing current best practices in improving patient safety, including other aspects like health IT governance.* ❖ *Contributing factors include lack of enforcement of best practices, for example, in the safe use of health IT systems.*
		Current professional guidance ❖ *Refers to existing guidelines that govern all aspects of healthcare, including the implementation and use of Health IT.* ❖ *Contributing factors can include non-implementation of existing guidelines, lack of clarity of guidelines, etc.*

ACCIMAP LEVEL	SYSTEM-LEVEL (CATEGORIES)	CONTRIBUTING FACTORS (SUB-CATEGORIES) AND DESCRIPTION
	productivity.	
		Collaboration ❖ *Refers to collaborative activities with other external stakeholders (regulatory and government).*
		Other ❖ *Other categories associated with the "Professional Bodies/Associations" element that could not be classified in the preceding categories.*

Appendix E: Case Incident Three (Septra Overdose) and Qualitative Results (Appendix to Chapter Six)

E-1 Summary of different metrics for reliability and validity assessment (Goode *et al.*, 2017)

Metric	Calculation	Strengths	Weaknesses
Percentage agreement for each code in the taxonomy	For each coding task, calculate for each category in the classification scheme: $$\frac{No.of\ participants\ who\ selected\ the\ code\ (sub-category)}{Total\ number\ of\ participants}\ x\ 100$$ This produces a percentage agreement for each category in the taxonomy (O'Connor, 2008)	Considered the easiest way to identify categories (or sub-categories) with the least agreement.	Produces an inflated result as it ignores the total number of categories selected by each participant.
Index of Concordance	For each pair of participants, a score designated for "**agreement**" or "**disagreement**" for each pair of codes assigned to each cause/contributing factor in the coding task. Calculate the Index of Concordance for each pair of participants: $$\frac{Agreements}{Agreements + Disagreements}\ x\ 100$$ Average the Index across all participant pairs to produce a percentage for the coding task (Goode, Salmon, Taylor, Lenne and Finch, 2017).	Accounts for the level of agreement and disagreement. Penalises schemes with large numbers of overlapping categories	Does not take into account "chance agreement".
Signal detection paradigm	For each pair of participants (e.g., Professional 1, Professional 2), score a "hit", "miss", "false alarm" or "correct rejection" for each sub-category in the taxonomy for a coding task. **Hit** = Category is selected by both Professional 1 and Professional 2; **Miss** = Category is selected by Professional 1 but not Professional 2; **False alarm (FA)** = Category is selected by Professional 2 but not Professional 1; **Correct rejection (CR)** = Category is not selected by Professional 1 or Professional 2.	Sensitivity index accounts for trade-offs between hits, misses, false alarms and correct rejections.	Sensitivity is artificially inflated by large numbers of correct rejections in schemes with a large number of categories (specifically sub-categories).

	Calculate the sensitivity index (Stanton & Stevenage, 1998) for each pair of participants: $$\frac{\left(\frac{Hits}{Hits + Misses}\right) + 1 - \left(\frac{FAs}{FAs + CRs}\right)}{2}$$ Average this score across participants.		

E-2 Consent Form (Chapter Six - Reliability Study)

PARTICIPANT CONSENT FORM: ACCIMAP TRAINING WORKSHOP AND CASE STUDY ANALYSIS

The objective of this study is the evaluation of the proposed Medi-Socio AcciMap taxonomy for accident analysing Health-IT related case studies. This will be achieved through a training workshop introducing the existing AcciMap approach. The model will then be evaluated by the participants.

INFORMATION

The information regarding the AcciMap Training Workshop will involve the following activities:

1.) A brief introduction of both the standardised AcciMap approach and the proposed Medi-Socio AcciMap taxonomy approach.
2.) Analysing an existing case incident in NHS using the AcciMap approach.
3.) Analysis of another case incident, "Overdose - Harm in a wired Hospital", using the proposed model (after the workshop)

BENEFITS

The application of system's thinking, in particular the AcciMap approach, will allow the provision of a 'big picture' of accidents that can occur within complex sociotechnical systems. More importantly, it will help users to identify areas for improvement within the health care system.

CONFIDENTIALITY

The information collected from the training workshop, including the participant's response record, will be kept confidential and can only be accessed by this research conductor. No reference will be made in any report, which may link to the identity of the participants in the study.

PARTICIPATION

Your participation in this study is voluntary. If you decide to participate, you may withdraw at any time without penalty or risk.

CONTACT

If you have questions about the study, please contact:

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DECLARATION

I confirm that I have read and understood the information above. I agree to participate in this study with the understanding that I may withdraw at any time."

Signed_____ **Date** _____

Contact Information_____

E-3 Case Incident 2 - Septra Overdose in a wired Hospital

This case incident occurred in one of the most recognised teaching hospitals in the United States in 2013 (Watcher, 2015). It describes a series of events from different perspectives about a patient diagnosed with a rare genetic disease called the NEMO syndrome resulting in a lifetime of reoccurring infections and bowel inflammations. The patient was previously admitted to the University of California San Francisco (UCSF) Medical Centre's Benioff Children's hospital in the early morning of July 27th, 2013. The hospital went digital a few years before this incident. This case incident was extracted from the original report book (Wachter, 2015) from different sections, including the Error itself, the System, the Doctor, the Pharmacists, the Alerts, the Robot, the Nurse, and the Patient

The summary of the timeline of events following the admission which culminated in the error taking place is summarised in the following table below:

Time	Event(s)
9:00 pm	Prior to when the patient was admitted to the hospital in the morning, he had already taken his evening medications to treat his immune deficiencies and infections
1:00 am	At around this time, the patient experienced numbness and discomfort in his body and the nurse who attended initially thought that his discomfort was due to the bowel cleansing solution (**GOLYTELY**). This solution was given to him in preparation for a procedure.
3:00 am	Around this time, the patient's (Pablo) condition grew worse, and the senior nurse (Levitt) came in to assess the situation. The chief resident had to be called in to check on the patient's physical condition. He then assessed the patient's electronic medical record and checked the medication list. The chief resident became very surprised after noticing that the nurse had given the patient ***an overdose of Septra pills, 38 ½ times the dosage!*** This discovery caused the resident to contact the hospital's poison control centre, but no one there was familiar with this type of accidental dosage, and this incident has never been reported in the medical literature.
5:32 am	The senior nurse then ran back into the room after hearing a scream and, within a few moments, saw the patient reacting and shaking violently back and forth with clenched teeth as signs of a grand mal seizure. This prompted a call for the Code Blue team, but the patient stopped breathing as they arrived.

E-4 Septra Overdose - Additional Information

- **The System:** The UCSF Medical Centre, at the time of the incident, was operating a hospital-wide software system, EPIC, which was installed in 2012 after over ten years since installing their first computer system (GE's EHR system) in 2000 (Wachter, 2015). At the time of the incident, there was strong evidence suggesting that the EPIC system was fulfilling requirements and goals for medical practitioners. This included the system providing computerised checklists, which assisted clinicians to implement safety practices and preventing thousands of medication errors using barcoding systems. Like every other system implementation, the hospital experienced challenges when implementing EPIC, including changes in workflow and communication. Installing the EPIC system was not as straightforward as installing an operating system and rebooting because many decisions needed to be taken by the

hospital regarding how the system will operate. This included setting the frequency of alerts and maximum dose limits in the system according to existing policies. Although in this case, the UCSF decided not to set limitations because many patients who had rare diseases were on research protocols like "overdoses". Additionally, setting up multiple hard stops could create scenarios where medical practitioners (doctors and pharmacists) will be stressed and could lead to overriding these settings. Other policy decisions also played a significant influence in setting and operating the EPIC System. These included decisions regarding weight-based dosing, which was expressed in milligrams per kilogram (mg/kg), and conversion of weight-based doses into pills. The maximum dosage allowed was also set depending on how many alerts were triggered. This is was particularly important in the paediatrics department, and based on the decision taken by the hospital committee, weight-based dosing was required for all children less than 88 pounds (approx. 40 kilograms). The UCSF, before they installed the EPIC system, also had the advantage of learning from the experiences of other academic medical centres that had also installed EPIC before 2012. Based on the feedback from those centres, they decided to disable thousands of alerts which were also designed into the EPIC's drug database system. However, there were still multiple alerts triggered, and this was particularly stressful for the paediatrics department. While these decisions taken by the hospital committee was to enhance safety improve workflow, it also created unintended consequences which potentially left the system vulnerable.

- **The Doctor:** The paediatric resident who was assigned to the patient's case was considered an excellent medical graduate student. Furthermore, she was trained in how to operate computer systems, including the EPIC system, which seemed usable and similar to what she had used in her prior medical school. It was also noted that every training program incorporated the hospital's policies and had a hidden curriculum regarding how processes are done. This highly suggests an established culture where medical staff created "workarounds" in being more efficient, especially in the matter of alerts (alerts fatigue). Lucca (the paediatric resident) was initially not comfortable with the status quo but felt that was the only way she could be more efficient in her work. On the day of the incident, she attended to the patient, who was with his mother. Lucca also accessed the patient's EMR and ordered the usual medications, including the GoLYTELY and his monthly infusion of immunoglobulins. She then ordered Septra, which the patient was taking twice daily and based on the existing weight-based dosing policy, the medication was in milligrams per kilogram. This was because the patient weighed about 38.6 kilograms which is equivalent to about 85 pounds. When the order was made into the EPIC system, Lucca was prompted to select from two dosing options, and she chose the "double-strength" option, which was 5 mg/kg of trimethoprim. The computer system calculated this dose, which should have been 193 mg of trimethoprim (38.6kg x 5 mg/kg), but the nearest tablet size was a double strength Septra containing 160mg. The computer system then recommended the dose to be rounded as a single tablet double strength Septra, which Lucca accepted as she intended. However, this action turned out to be a fatal one.

- **The Pharmacist:** Benjamin Chan was the resident paediatrics pharmacist, and his responsibility was to sign off on all medication orders placed on the paediatric service. The hospital's safety procedure required that orders were not to proceed

from the doctor's electronic signature to the administering nurse directly (Wachter, 2015). Orders prescribed for children were processed differently from orders for adults, and this was carried by specialised paediatric pharmacists (Chan) who also works in satellite pharmacies. After the order was given for the patient, Chan received it from his computer screen and noticed that the order given was already above the hospital policy. Chan was required to contact Lucca to make changes to the initial order given, and after she received the text from Chan, she re-opened the medication ordering screen. Based on the text message of rounding up the dosage to 160 mg, Lucca typed in "160" into the dosage box and confirmed changes. However, there were subtle issues relating to the density of the screen as well as the default settings of the ordering process. The EPIC system can also order in either milligram (mg) or milligrams per kilogram (mg/kg), although a decision was made to keep the default settings the same. This led to a situation where Lucca's screen, which was being set at "mg/kg", Lucca ended up ordering the dose at "160 mg per kg", which turned out to be $38^{1/2}$ of them (Wachter, 2015).

- **The Alerts:** As crucial as setting alerts in health IT systems as a safety measure, it can become a source of hindrance affecting the performances of medical staff. This is especially evident when there are thousands of alerts set up in these systems administering medication doses. Although there wasn't strong evidence to suggest that alerts played a direct role, it does present itself as a contributing factor (latent condition). This can lead to a situation called "alert fatigue".

- **The Robot:** A Swiss-based pharmacy robot was installed at the UCSF' Mission Bay satellite campus in 2010, costing $7 million. It was programmed to carry out specific tasks including "*pulling off medications from shelves, inserting pills into shrink-wrapped, bar-coded packages; binding these packages together with little plastic rings and sending them to locked cabinets on the patient floors by van"* (Wachter, 2015). It was considered a very critical step in preventing potential human error. For example, the robot accurately collected $38^{1/2}$ Septra tablets, placing them on a half-dozen rings and sending them to Pablo's floor for the nurse to administer them at the designated time. However, according to the paediatric resident, there weren't any checks regarding the robot's activities (Chan).

- **The Nurse:** Brooke Levitt, who had worked as part of the nursing staff at UCSF for approximately ten months, was assigned to Pablo's case.

E-5 Qualitative Coding Instructions

The coding rules to be applied by reviewers on case incident (Septra overdose) are summarised based on the application of the Standard and Proposed AcciMap as follows:

Standardised AcciMap approach (Contributing factors)

1.) Each table of contributing factors identified from participants' AcciMap outcomes is assigned a code and a colour (i.e., C1).
2.) Assign the alphanumeric code and colour to the contributing factors similarly identified by more than one professional participant.

3.) Any other contributing factors not commonly identified should be assigned the codes based on the tables for each respective AcciMap result.

Medi-Socio AcciMap approach (Contributing factors)

1.) The same process described in number (1) for the standardised AcciMap approach
2.) Assign the alphanumeric code, colour AND a **black-bolded** box for any common contributing factor (similar in meaning) that was classified in the SAME sub-category.
3.) Assign the alphanumeric code, colour AND a **black-bolded broken** box for any common contributing factor (similar in meaning) that was classified in DIFFERENT sub-categories.
4.) Any other factors not commonly identified should be assigned the codes based on the tables for each respective AcciMap result.

Causal Relationships (application to both AcciMap approaches)

1.) Indicate the same link number (i.e., link-1) and indicate the link with a **bold red colour** for any causal relationships identified between commonly identified factors.
2.) Compare direct links (between commonly identified factors) (i.e., A – B) and multiple links (A-C–B) as long as A and B are similar to other participants' A and B factors.

Safety Recommendations (application to both AcciMap approaches)

1.) The same process applies to safety recommendations using both AcciMap approaches. Use the table of safety recommendation themes to determine similar meanings in recommendations by each participant (Professionals).
2.) Use the denoted safety recommendation code and colour code to highlight safety recommendations similarly identified by multiple participants (you can use MS Word colour schemes to highlight them).

E-6 Coding Rules for Validity and Reliability Assessment

Case Incident: Septra Overdose

The case incident summarises a patient admitted to the UCSF hospital but was given a very high dose of Septra medication (38.5) times the intended dose. Based on identifying contributing factors and safety recommendations formulated by professional participants, similarities and differences in how these factors were presented need to be noted.

For the Actors (medical staff) that were involved with the patient, the following words based on the qualitative analyses from all participants are shown below:

1.) Physician/Paediatrician/Doctor refers to the actor "Lucca."
2.) Staff member A refers to "Lucca" (Doctor).
3.) Staff member B refers to "Chan."

4.) Pharmacist refers to the actor "Chan" or "Benjamin Chan (BJ)".
5.) The nurse refers to the actor "Levitt".
6.) The term "System" used within the context of issues relating to **its design and production of multiple alerts or any IT-related issues** refers to the "EPIC software system".

VALIDITY ASSESSMENT (Standardised AcciMap Approach)

Causal/Contributing Factors

1.) Did they identify a cause (contributing factor) with the same meaning as the expert's cause? (Y/N). If yes, identify the cause (e.g., Y:3 or Y:2,3 of ½:2)

Example expert cause: *"Lucca types "160" under the assumption of ordering one Septra tablet and accepts next task on long lists"*

CODE	CAUSAL/CONTRIBUTING FACTOR CODING EXAMPLE
Y: Number	• If they identified a cause (contributing factor) that means the same thing as the correct cause, whether or not the wording is identical. ○ e.g., *"The paediatrician inputs "160" assuming she ordered one Septra tablet."* • If they identified a cause, that means the same thing as the correct cause, but also had additional information (that is not a cause). ○ e.g., *"The paediatrician inputs "160" assuming she ordered one Septra tablet before accepting the next task."* • If they identified a cause, that means the same as the correct cause and included another cause in the same sentence. ○ e.g., *"The paediatrician (Lucca) inputted "160", and she assumed that she had ordered one Septra tablet AND disregards disregarded a warning alert."* • If they identified multiple causes that, together, mean the same thing as the correct cause (if so, include both cause numbers) ○ e.g., *"The paediatrician (Lucca) inputted "160", and she assumed that she had ordered one Septra tablet."*
½: Number	• If they identified half, but not all, of the cause ○ *"The paediatrician (Lucca) inputs "160""*
N	• If they did not identify a cause, that means the same thing as the correct cause • If the correct cause was implied in the causes, they did identify but was not explicitly identified

VALIDITY ASSESSMENT (Medi-Socio AcciMap Approach)

Causal/Contributing Factors

1.) Did they identify a cause (contributing factor) with the same meaning and classification as the expert's classified cause/contributing factor? (Y/N). If yes, identify the cause (e.g., Y:3 or Y:2,3 of ½:2)

Example expert classified cause: **P-SI6** (*"Lucca types "160" under the assumption of ordering one Septra tablet and accepts next task on long lists"*)

CODE	CAUSAL/CONTRIBUTING FACTOR CODING EXAMPLE
Y: Number	• If they identified a cause (contributing factor) that means the same thing as the correct cause, whether or not the wording is identical. ○ e.g., **P-SI6** (*"The paediatrician inputs "160" assuming she ordered one Septra tablet"*) • If they identified a cause, that means the same thing as the correct cause, but also had additional information (that is not a cause). ○ e.g., **P-SI6** (*"The paediatrician inputs "160" assuming she ordered one Septra tablet before accepting next task"*) • If they identified multiple causes that, together, mean the same thing as the correct cause (if so, include both cause numbers) ○ e.g., **P-SI6** (*"The paediatrician (Lucca) inputted "160", and she assumed that she had ordered one Septra tablet"*)
½: Number	• If they identified half, but not all, of the cause (contributing factor) ○ **P-SI6** (*"The paediatrician (Lucca) inputs "160")* • If they identified the factor similar to the expert factor but classified it under a different sub-category from the expert ○ **P-SI3** (*"The paediatrician (Lucca) inputs "160" assuming she ordered one Septra tablet"*)
N	• If they did not identify a classified cause/contributing factor, that means the same thing as the correct classified cause • If the correct cause/contributing factor was implied in the causes, they did identify but was not explicitly identified

Causal Relationships (Links) – Standard and Medi-Socio AcciMap

1.) Did they identify a similar causal link with the expert's causal link? (Y/N). If yes, identify the causal link (e.g., Y: Number).
   a. If the participant identified a similar causal link that has intermediate links (similarity between A-B will be similar to A-B-C, as long as A and B have similar cause and effect contributing factors).
   b. If there are no causal links identified that are similar between participant and expert, indicate **N**.
2.) The above rules apply in determining the validity of causal links regarding using the Medi-Socio AcciMap approach.

Safety Recommendations (Standardised and Medi-Socio AcciMap Approaches)

1.) Did they identify a recommendation with the same meaning as the expert's recommendation? (Y/N). If yes, identify the cause (e.g., Y:3 or Y:2,3 or ½:2)

Example expert recommendation: *"Redesign continual training in IT systems to ensure all clinical staff are aware of medication errors that are common with IT systems such as EPIC. Appropriate training and evaluation on a system that has been designed from staff up to be effective."*

CODE	SAFETY RECOMMENDATION CODING EXAMPLE
Y: Number	• If they identified a recommendation that means the same thing as the correct recommendation, whether or not the wording is identical. ○ *"Redevelopment of continuous training for clinical staff in using IT-systems on medication errors that common with such systems".* • If they identified a recommendation that means the same thing as the correct recommendation but also had additional information (that is not a cause). ○ *"Redesign continual training in IT systems to ensure all clinical staff are aware of medication errors that are common with IT systems such as EPIC to help staff to be able to easily identify and avoid making such errors".* • If they identified a recommendation that means the same thing as the correct recommendation and also included another recommendation in the same sentence. ○ *"Redesign continual training in IT systems to ensure all clinical staff are aware of medication errors that are common with IT systems such as EPIC. Appropriate training and evaluation on a system that has been designed from staff up to be effective."* • If they identified multiple recommendations that, together, mean the same thing as the correct recommendation (if so, include both recommendation numbers) ○ *"Redesign continual training in IT systems to ensure all clinical staff are aware of medication errors that are common with IT systems such as EPIC."*
N	• If they did not identify a recommendation that means the same thing as the correct recommendation • If the correct recommendation was implied in the recommendations, they did identify but was not explicitly identified • If they identified the same recommendation but directed it at a different party so that the actual actions are not the same

RELIABILITY ASSESSMENT (Standardised and Medi-Socio AcciMap Approaches)

<u>Standardised AcciMap - Causal/Contributing Factors</u>

- ❖ AcciMap results from both groups of participants have been printed with different shades of grey colour for each participant. Causal/contributing factors are also arranged in the Microsoft Excel spreadsheet by its **reference number** and according to each participant (Professionals).
- ❖ The aim is to arrange these contributing factors so that those with the same meaning are grouped together. Leave those that don't have the same meaning as a separate file. Try using the same judgements as involved in the validity assessment.
- ❖ Based on the number of professionals (3 per incident analysis), each AcciMap result are to be compared in pairs of two (**AB, AC, BC**), resulting in a total of 3.
- ❖ When deciding if two causes have a similar meaning, consider whether they mean the same thing within the context. It is not necessary to check that every component in one cause is present in the other – just that they are referring to the same type of thing.

- Refer to the table on the validity of contributing factors, on if contributing factors identified by the first pair (e.g., A and B) are similar in meaning (**Y: Number**)
- If they partially identified the factor and not all (**1/2: Number**)
- If they did not identify the factor (**N**)

❖ However, if the first analyst includes two or more causes in one box, and the second analyst identified only one of them, underline the causes in the first analyst's box that the second analyst missed.

Medi-Socio AcciMap - Causal/Contributing Factors

❖ AcciMap results from both groups of participants have been printed with different shades of grey colour for each participant. Causal/contributing factors are also arranged in the Microsoft Excel spreadsheet by its **reference number (REF)** and according to each participant (Professionals).
❖ The same rules apply when arranging factors that have already been classified, for as long as they *convey similar meanings* **AND** *are classified under the same sub-category* from the taxonomy (refer to the table on the validity of the Medi-Socio AcciMap).
- Refer to the table on the validity of contributing factors, on if contributing factors identified by the first pair (e.g., A and B) are similar in meaning (**Y: Number**)
- If they partially identified the contributing factor or if they identified the factor but placed it in a different sub-category (**1/2: Number**)
- If they did not identify the factor and were not placed in the appropriate sub-category (**N**)

❖ The same rules apply when comparing two pairs from the subgroups of professional participants (see the section on contributing factors).
❖ The same rules apply when determining similarity in meanings. However, if the first analyst includes two or more causes in one box (sub-category), and the second analyst identified only one of them, underline the causes in the first analyst's box that the second analyst missed.

Causal Relationships (Links) - Standard and Medi-Socio AcciMap

❖ Causal relationships are denoted as links between causes/contributing factors and with the outcome (accident). Each link is designated a number for each AcciMap result.
❖ For reliability assessment, causal links between two pairs of results (similar process with contributing factors) are to be compared using each link from the first pair with the second pair (see Excel spreadsheet for the format).
❖ The following rules are to be applied when comparing links:
- If the causal relationship exists between two factors (i.e., A and B) from between two pairs, indicate it with the link number (i.e., **Y: 1**).
- If there exists a causal relationship between contributing factors from both pairs that are not similar in a structure of A and B, then indicate the corresponding link numbers as long as they convey similar meaning (i.e., **Y:1, 3, 4**). See the excel spreadsheet (Causal link).

- If there are no similar meanings between causal links, then indicate **N**.

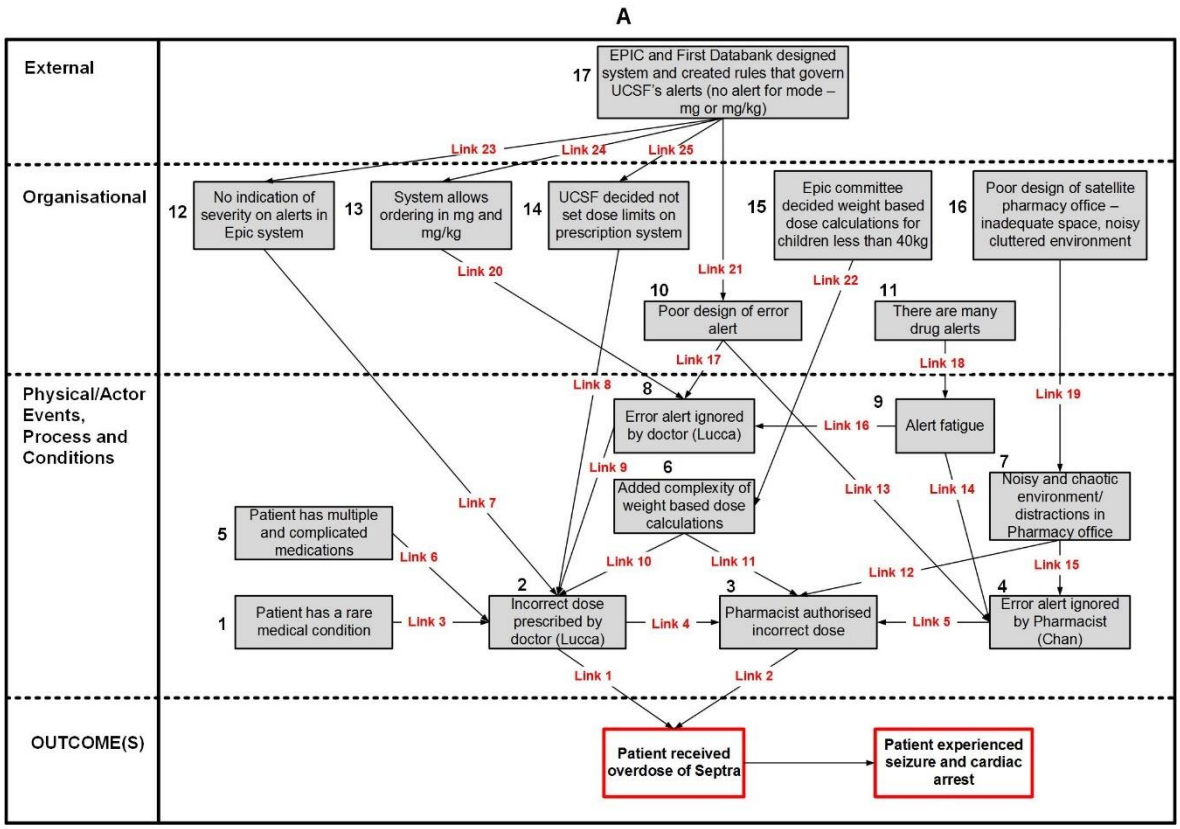
Safety Recommendations (Standardised and Medi-Socio AcciMap approaches)

- The same rules apply when determining similar recommendations between participants from each subgroup (Professionals).

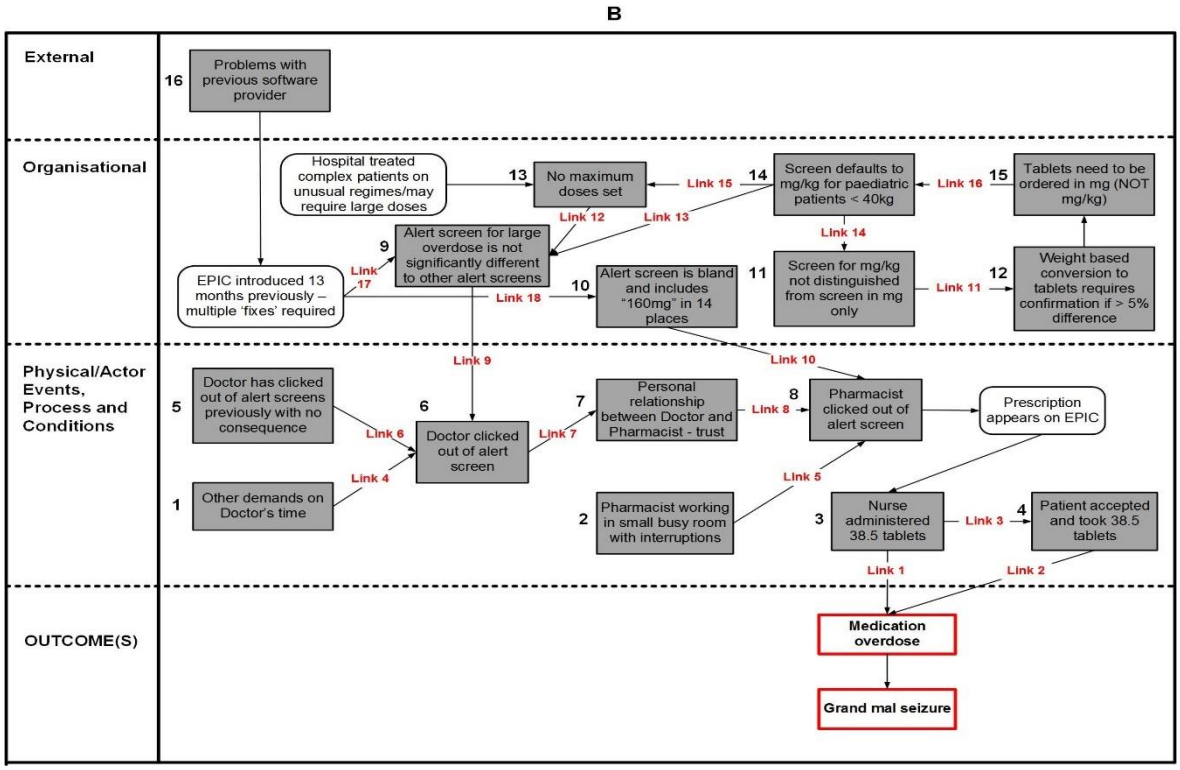
Appendix F: AcciMap Outputs (Septra Overdose Incident) and Safety Recommendations – Professionals (Appendix to Chapter Seven)

F-1 ACCIMAP RESULTS (PROFESSIONALS A) – Standardised AcciMap

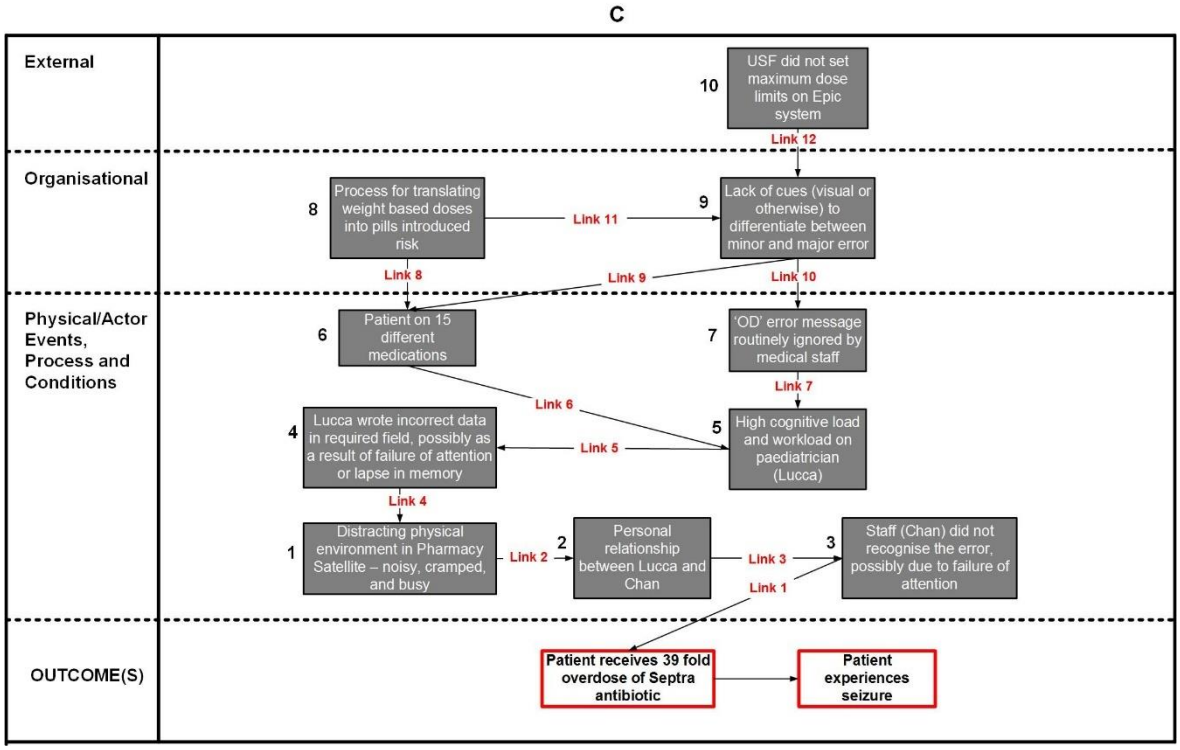
F-1.1 Professional 1A – Original



F-1.2 Professional 2A – Original

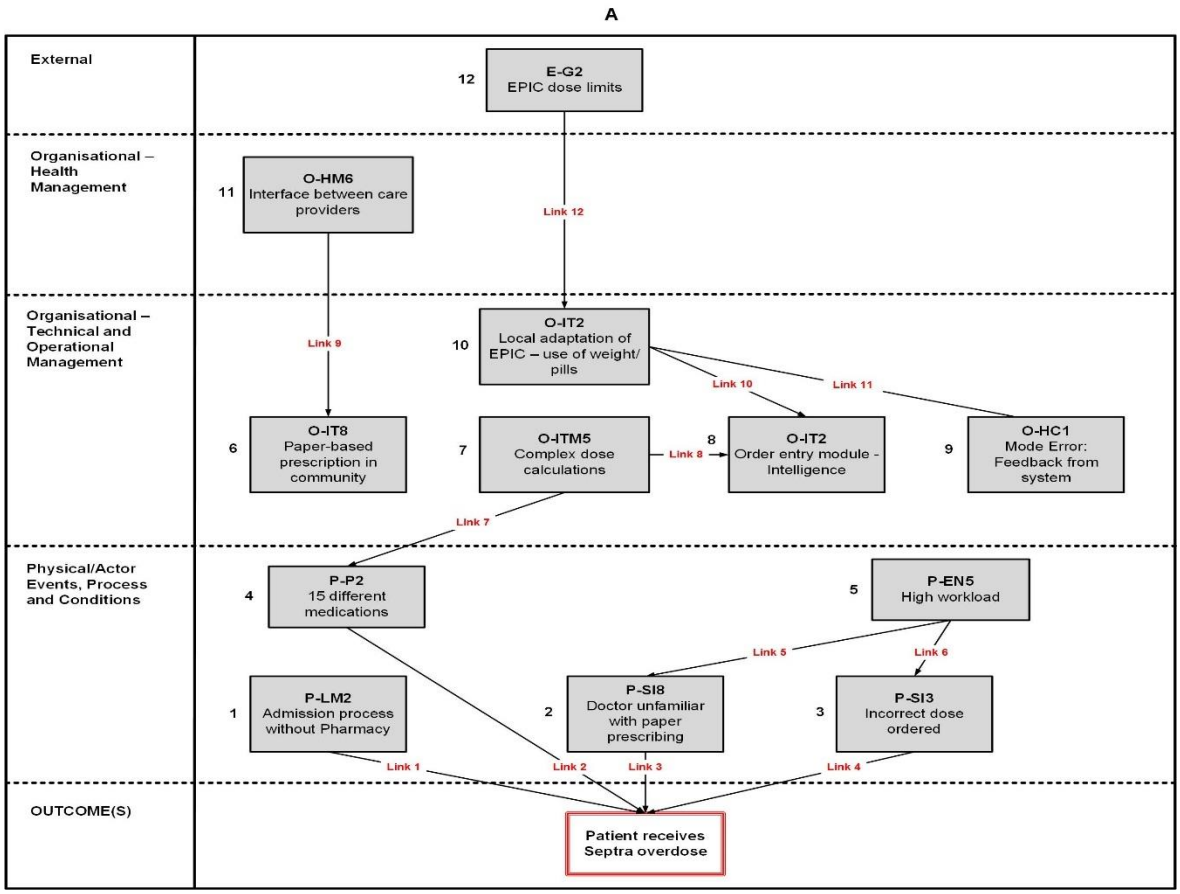


F-1.3 Professional 3A – Original

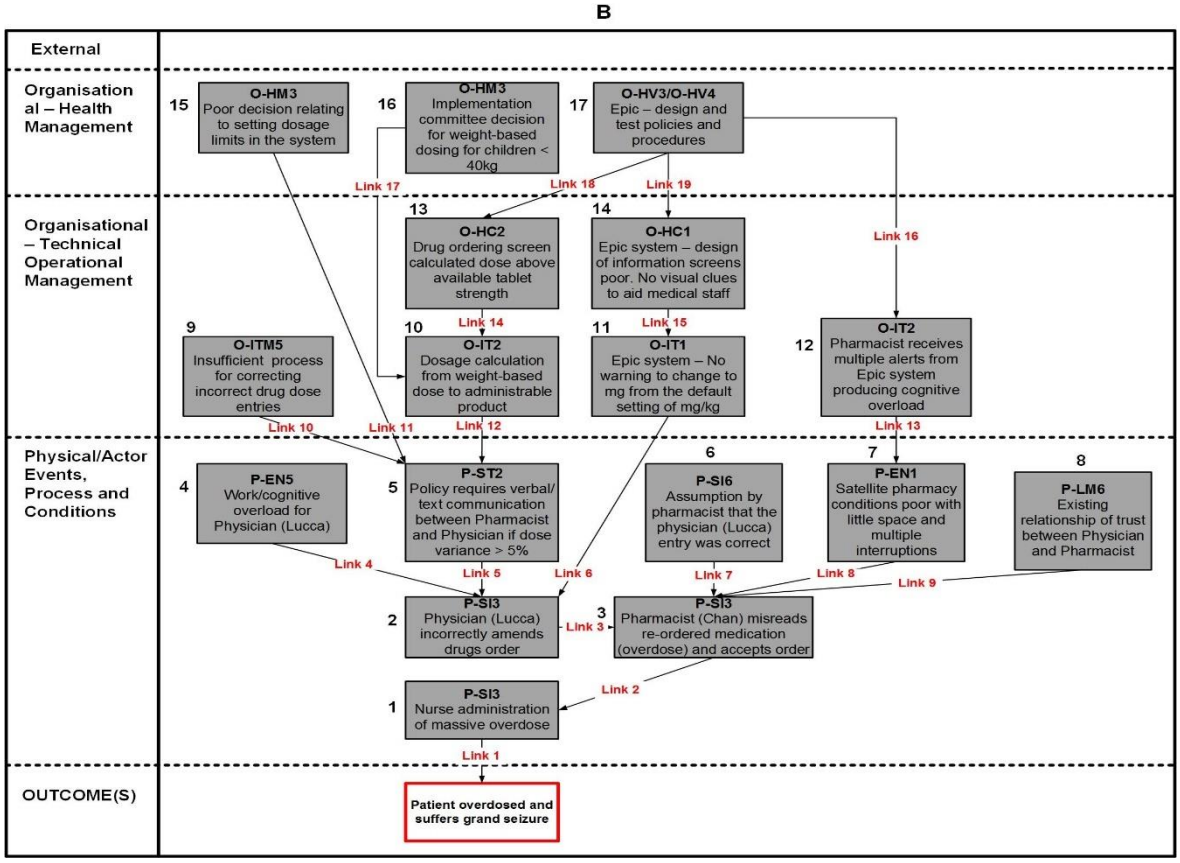


F-2 ACCIMAP RESULTS (PROFESSIONALS B) – Medi-Socio AcciMap approach

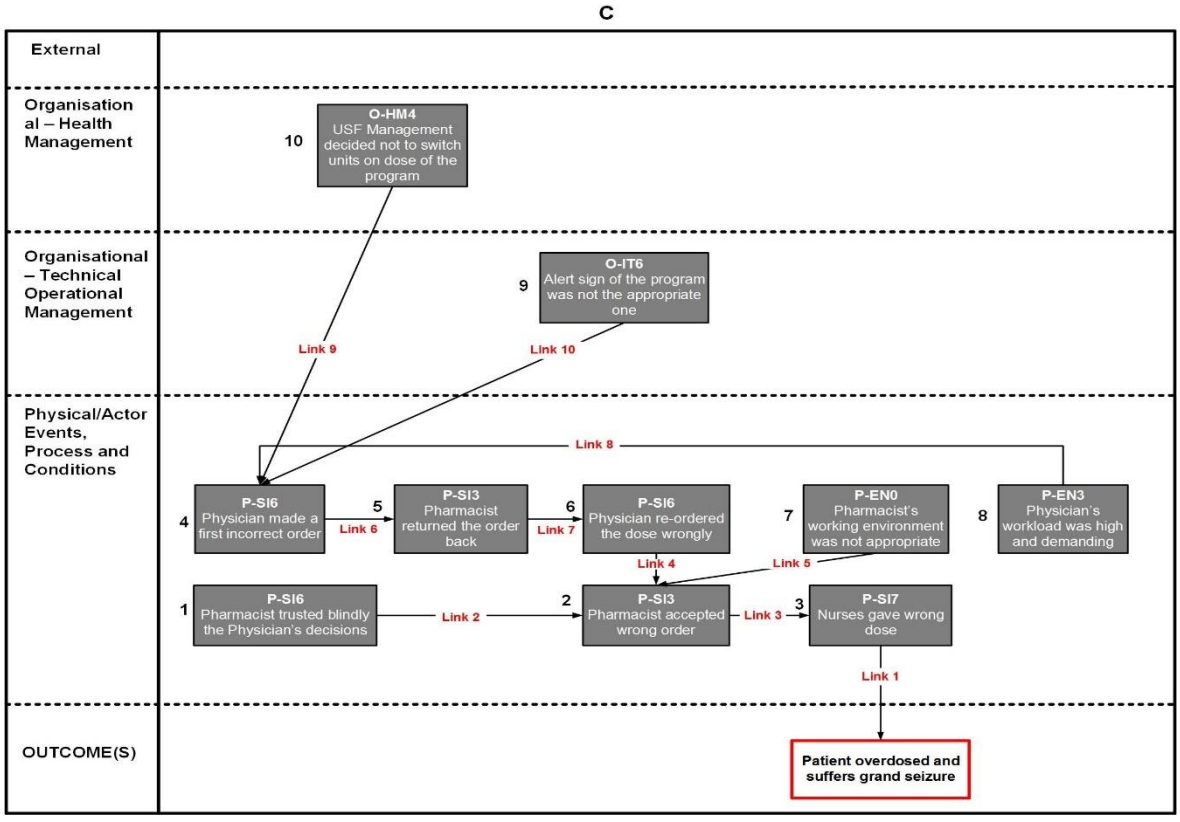
F-2.1 Professional 1B – Proposed



F-2.2 Professional 2B – Proposed



F-2.3 Professional 3B – Proposed



F-3 Safety recommendations developed based on the application of both AcciMap and Medi-Socio AcciMap approaches

Case Incident Two (Septra Overdose)

Standardised AcciMap Approach

Professional 1 (A)

1.) Dose limits should be applied – the EPIC committee should be responsible for this.
2.) Error alerts should be rationalised, and the design of these alerts reviewed using Human Factors principles to ensure they are effective – the EPIC committee should be responsible for this
3.) Dose ordering only be allowed in mg, not mg/kg, to avoid confusion. The EPIC committee should be responsible for this change to the system
4.) Pharmacy working environment and tasks should be reviewed in terms of reducing distractions and providing an environment to allow safe and effective working – pharmacy should be responsible for this recommendation. Specifically, when prescriptions are being checked, or high-risk procedures are undertaken, these should be performed in an environment away from distractions, not in satellite units tasked with multiple functions and regular interruptions.

Professional 2 (A)

1.) EPIC/trust IT team
   a. Design screens on EPIC to clearly differentiate between prescribing in mg or mg per kg.
   b. Review the multiple alert screens – would it be possible to distinguish between a small discrepancy and a large discrepancy? What would constitute 'small' or 'large'? Is this a viable distinction? In some medications, a small discrepancy may still have significant consequences.
   c. Review current alert screens – are there too many? Can these be rationalised?
   d. Review alert screens – can they be clearer re actual dose being prescribed
2.) Pharmacy
   a. Review the decision not to set 'maximum' doses – should there be maximum doses in some cases? Set such as to minimise the 'alerts' but keep patients safe?
   b. Review the pharmacists working environment. Look at protected space for tasks that require concentration; remove distractions; short periods on tasks that require high concentration; and rotate staff around.
3.) Nursing management
   a. Need further information to understand why the nurse did not challenge a prescription requiring 38 tablets. Is this lack of knowledge? A culture around a challenge?

Professional 3 (A)

1.) Training for staff across the organisation on the basics of Human Factors, including a focus on just culture
2.) The only error messages should be safety-critical (as defined by the organisation), , maximum doses or chance of significant harm
3.) Reduce distractions in Pharmacy; the environment design does not support an organised and safety-critical service. Designate people to take calls to minimise interruptions and distraction

Medi-Socio AcciMap Approach

Professional 1 (B)

1.) Ensuring the user interface of the EPIC system displays units of medication in a consistent way. The use of ecological interface design should be considered.

Professional 2 (B)

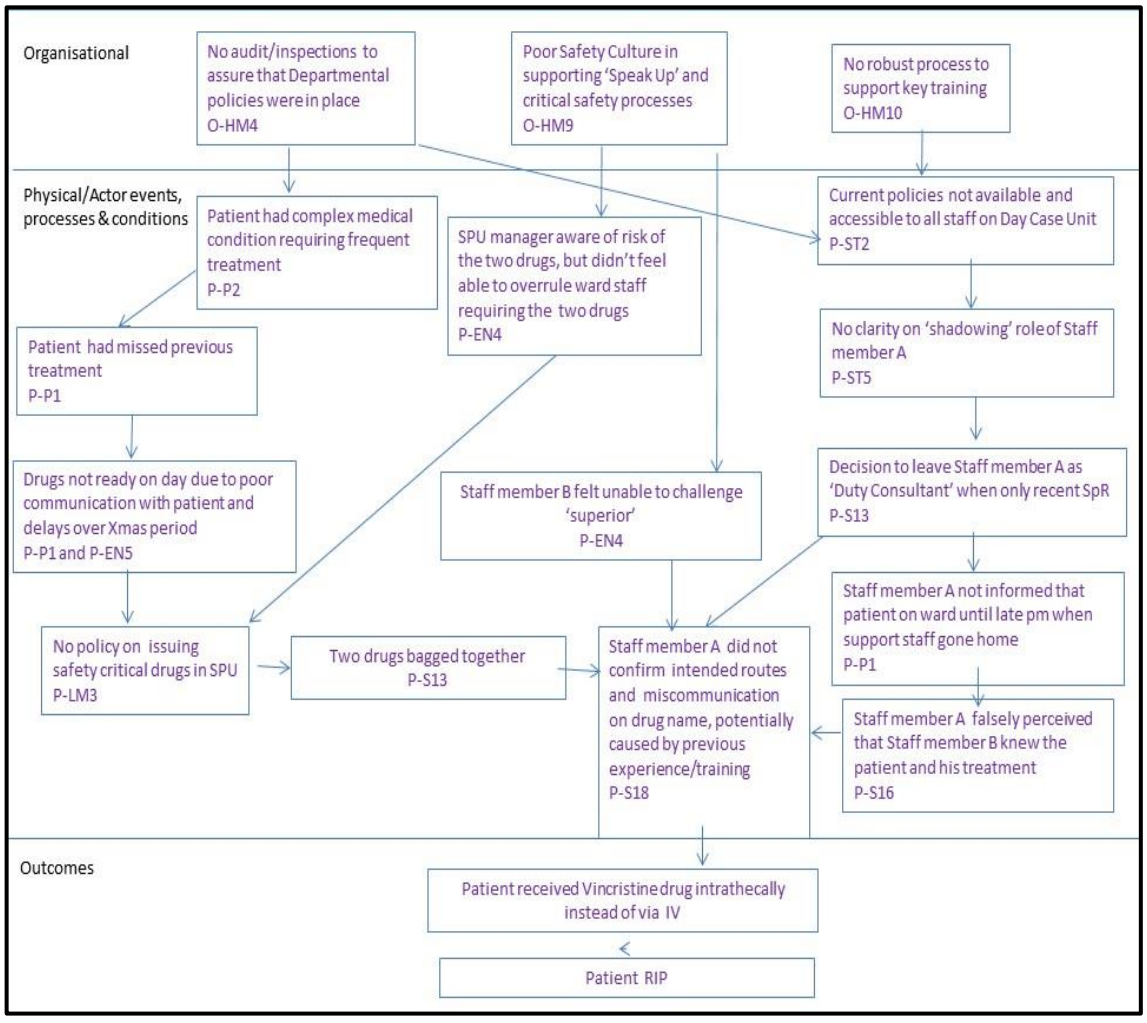
1.) Review and document the clinical safety processes, including the generation of a risk register

2.) Review the evidence base for weight-related dose age calculations
3.) Redesign the system interface to introduce better visual clues for both data entry (drug orders) and alerts/confirmation of dose changes.
4.) Have the EPIC provide metrics for the number of incidents of a similar type that have happened but been picked up – that should help inform the introduction of correct triggers for overdose.
5.) Review policy for challenging perceived incorrect medication doses – links to what is now known as the professional duty of candour.

Professional 3 (B)

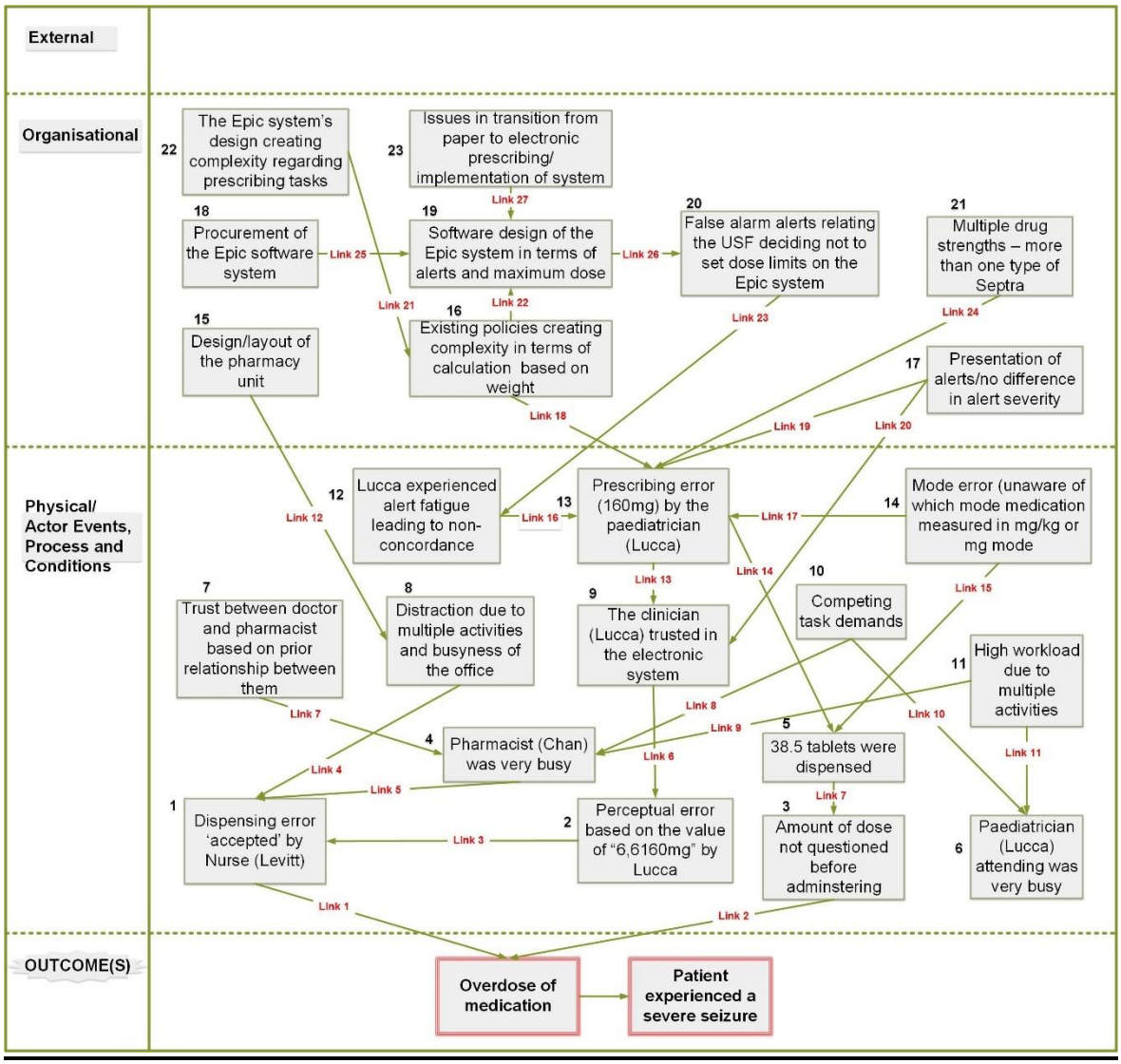
1.) UCSF Management should reconsider the roles of the dosing of the IT system for managing drugs.
2.) The pharmacist should change his/her working environment for a quieter one.
3.) The physician should never bypass alert signs of the program again.
4.) Alert signs of the program should be changed according to the severity of overdosing (some X sign with red colour).
5.) One dedicated pharmacist should accept and give orders on the program and be trained appropriately.
6.) The physician should discuss any decision making with another backup physician when he/she is not sure about the dose.

F-4 AcciMap analysis of the QMC incident (Medi-Socio AcciMap approach)

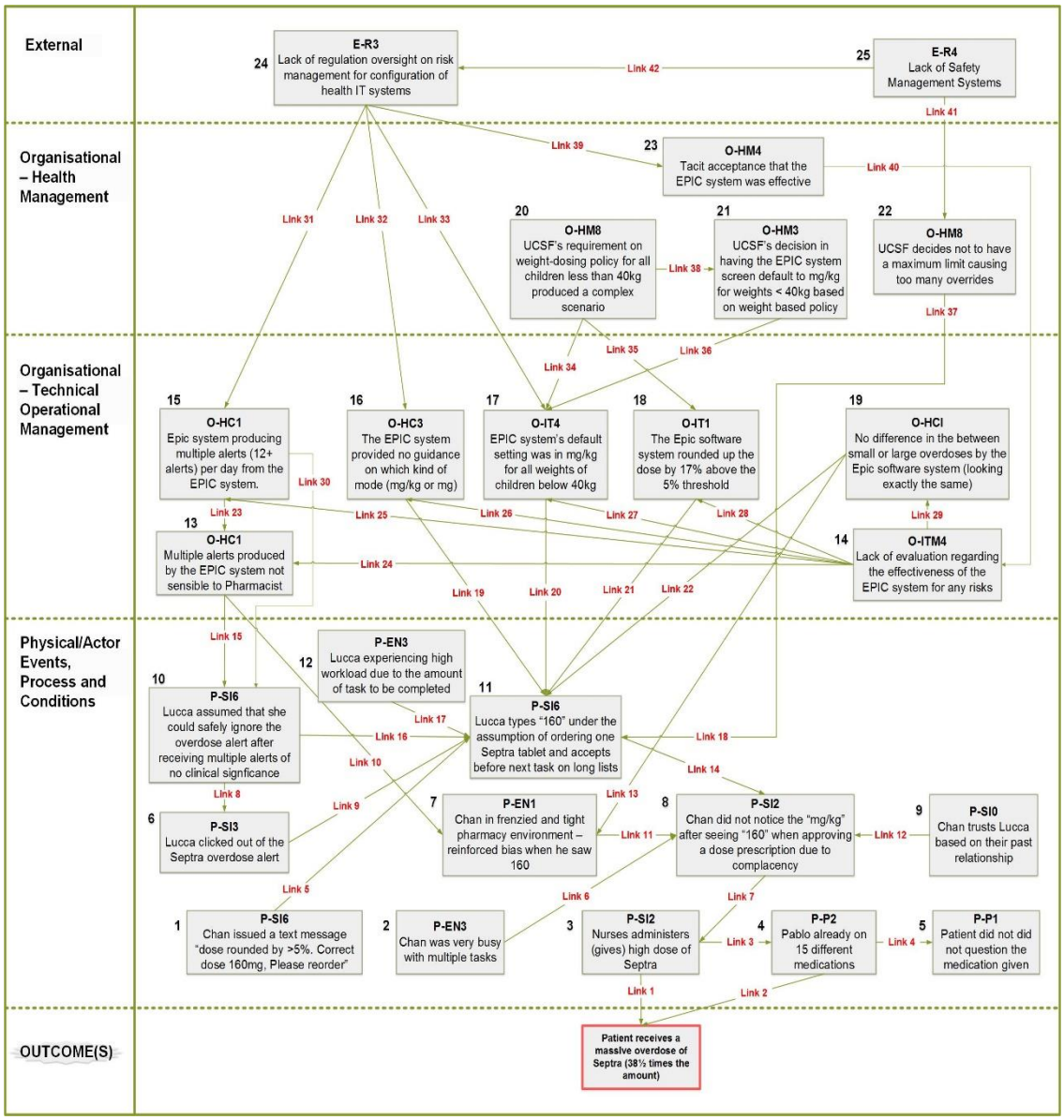


Appendix G: Expert Analysis of the Septra Overdose Incident (Appendix to Chapter Seven)

G-1 Safety expert AcciMap analysis of the Septra case incident (Standard AcciMap approach)



G-2 Safety expert analysis of the Septra overdose incident (Medi-Socio AcciMap Taxonomy approach)



Appendix H: Medi-Socio AcciMap Taxonomy Survey (Clinical Patient Safety Practitioners, NHS Patient Safety Attendants, and Experts (HSIB)) (Appendix to Chapter Eight)

H-1 Questionnaire on Medi-Socio AcciMap Taxonomy Evaluation – Patient Safety Practitioners/AcciMap Training

Section One: General Information

1.) Name

2.) Gender

3.) Age

a. Male

b. Female

4.) Job role/Responsibility _____

5.) How many years of experience in Accident Investigation and Analysis (in general)?

_____

6.) How many years of experience conducting Accident analysis in healthcare? _____

Section Two: Evaluation of the application of the Standardised AcciMap approach

7.) Are you familiar with the concept of "Systems Thinking"?

a. Yes

b. No

8.) Prior to this workshop, were you familiar with the AcciMap approach?

c. Yes

d. No

9.) If your answer to question 8 is "yes", have you ever applied the approach for analysing incidents/accidents?

a. Yes

b. No

10.)Did the workshop training help you understand general concepts regarding the AcciMap approach?

a. Yes

b. No

c. Maybe

11.)Did the AcciMap guidelines help you understand how to apply the AcciMap approach to an incident?

a. Yes

b. No

c. Maybe

12.)Did you find the application of Branford's standardised AcciMap approach intuitive?

a. Yes

b. No

c. Maybe

13.)Briefly highlight strengths you found using the standardised AcciMap approach

_____

14.)Briefly highlight any limitations you found using the standardised AcciMap approach

Section Three: Application of the Medi-Socio AcciMap Taxonomy approach

15.)Did the use of the contributory classification scheme of the Medi-Socio AcciMap and its code guidelines help in your analysis of case incidents?

a. Yes
b. No
c. Maybe

16.)Were there cases of overlapping categories when classifying contributing factors at the Physical Actor and Processes level? (Briefly explain)

17.)Were there cases of overlapping categories when classifying contributing factors at the Organisational level (Technical and Operational Management)? (Briefly explain)

18.)Were there cases of overlapping categories when classifying contributing factors at the Organisational level (Health Management)? (Briefly explain)

19.)Were there any cases of overlapping categories when classifying contributing factors at the External level? (Briefly explain)

20.)What were the strengths or advantages in applying the Medi-Socio AcciMap taxonomy compared to the original AcciMap approach?

21.)What were the limitations in the application of the Medi-Socio AcciMap taxonomy compared to the original AcciMap approach?

22.)Briefly highlight areas of the Medi-Socio AcciMap taxonomy that can be improved in terms of usability for incident analysis.

23.)Briefly highlight areas of the Medi-Socio AcciMap taxonomy that can be improved in terms of reliability of the analysis.

24.)Briefly highlight areas of the Medi-Socio AcciMap taxonomy that can be improved in terms of the validity of the analysis.

25.)General comments on the workshop

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