Development of New Methods to Support Systemic Incident Analysis

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Statement of originality

I, Huayi Huang, confirm that the research included within this thesis is my own work or that where it has been carried out in collaboration with, or supported by others, that this is duly acknowledged below and my contribution indicated. Previously published material is also acknowledged below.

I attest that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge break any United Kingdom law, infringe any third party's copyright or other Intellectual Property Right, or contain any confidential material.

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Signature:

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Related publications

Journal publications:

Huang, H., Ruksenas, R., Ament, M.G.A., Curzon, P., Cox, A.L., Blandford, A., Brumby, D., 2011. Capturing the distinction between task and device errors in a formal model of user behaviour. Electronic Communications of the EASST 45.

Huang, H., Hough, J., Curzon, P., White, G., Blandford, A. (revised manuscript). A method for analytically evaluating the methodological constraints and affordances of an incident investigation approach. Revised submission to Reliability Engineering & System Safety. (Chapters 6, 7)

We plan to prepare a journal submission based on the work for the **Information Safety Method**. (Chapters 3, 4)

Conference publications:

Masci, P., **Huang, H.**, Curzon, P., Harrison, M.D., 2012. Using PVS to investigate incidents through the lens of Distributed Cognition. Proceedings of the 4th NASA Formal Methods Symposium, Lecture Notes in Computer Science 7226, 273-278. Springer.

Huang, H., Curzon, P., White, G., Blandford, A., 2013a. An analytical evaluation of the methodological constraints and affordances of an incident investigation manual. Proceedings of the Workshop on Human Factors in the Safety and Security of Critical Systems, University of Glasgow, Scotland. (This paper presented an earlier part of the work of chapters 6, 7)

CHI+MED technical reports:

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Huang, H., Curzon, P., White, G., Blandford, A., 2013b. A chronological record of the data collection and analysis part of a Root Cause Analysis investigation into a parking incident.

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Presentations:

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Huang, H., 2014. Two Analytical Approaches To Support Patient Safety Incident Investigation Methodology. Doctoral Consortium, Sixth ACM SIGCHI Symposium on Engineering Interactive Computing Systems (EICS 2014); Rome, Italy.

***** Throughout this thesis, the author 'Huang' refers to myself. Like in the current section, these references are highlighted in **bold** throughout.

Abstract

Explaining incidents as *systems* is a fast growing area of safety scientific research. The misleading conception of naturalistic human communication in terms of ‘objective information’ remains a pervasive influence on systemic explanation of incidents, despite over a decade of methodological developments in the area. Currently, interested stakeholders are offered with few alternatives for analysing how information systems emerge naturally, and contribute towards the structuring of incident situations. Extant methods are also yet to be widely adopted by the practitioner community, and a research-practice gap has formed.

In this PhD research, a new method of systemic incident analysis is developed, to counterbalance against the extant methods being developed in the area. The new method draws on insights from both Distributed Cognition, and linguistics research, in order to present a distributed means of doing systemic incident analysis. The new method de-objectifies the notion of information, to support analysis of how information ‘flow’ is constitutive of the formation of distributed cognitive systems. In embedding an intersubjective component into the core method design, we aim to increase the likelihood of systematic learning from incident situations. The incident analyst is required to explicitly relate past explanations of incident situations, in detail, to data and hypotheses from new incident situations.

To increase the potential for theorists in the area to better account for the demands of incident analysis as practiced, data, insights, and method are contributed towards the bridges been built between research and practice. We first develop additional understanding of the practice of incident analysts from the patient safety background. Next, we provide a second new method of analysis, to allow research scrutiny of the empirical phenomena of using systemic incident analysis methods. This second method considers the detailed relationship: from the theory of the systemic incident analysis method into its practice as part of real incident investigation. This provides a new research instrument, for systematically examining how systemic incident analysis methods may afford or constrain elements of their practice.

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Abbreviations, acronyms, and technical terms

CAST – **C**ausal **A**nalysis based on **ST**AMP

FRAM – **F**unctional **R**esonance **A**nalysis **M**ethod

Investigative hypothesis (or **hypotheses** for the plural form)
This is a generic technical term, used to highlight the inherently uncertain nature of structures resulting from analysis of incidents. These structures are inclusive of the internal conceptual structures of incident analysts developed during incident analysis (not directly observable), as well as the external conceptual structures that are developed (seen in the form of published incident analyses for example).

Natural information system(s)
This is a technical term used to refer to the natural representation co-ordination systems that are formed through various acts of communication. For example, a small *natural information system* emerges through the writing and reading of an arbitrary document. Here, the co-ordination of *states of representation* occurs between one or more writers, the document itself as a participant in the interaction, and one or more readers of the document. A second example, in terms of more culturally-standardised norms for representation, is in the case of writing and reading a mathematical equation. Here strong cultural norms [1] have developed over time, to support consistent flow of (mathematical) information between mathematical equation writers and readers. Distributed Cognition provides us with a generalised focus on *propagating states of representation*. The ***Information Safety Method*** presented in Chapter 3 leverages its Distributed Cognition heritage, to provide a general analysis method with which to describe and understand any natural information representation co-ordination system. In theory, the ***Information Safety Method*** may be utilised to support analysis of *any* system of representation. The system of *MEWS reading* representations, and the system forming around representations of *a doctor's interpretation of a patient x-ray* in Chapter 4 provide further examples. There, *MEWS reading* information 'flows' through the system participants, by virtue of taken for granted assumptions for representation and interpretation (analogous to norms of mathematical representation construction and interpretation). In contrast, how *a doctor's interpretation of the x-ray* 'flows around' is arguably relatively less constrained and normalised, by *a priori* assumptions about how such representations are to be constructed and interpreted (e.g., based on written or electronic natural language representations).

[1] 'Culture' in the anthropological sense of the word, as the sum total of ways of living built up by a group of human beings and passed on from one generation to another.

Representation

This is a technical concept from Distributed Cognition, as a general way to refer to both structures 'in the head', as well as those 'out there in the world' (cf. Hutchins 2001). The **investigative hypotheses** defined above are seen as one instance of such structures, for the purposes of this thesis. These investigative hypotheses are developed as part of the process of analysing incident situations to achieve understanding or explanation.

RCA – **R**oot **C**ause **A**nalysis.

Safety Function

A term used to uniquely refer to the particular probabilistic characterisation of causation, presented for use as part of the ***Information Safety Method***.

STAMP – **S**ystems-**T**heoretic **A**ccident **M**odel and **P**rocesses (this is the underlying conceptual model of incident situations being operationalised through **CAST**, see above)

Chapter 1 – Introduction

This chapter:

- Briefly summarises the outcomes of the literature review conducted in Chapter 2
- Identifies the research gaps motivating the need for the thesis work
- Provides a clear statement of the aims and objectives of the thesis
- Gives a brief overview of the thesis structure, and what to expect in each chapter

The need to understand and account for safety incidents has existed for centuries. Before the 19th century, preventing incidents was predominantly a practical activity (Hale and Hovden 1998). Such human endeavours have evolved over the years, into an area of contemporary study known under the rubric of **Safety Science**. At present, its scientific foundations are multiple, diverse, and fragmented. As yet, few established normative criteria for evaluating scientific validity exists for safety scientific research (Le Coze et al. 2014).

As noted by Le Coze et al. (2014), ongoing developments are taking place across all three major strands of safety scientific research: in the form of *methodological*, *theoretical*, and *empirical* contributions to the field. In particular, a topic of research receiving increasing interest in recent years is **systemic incident analysis**. Under this emerging subfield, incidents are *understood* and *explained* thorough treating them as *systems*. In this subfield, incident situations are characterised in terms of how *individual parts* relate to the *whole* (system).

In the subfield of systemic incident analysis, a number of major ways of conceptualising incident situations in terms of systems exist. In the general systemic incident analysis literature, incident situations are analysed as:

1) **systems of social-technical influence, decision making, and communication channels (Rasmussen and Svedung 2000, 2002)**. Under this conception, communication channels are conceived to be

the means by which *content (objects)* may be transmitted between *sources* and *destinations* across society.

2) **systems of socio-technical hazard control (Leveson 2002, 2011)**. Under this conception, 'Control commands' for communicating *safety constraints for controlling hazards* are potentially exerted through *reference channels* for communication (as part of organisations and society); Similarly, the efficacy of the hazard control commands is *monitored* through the transmission of information as objects through the *measuring* channel corresponding to each *reference* channel.

3) **a system of work functions, and variability propagation (Hollnagel 2012).** Under this conception, the incident analyst is encouraged to analyse how *information* acts both as a *resource* to be inputted into work functions and activities, and also acts as an *output* resulting from these work functions and activities. *Information (objects)* can also be used up as part of *resources* needed for organised work, or as part of the *conditions* for executing the work.

As substantiated through the detailed literature review (Chapter 2), all three of these major methods of systemic incident analysis sustain the illusion of 'objective information' – which may be passed as an object between members of society and organisations. In terms of systemic incident analysis methods in patient safety, little concrete guidance is provided in depth for the incident analyst seeking to understand *how* natural information systems form. In patient safety, incident situations are usually conceptualised in terms of systems of causes (Parker 2007, Wu et al. 2008).

Since conceiving naturalistic human communication in terms of 'objective information' is deeply misleading (Lakoff and Johnson, 2003), an *interactive, contextual,* method of analysing how information systems naturally form during incident situations is needed. Such a new method would act to offset the misleading dominant illusion of 'objective information transmission' during incident situations, currently present in the field of systemic incident analysis.

While safety scientists continue to develop new methods of systemic incident analysis, these conceptual innovations are of limited practical impact unless they are at some point used to analyse and learn from real incident situations as part of real incident investigation (Underwood 2013). For systemic incident analysis researchers, this is currently a major unresolved concern (Underwood 2013). The literature review conducted in Chapter 2 supports this view. Further research is needed in order to start to bridge the gap between systemic incident analysis methods in theory, and their usage and utilisation in practice.

1.1 Research aims and objectives

To address the two gaps identified above, the aims of this PhD research project are twofold:

A. To develop a new method to offset the misleading dominant illusion of 'objective information transmission' during incident situations, currently present in the field of systemic incident analysis. And to demonstrate this new method of systemic incident analysis through application to the analysis of a diversity of recent patient safety incident situations.

B. To start to bridge the gap between systemic incident analysis methods in theory, and their usage and utilisation in practice. This is done through examination of empirical data on contemporary safety incident analysis and investigation practice; as well as through empirical analysis of the move from systemic incident analysis methods in theory, into their practice as part of real incident investigation.

The specific project objectives are:

<u>**Objective 1 (to address aim A, Chapter 3)**</u>

To develop a new method of systemic incident analysis based on Distributed Cognition ideas and its worldview, called the **Information Safety Method**. This new incident analysis method is based on the Distributed Cognition focus on *propagation of representation states*, for example, through the act of a doctor writing a prescription chart, *propagation* of prescription information occurs through the coordination of at least two *representation states* (across the doctor and prescription chart). As part of the new analysis method, two new concepts are proposed based on the Distributed Cognition worldview: the incident analyst is prompted to assess for ***correct*** *representation,* and ***consistent*** *coordination of representation states* during incident situations. For example, if there is a spelling mistake in writing the prescription, *incorrect representation* can be said to have occurred for the representation in the form of the prescription chart; relatedly, if the doctor had in mind the right prescription, yet still wrote the wrong prescription down, an *inconsistent coordination* of prescription representations can be said to have occurred between the (incorrect) representation in the form of the prescription chart, and the (correct) representation of the right prescription information the doctor had in mind.

Through doing this, we are able to systematically analyse how information ‘flow’ is *constitutive* of the formation of distributed cognitive systems. The incident analysis is conducted through identifying the *systemically interactive*, *emergent*, and *naturally fallible* acts of communicative representation during the incident situation. Such systems are continually being formed daily, regardless of the robustness and success of the communicative acts and interactions constituting these emergent systems. Communication during incident situations is understood as a direct function of the communication *context*, irrespective of the degree of success or failure in attempting communication.

The new analysis method developed here embodies a strong interpretation of Distributed Cognition concepts (cf. Pea 1993, Moore and Rocklin 1998). The new method is based on a disbelief of the possibility of cognition residing solely in people, and the flow of objective information between them in communicating (Lakoff and Johnson 2003). Instead, the incident analyst is prompted to focus on *interactive co-ordination*, as the *sole and only* means of empirically evidencing *any* of the communicative and cognitive aspects of incident situations.

The new method also seeks to improve the likelihood of actual *learning from incidents*, through treating incident analysis as a distributed cognitive process; of ongoing *incident analyst and data triangulation* (cf. Rothbauer 2008); to explicit reflect the heavily qualitative nature of systemic incident analysis, as both conceived and practiced. Like existing methods of systemic incident analysis, the new method of systemic incident analysis is intended to be generalised and generative in nature, to play a part in enriching constructive discourse about incident situations regardless of the particular safety domain in question.

The new method represents an *advance in theory*, through codifying Distributed Cognition ideas for the specific empirical purposes of systemic incident analysis. This follows through on the recognised promise of Distributed Cognition based safety explanations (cf. Busby and Hughes 2003, Sweeney 2009), for explaining problems of communication during contingent incident situations. The Information Safety Method also advances safety science *methodology*, through contributing a new method of systemic incident analysis.

<u>Objective 2 (to address aim A, Chapter 4)</u>

To conduct a study of the new method of systemic incident analysis, in order to investigate whether the Information Safety Method *does what it is supposed to do*. A controlled empirical study was conducted, to explore the empirical consequences following from using the new method of incident analysis. Five diverse and relevant patient safety incident situations were independently selected by practicing patient safety incident investigators. These situations were then analysed using the Information Safety Method. The empirical study suggests that the method:

> 1) can help the incident analyst better understand how communicative fragilities develop as *natural information systems* form during incident situations,
> 2) and can support the *active* sharing of knowledge across individual incident analysis situations.

Various safety implications not identified through the prior incident analysis and investigation were also consistently uncovered during this study, relating to the particular incident situations analysed.

As indicated by Branford (2007), whether methods perform as intended is a suitable validation criterion for validating incident analysis methods. The current study indicates that the Information Safety Method can indeed do what it is supposed to do – which is to help illuminate how distributed cognitive systems form during incident situations through attempts at communicative interaction.

<u>Objective 3 (to address aim B, Chapter 5)</u>

In order to better understand contemporary incident analysis practice, we explore the degree to which systemic incident analysis is in fact practiced as part of patient safety incident investigation. In-depth interviews with two patient safety incident investigators were held to better understand their practice. The safety incident investigators provided detailed insight into their analysis concepts, methods, process, and the constraints of their work practice. The study findings obtained suggest that mixed rationales are in operation in patient safety incident investigation practice. In conducting their analysis work, the two incident investigators draw on both the belief that there *is* a *single, ultimate cause* to be uncovered, alongside the conflicting belief that such a *single cause* is impossible to determine practically. In addition, the idea that incidents occur due to *many causes* seems to be accepted only in part, as part of their practice. As with previous empirical research in the area, a complex mix of ideational and practical concerns and pressures seem to drive the conduct of patient safety incident analysis and investigation. In this particular study, five concepts significantly driving incident analysis and investigation practice are identified.

Objective 4 (to address aim B, Chapter 6)

To develop a new research method which can give detailed insight into how chosen systemic incident analysis methods relate to incident analysis practice, as part of real incident investigation. Here, we do not provide a second method for analysing incident situations; but provide a method of understanding *how* systemic incident analysis methods are utilised in practice. We examine the detailed relationship between the theoretical and practical aspects of doing systemic incident analysis. The new method is used to identify the *constraints* and *affordances* of each systemic incident analysis method, when it is utilised as part of individual real incident investigations in practice. Through doing such analysis, we may better understand how particular systemic incident analysis methods supported particular incident investigations, and the strengths and limitations of the chosen analysis method.

Objective 5 (to address aim B, Chapter 7)

To investigate the empirical implications of the new research method mentioned in Objective 4, the author acted both as *researcher* and *practitioner*. In the capacity of *practitioner*, the author conducted systemic incident analysis through 'wearing the shoes' of a small scale incident investigator. In the capacity of safety science *researcher*, the author designed this study to include independent replication of the use of the new research method, by another researcher not otherwise involved (in addition to the author's own analysis using the new research method).

Empirical data was thus examined in this study, of how the research theory *moved into practice,* for an established method of systemic incident analysis (ISMP Canada 2006). The incident analysis method used, and critically examined, was drawn as an exemplar from the pool of existing systemic incident analysis tools in patient safety. The detailed primary account of both the method and its practice, together, formed the empirical data critically examined and analysed using the new research method.

This study shows that the new research method can be applied in practice productively. Taken as a whole, the study also suggests that upon detailed research examination, even a relatively simple and well-developed systemic incident analysis method raises substantial methodological challenges, when used and enacted in practice by a junior safety scientific researcher.

1.2 Thesis overview

This thesis consists of eight chapters in total. They are outlined as follows.

Chapter 1: Introduction

This chapter has introduced systemic incident analysis as a subfield of safety scientific research. We have identified the two main gaps motivating the work of the following chapters. First, we identified a need to develop a new method to offset the misleading dominant illusion of 'objective information transmission' during incident situations, currently present in the field of systemic incident analysis. Secondly, we identified a need to start to bridge the gap between systemic incident analysis methods in theory, and their usage and utilisation in practice. This motivates the aim and objectives of the thesis work.

Chapter 2: Literature review

This chapter creates the substantive background for the thesis. We first set out the foundational assumptions on which the research project is based. Specific topics relevant to the research are then reviewed. Topics reviewed include:

- major developments in theoretical systemic incident analysis research,
- core precepts of Distributed Cognition,
- research on learning from incidents, and
- emerging evidence on the gap between systemic incident analysis research and incident analysis practice.

Through this review, we identify a need to develop a new method to offset the misleading dominant illusion of 'objective information transmission' during incident situations, and the need to start to bridge the gap between systemic incident analysis methods in theory, and their usage and utilisation in practice. These two needs are addressed through the subsequent chapters.

Chapter 3: A new method of systemic incident analysis (1st methodological and theory contribution)

This chapter develops the first of two new analysis methods contributed by the thesis. Here, we develop a new method of systemic incident analysis based on Distributed Cognition precepts, called the **Information Safety Method**. This new incident analysis method integrates the Distributed Cognition focus on *propagation of representation states*, with notions of *correctness* and *consistency*. The new method is illustrated with a concrete running example throughout this chapter, drawn from one of the two concrete incident situations analysed as part of preliminary trials of the new method. Like existing methods of systemic incident analysis, the new method developed in this chapter is intended to be generalised and generative in nature, to play a part in enriching constructive discourse about incident situations regardless of the specific safety domain in question.

Chapter 4: Analysing five patient safety incident situations using the Information Safety Method (1st empirical study and contribution)

This chapter follows directly from the methodological development work reported in Chapter 3, taking place after the development of the new incident analysis method, and its preliminary study. In particular, here we investigate whether the Information Safety Method *does what it is supposed to do*, through a subsequent controlled empirical study using incident data from five diverse and relevant patient safety incident situations. These incident situations were independently selected by practicing patient safety incident investigators using predefined inclusion criteria, as relevant to the analytical purposes of the Information Safety Method. Based on the resulting analysis of the five incident situations, we discuss some broader implications for improving the robustness of systems of information coordination and representation using the Information Safety Method.

Chapter 5: Concepts significantly driving incident analysis and investigation practice (2nd empirical study and contribution)

This chapter explore the extent to which systemic incident analysis research is in fact practiced in patient safety incident investigation, to contribute towards resolution of the lack of systemic incident analysis as part of incident investigation practice. In-depth interviews with two patient safety incident investigators were held, to better understand the concepts significantly driving their practice. Through using semi-structured interviewing with thematic data analysis, five significant concepts are identified to drive their incident analysis and investigation practice.

Chapter 6: A new method for relating incident analysis research theory to its practice (2nd methodological and theory contribution)

This chapter develops a new way of understanding how chosen systemic incident analysis methods relate to incident analysis practice, as part of real incident investigation. Here, we do not seek to analyse incident situations, but seek to provide a new empirical research method for advancing our understanding of *how* systemic incident analysis methods are utilised in practice. The new research method is based on the dual established notions of *constraint* and *affordance*. It offers a way to scrutinise the relationship between 1) the theoretical aspects of methods of systemic incident analysis, and 2) their empirical practice as part of real incident investigation. The new method developed in this chapter is called the **Systematic Reanalysis Method**.

Chapter 7: Exploring the implications of the Systematic Reanalysis Method (3rd empirical study and contribution)

This chapter follows directly from the methodological development work reported in Chapter 6. In the capacity of safety science *researcher*, the author designed this study to include independent replication of the use of the Systemic Reanalysis Method by another researcher not otherwise involved. The primary account of incident investigation used as data, was obtained through the author's practice of systemic incident analysis, through 'wearing the shoes' of a small scale incident investigator. The detailed primary account of both the chosen method and its practice, together, formed the empirical data critically examined and analysed using the Systematic Reanalysis Method.

This study shows that the Systematic Reanalysis Method, developed in Chapter 6, can be applied in practice productively. Taken as a whole, the study also suggests that upon detailed research examination, even a relatively simple and well-developed systemic incident analysis method raises substantial methodological challenges.

Chapter 8: Conclusions & Future work

This chapter highlights the contributions of the thesis to safety scientific research. The concluding chapter of the thesis returns to the context reviewed in Chapter 2, to summarise how the thesis has contributed method, theory, and empirical findings to the science of systemic incident analysis. Based on this work, and experience gained through the research investigations of the last few years, some recommendations for future work are presented for further consideration in this final chapter.

1.3 Ethical approval

For the two empirical studies presented in Chapter 4 and Chapter 5, the research was approved by the Queen Mary Joint Research Management Office (ReDA Ref: 009200). For the interview study of Chapter 5, a standard university information/consent sheet was adapted, provided to, and signed by the two participating incident investigators.

Chapter 2 – Literature review

This chapter:

- Clearly states the theoretical foundations informing the research
- Reviews the literature relating to systemic incident analysis and learning from incidents, and provides a basic introduction to Distributed Cognition
- Identifies the research gap motivating Aim A of the project: to develop and explore a new method to offset the misleading dominant illusion of 'objective information transmission' during incident situations (see chapters 3, 4)
- Reviews the emerging empirical evidence on the gap between systemic incident analysis research and practice
- Identifies the research gap motivating Aim B of the project: to make a start in bridging the gap between systemic incident analysis methods in theory, and their usage and utilisation in practice (see chapters 5, 6, 7)

2.1 Introduction

In this chapter, we contextualise the thesis through reviewing the extant literature. We begin by setting out and illustrating four foundational assumptions underpinning the primary work presented in the subsequent chapters. We then examine the latest major developments in systemic incident analysis research: through reviewing both basic principles of systemic methods in patient safety, as well as from the wider systemic incident analysis literature.

In patient safety, systemic analysis is predominantly done through explaining incidents as resulting from systems of *causes* and *contributory factors*; as an adaptation of basic principles from the RCA family (White 2009, Besnard and Hollnagel 2014). Two exemplars of 'systemic Root Cause Analysis' are reviewed in detail for illustration, in the current chapter. In the wider research literature however, incidents have been framed quite differently, based on more divergent lines of theoretical thinking. AcciMap (e.g., Rasmussen and Svedung 2000), CAST (e.g., Leveson 2011), and

FRAM (e.g., Hollnagel 2012) currently dominate the wider systemic incident analysis literature. These three major alternatives for systemic explanation are reviewed in turn, to evidence how the 'information as object' illusion is apparent from their language, terminology, and presentation to the prospective user. Since conceiving naturalistic human communication in terms of 'objective information' is deeply misleading (Lakoff and Johnson, 2003), a new alternative method of analysing how information systems naturally form during incident situations is needed. Developing a new method to offset the 'objective information' illusion, is one major aim of the thesis (Chapter 3).

The next part of the chapter then goes on to review basic principles of Distributed Cognition. This established theory about cognition provides the basis for the new analysis method developed in Chapter 3. The Distributed Cognition worldview also provides the starting point for the second of the two new methods developed by this thesis. It is designed to support empirical examination of *how* systemic incident analysis methods are followed as part of practice (Chapter 6). It supports understanding, through analysis, of how codified representations of systemic incident analysis methods (i.e., manuals representing the particular method) demonstrably shape and transform their enactment as part of real incident investigation (Chapter 7).

In the third part of this chapter, we review literature on learning from incidents. We start by examining simplified conceptual models proposed by researchers in the area, which attempt to distil the process of learning from incidents into a set of general and commonly reoccurring steps. We then turn to the older field of organisational learning, and find that the *dynamic, adaptive,* and *intersubjective* nature of learning emerges as a common thread. *Dynamic, adaptive*, and *intersubjective* processes of cognition (such as learning) lie at the heart of the Distributed Cognition worldview (Osbeck and Nersessian 2014). These aspects are consonant with the wide diversity of natural factors known to potentially hinder organised learning from incidents in practice. The new analysis method developed in Chapter 3 explicitly embraces the *dynamic* and *intersubjective* aspects of *adaptive* development of possible incident explanations. Such an approach may therefore help mitigate against some of the variable natural factors, where they serve only to hinder rather than enhance the quality of organised learning achieved. This is done through ongoing calibration and triangulation of the developing explanations (chapters 3, 4).

Finally, we turn our attention to emerging evidence on the gap between systemic incident analysis research and practice. We review empirical literature on the nature and extent of this research-practice gap. Underwood's (2013) initial examination of this issue provides our high-level overview. His initial map of the nature of this gap is supplemented by additional relevant literature specifically from patient safety. Together, this extant literature indicates a substantive gap between systemic incident analysis research, and existing incident analysis practice. A deeper understanding of how theoretical research in this area relates to existing practice is therefore needed. And provides the basic motivation for the work presented in the later part of the thesis: which seeks to advance knowledge and practice with respect to the current gap between systemic incident analysis research and practice (chapters 5, 6, 7). In particular, the method developed in Chapter 6 provides us with a way to generate detailed and substantiated understandings, of *how* systemic incident analysis methods are interpreted and followed in practice.

2.2 Theoretical foundations

Perrow's (1984) provocative thought experiment provides our point of departure for the thesis project. The five theoretical foundations on which the thesis work rests are illustrated and explained in this section, using examples drawn from Perrow's concrete incident scenario (where relevant). Diverse safety scientific conversations and contestations are ongoing around whether reality is singular or multiple; and around related issues of how we can come to know such realities with certainty. The theoretical foundations of the thesis are therefore explicitly declared, at the outset of our review of extant literature. The following illustrated explanations are intended to help position the subsequently narrative more clearly, within its parent domain of safety scientific research.

The incident situation he presents is arguably simple in nature; however, we make use of this simple scenario as a means to concretely ground the following foundational and abstract discussions. As we will see, the issues raised are both general in nature, and of relevance regardless of the severity and scope of the particular incidental situation being considered. We add numbers in curly brackets to the body of the quotation from Perrow, to allow reference to particular parts of his thought experiment.

<u>Perrow's **'A Day in the Life'** incident scenario</u>

" {1.1}You stay home from work or school because you have an important job interview downtown this morning that you have finally negotiated. {1.2}Your friend or spouse has already left when you make breakfast, but unfortunately he or she has left the glass coffeepot on the stove with the light on. {1.3}The coffee has boiled dry and the glass pot has cracked. {1.4}Coffee is an addiction for you, so you rummage about in the closet until you find an old drip coffeemaker. {1.5}Then you wait for the water to boil, watching the clock, and after a quick cup dash out the door. {1.6}When you get to your car you find that in your haste you have left your car keys (and the apartment keys) in the apartment. {1.7}That's okay, because there is a spare apartment key hidden in the hallway for just such emergencies. (This is a safety device, a *redundancy*, incidentally.) {1.8}But then you remember that you gave a friend the key the other night because he had some books to pick up, and, planning ahead, you knew you would not be home when he came. (That finishes that *redundant pathway*, as engineers call it.)

{2.1}Well, it is getting late, but there is always the neighbor's car. {2.2}The neighbor is a nice old gent who drives his car about once a month and keeps it in good condition. {2.3}You knock on the door, your tale ready. {2.4}But he tells you that it just so happened that the generator went out last week and the man is coming this afternoon to pick it up and fix it. {2.5}Another "backup" system has failed you, this time through no connection with your behavior at all (*uncoupled* or independent events, in this case, since the key and the generator are rarely connected). {2.6}Well, there is always the bus. {2.7}But not always. {2.8}The nice old gent has been listening to the radio and tells you the threatened lock-out of the drivers by the bus company has indeed occurred. {2.9}The drivers refuse to drive what they claim are unsafe buses, and incidentally want more money as well. (A safety system has foiled you, of all things.) {2.10}You call a cab from your neighbor's apartment, but none can be had because of the bus strike. (These two events, the bus strike and the lack of cabs, are tightly connected, dependent events, or *tightly coupled* events, as we shall call them, since one triggers the other.)

{3.1}You call the interviewer's secretary and say, "It's just too crazy to try to explain, but all sorts of things happened this morning and I can't make the interview with Mrs. Thompson. Can we reschedule it?" {3.2}And you say to yourself, next week I am going to line up two cars and a cab and make the morning coffee myself. {3.3}The secretary answers "Sure," but says to himself, "This person is obviously unreliable; now this after pushing for weeks for an interview with Thompson." {3.4}He makes a note to that effect on the record and searches for the most inconvenient time imaginable for next week, one that Mrs. Thompson might have to cancel. "

(Perrow 1984, p5)

2.2.1 The many contributors to incident situations

In contemporary safety science research, a basic starting assumption is that incident situations are a consequence of much more than a single 'main cause' [2]. Instead, any incident situation is assumed to result from *conjunctions* of its multiple aspects (Stoop 1995). Specific examples of this basic view include both James Reason's 'Swiss cheese' metaphor (e.g., Reason 2000, Reason et al. 2006), and Mackie's (1965) **INUS** conditions. These and other theoretical contributions to safety science provide many further examples, where the monocausal assumption of a single main cause is rejected as a basis for analysis. In attempting to explain Perrow's example through rejecting the monocausal assumption, the fact that the person *missed the job interview with Mrs. Thompson* {1.1, 3.1} can be explained through the following potential causes, including:

1) the lock-out of the drivers by their bus company {2.8},
2) the fact that coffee is an addiction for you {1.4},
3) that you gave your spare apartment key to your friend the other night {1.8},

(and so on ...)

This assumption that *incident situations develop as a result of multiple contributors* seems self-evident in principle, as a basis for analytical understanding and explanation. However, the *many contributors to incident situations* remain a difficult starting assumption, for every relevant safety stakeholder to accept fully and act on in practice. We will see primary evidence of these difficulties later, in examining the findings from research interviews to understand more about conducting incident analysis as part of patient safety incident investigation (Chapter 5).

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[2] Reference to 'causes' may go under a variety of different names and definitions, such as 'contributory factors' or 'barriers' in the patient safety literature for example.

2.2.2 Natural fallibilities and biases in investigative reasoning

Previous research across a diversity of investigators and disciplines suggests that investigative reasoning in practice can often fall far short of the ideals purported (cf. Mahoney 1977, Reason 1990, Miles and Huberman 1994, Esser 1998, Nickerson 1998, Johnson 2003a, Kahneman 2003, Reiman and Rollenhagen 2011, Manuele 2014). This previous research therefore provides the warrant, for assuming that the reasoning of *any* investigator can be *naturally* biased or fallible – even despite deliberate efforts at 'objective', impartial, inference.

An illustration of some of the natural fallibilities and biases in investigative reasoning can be seen in Perrow's example: due to the differing knowledge bases, and perspectives of the people involved in this case. Here, Mrs. Thompson's secretary made a snap judgement about the candidate interviewee's character, based on incomplete knowledge of the full *context* leading up to the interviewee's phone call to postpone {3.3, 3.4}. As the reader of the whole scenario, we have more 'impartial' and complete knowledge of its situational aspects, which helps to clarify the mismatch between the individual perspectives and knowledge involved. For each of the two people involved in the scenario however, their own behaviour and responses are not unreasonable (e.g., the interviewee making the phone call to postpone, and the secretary responding by deliberately searching for the most inconvenient time due to a lack of *full* understanding of the interviewee's particular situation). When various organisational factors and other pressures of working life are also introduced or recognised (e.g., Lundberg et al. 2010, Drupsteen and Hasle 2014), investigative reasoning is likely to be often quite imperfect: with lots of room for improvement in more fully accounting for the perspectives of all of the participants involved in the incident situation.

It is currently impossible to conclusively demonstrate that 'complete knowledge' of what caused an incident has been achieved (cf. Branford 2007, Harms-Ringdahl 2013). Particularly given the more ill-defined and ill-bounded elements relating to management, sociality, and organisation, accounted for in systemic understanding and explanation of incident situations. No incident analysis (systemic or otherwise) is likely to be indisputably perfect. All are open to potential improvement, at least in principle.

2.2.3 Non-subversive efforts in incident participation, and incident analysis

When interpreting interview data about investigative analysis of incident situations, we assume that both the incident participants, and incident analyst(s) are genuinely trying to do the best they can in the context of their particular working situations. The practices known through such interviews would need to be interpreted quite differently, if the potential for subversive efforts was assumed as a basis for empirical research. One major aim of theoretical work in the safety sciences is to ultimately develop ways to help relevant organisations attempt safety improvements, and hopefully reduce the likelihood of future incidents. It seems then sensible to conduct research investigations into systemic incident analysis on the basis of differing assumptions, compared to those of investigations based on adversarial disciplinary or criminal hearing. In assuming non-subversive efforts throughout the occurrence of incident situations, and their analysis (often done as part of incident investigation), we are likely to maximise constructive participant cooperation and involvement to support organised learning (cf. Canadian Patient Safety Institute et al. 2012). This forms the third theoretical foundation of the thesis work.

2.2.4 Inherent uncertainties in practicing incident analysis

The process of incident analysis is but one part of the broader incident investigation work (Hendrick and Benner 1987). Investigation of incidents is non-linear in practice, cognitively demanding, and distributed throughout the broader process of incident investigation (ESReDA 2009). Figures 2.1 and 2.2 show two approximations of how incident investigation is conducted, from both a practitioner (ESReDA 2009), and more academic perspective (Johnson 2003a), respectively. Whereas Figure 2.1 highlights the non-trivial role of *initial* analyst knowledge in informing the course of an incident investigation, Figure 2.2 highlights the role of detection and reporting during latter parts of the process.

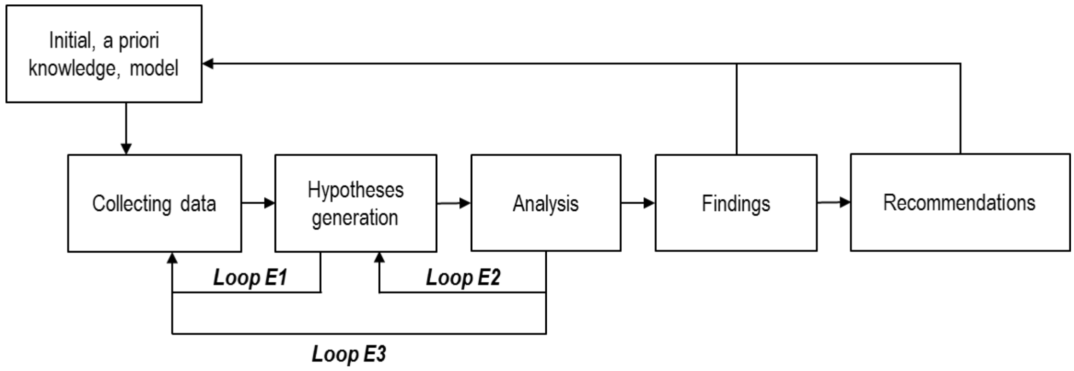

Figure 2.1: A perspective of incident investigation process according to ESReDA (adapted from ESReDA, Figure 7, 2009). The work-flow arrows of the original have been simplified here.

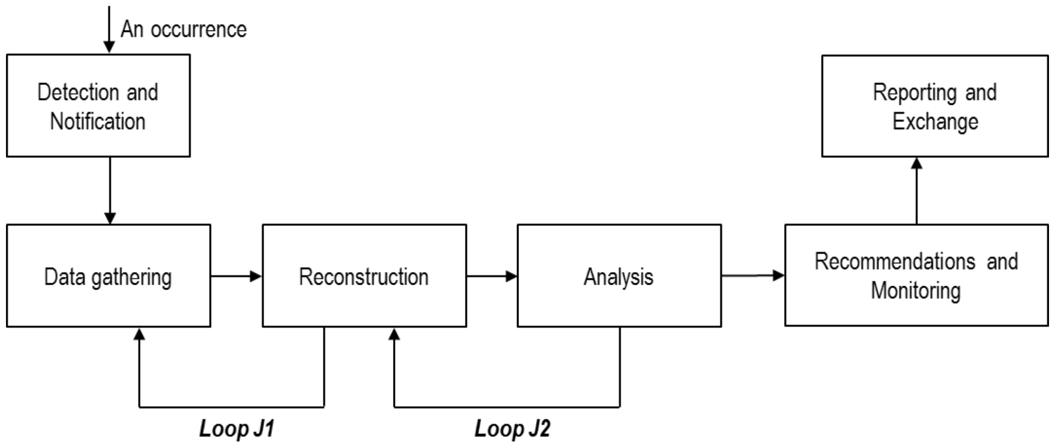

Figure 2.2: A perspective of incident investigation process according to Johnson (adapted from Johnson, Figure 5.1, 2003a). Here 'an occurrence' refers to an incident situation having been detected.

These figures show that a large part of an investigation is iterative across multiple phases: for example when collecting 'facts' about an incident (Loops E1, E3, J1), and when making inferences based on the incident data collected (i.e., all of the five loops highlighted in Figures 2.1 and 2.2). In conducting such iterative sense making, analysts may decide that their incident understanding is sufficient, and move on to the post-analysis phases shown in each of the two figures. Alternatively, more data regarding the incident situation may be deemed necessary, to enrich the analyst's existing understanding of the incident situation (e.g., Loop E3). Such cycles of gathering data and sense making, helps the investigators to generate and refine ***investigative hypotheses***, in a similar way to how qualitative analysts routinely deal with empirical data (cf. Miles and Huberman 1994, Figure 1.4). Like the hypotheses developed during qualitative data analysis, the *investigative hypotheses* developed during incident analysis are also inherently uncertain in nature. For this thesis, the dialogue between ideas and evidence is conducted under the following rationale, where an investigation is done to diagnose:

> **“***unknown situations through an iterative reasoning cycle in which a temporary and conditional adaptation of the hypothesis under investigation takes place. One way of looking at the investigation is that it is about reducing uncertainty about what happened, why it happened and what should be done about it by applying the knowledge available to the investigator(s) based on the evidence obtained during the investigation.***”**
> (ESReDA 2009)

As suggested by the consensus statement above, the interpretative ideas resulting from investigative reasoning, and their reporting, are both ultimately revisable. Published reports of analysis of incidents often use language suggesting the presentation of ‘hard’ factual knowledge. The reality of practicing analysis of incidents is much more uncertain however, as reported by practicing incident investigators (e.g., ESReDA 2009, Clinical Human Factors Group 2012). Our ***investigative hypotheses*** about the *relevant* structuring of incident situations are indeed just ‘best-efforts’: at alternative understandings, explanations, and illumination of selected aspects of a highly complex and ill-defined empirical phenomena. Such reasoning structures aim to derive order, in the face of an often far from complete picture of what is known, supported by the background knowledge and expertise of particular incident analysts and investigators. This background can be highly diverse and variable, depending on the particular issue of concern, and aspects of the incident situation pertaining to the concern. The *validity* of these representations, on which to base subsequent action, is therefore inherently uncertain to some degree, regardless of what theories and methods are used to support the incident analysis done.

As warranted by Distributed Cognition theory, we use the term *representation* in this thesis to include *all* of the representation structures generated during incident analysis. These representational structures include both structures ‘in the head’, as well as those available for independent inspection by others (e.g., the various ideas about why the incident happened, which may or may not be written down). Such internal and external structures are therefore both included, in discussing the ***investigative hypotheses*** developed during/through incident analysis. A firm basis in natural language is often the representation of choice for both recording ‘incident data’, and presenting investigative hypotheses to others for review. The non-legislated, loosely consensual, and dynamically evolving nature of natural language (Pinker 2014) may thus act as an additional contributor, to the natural uncertainties of incident analysis process.

Despite their inherent drawbacks as sources of 'factual' evidence, reports of incident investigations are nevertheless commonly used as a source of incident data for testing analysis methods (Benner 2013). This is the approach taken later in this thesis, when empirically exploring some of the implications of the new method of systemic incident analysis we develop in Chapter 3.

2.3 Latest major developments in theoretical Systemic Incident Analysis research

2.3.1 A system of *causes* as the unit of incident analysis

In the nascent area of patient safety research and practice (Vincent and Hewett 2013), variations on **Root Cause Analysis (RCA)** principles are the most popularly promoted kind of approach (Parker 2007, Wu et al. 2008). While details vary, the following six aspects reoccur across most RCA based analysis methods (Hollnagel and Speziali 2008):

Aspect 1: Determine sequence of events,
Aspect 2: Define causal factors,
Aspect 3: Analyse each causal factor's root causes,
Aspect 4: Analyse each root cause's generic causes,
Aspect 5: Develop and evaluate corrective actions,
Aspect 6: Report and implement corrective actions.

Many existing incident analysis proposals in patient safety elaborate on these six common aspects. In some, there is a clear focus on constructing *systems of causes* as the unit of analysis. Two particularly comprehensive examples of such *systemic* Root Cause Analysis, are the **London Protocol** (Taylor-Adams and Vincent 2004a, 2004b), and the **Canadian Incident Analysis Framework** (Canadian Patient Safety Institute et al. 2012). The **London Protocol** suggests that *systems of causes* are to be constructed through first identifying a number of proximal '*care delivery problems*', followed by the more distal factors contributing to each *care delivery problem* (Figure 2.3).

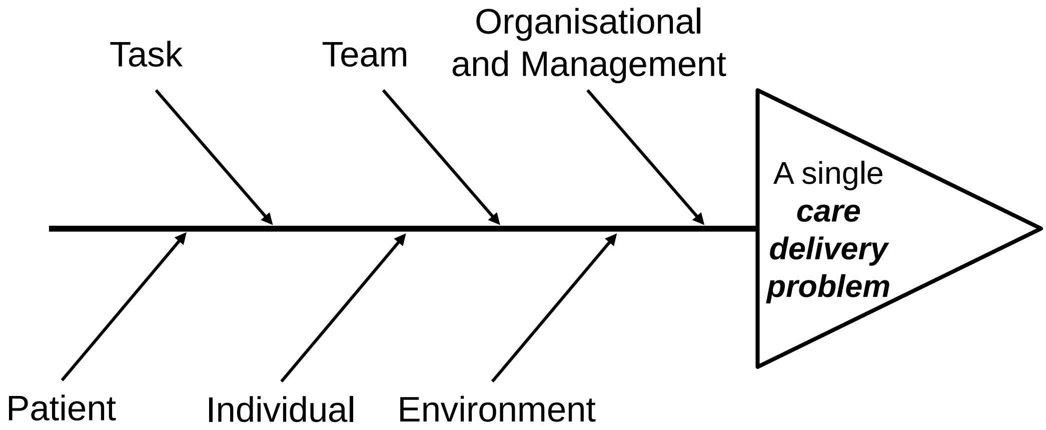

Figure 2.3: Six kinds of potential latent causes for a care delivery problem. Adapted from Taylor-Adams and Vincent (2004b, Figure 5).

Somewhat similarly, a so called ‘constellation diagram’ is proposed as part of the **Canadian Incident Analysis Framework**, which provides an alternative data coding scheme to support the construction of systems of causes (Figure 2.4). These aspects of the two methods correspond to **Aspects 2 through to 4**, as described by Hollnagel and Speziali (2008) above.

In patient safety, the main difference between individual RCA variants is usually in terms of the specific *typologies of causes* proposed, for supporting the incident analyst. The role of these typologies also vary, in helping analysts generate concrete systems of causes as pertaining to the specific incident situation. For example, the **London Protocol** mediates identification of latent causes through the abstract construct of *care delivery problems* (Figure 2.3). A different typology is proposed as part of the **Canadian Incident Analysis Framework**. The typology there is mediated more directly, through the construct of *(adverse) incident outcome* (Figure 2.4). In either case, the construct of ‘cause’ is left very loosely defined, facilitating flexible interpretation and construction of such systems of causes in principle. While details vary, the general aim of such methods is to move the thinking of the incident analyst towards conceptualising incident situations in a *fully multifactorial* fashion, as explained earlier in Section 2.2.1, and *away* from the ‘single main cause’ conceptualisation common to everyday causal thinking (at odds with contemporary safety scientific thinking).

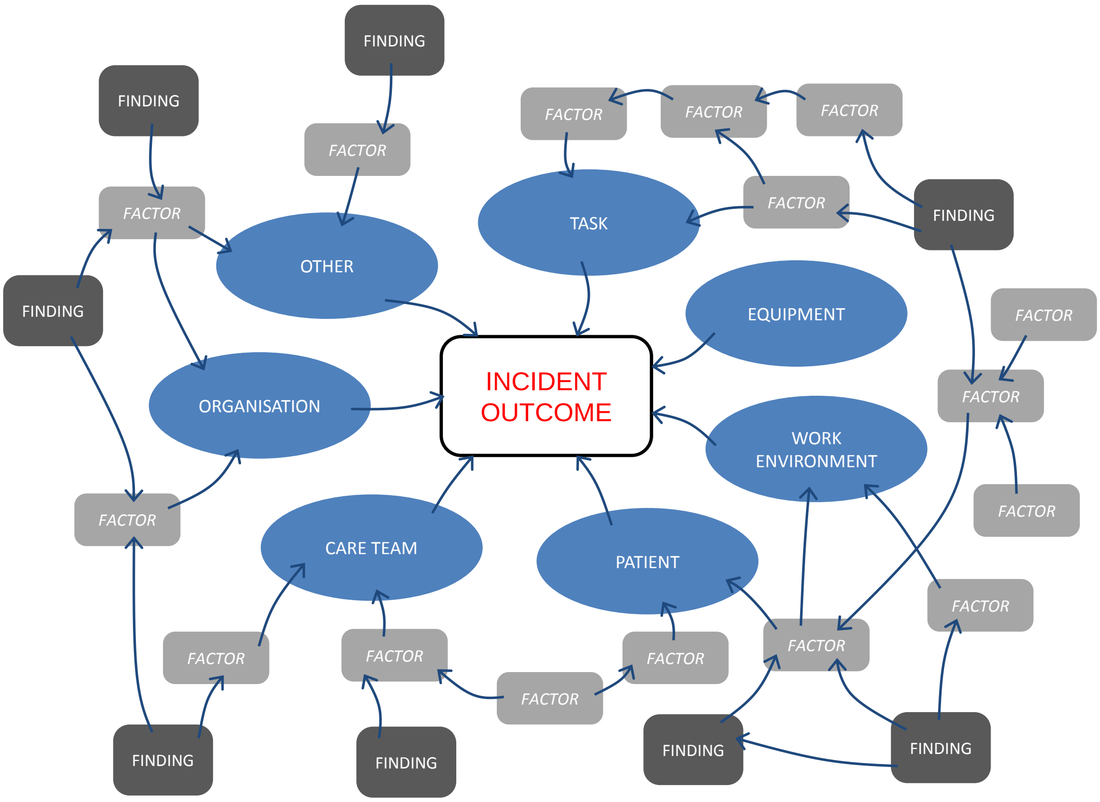

Figure 2.4: A so-called 'generic constellation diagram'. Arrows represent perceived causal links into increasingly distal parts of the incident and 'system'. Adapted from Canadian Patient Safety Institute et al. (2012, Appendix H).

The abstract typologies shown in Figures 2.3 and 2.4 may be sometimes broken down further, to help the incident analyst as part of the provisions of the method. Table 2.1 presents one such example from the **London Protocol**. The more detailed prompts for use are shown down the right hand column of this table; the left hand column corresponds approximately to the six 'cause categories' shown in Figure 2.3. In this case, the prompts shown in Table 2.1 were proposed following an informed synthesis (Vincent et al. 1998) – of both the 'resident pathogen' metaphor of Reason (1990), alongside aspects from the human factors literature.

Table 2.1: A proposed framework of contributory factors influencing clinical practice. Adapted from Taylor-Adams and Vincent (2004b, Table 1). Prompts obviously to do with issues around **information/communication** are **highlighted in bold** here.

Different types of contributory factors to consider in analysis	**More detailed breakdown of each major prompt** (e.g., a *patient factor* relating to *patient condition*)
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 etc).**
Work environmental factors	Staffing levels and skills mix, Workload and shift patterns, Design, availability and maintenance of equipment, Administrative and managerial support, Environment, Physical.
Organisation 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.**

While abstract typologies are routinely used across many patient safety RCA methods, few go beyond the presentation of taxonomic hierarchies (cf. Table 2.1, Snijders et al. 2009, Taitz et al. 2010, Lawton et al. 2012). As illustrated here, RCA based analysis methods in patient safety do not usually support explicit analysis, of *how* natural systems of information representation form.

2.3.2 Systems of social-technical influence, decision making, and communication channels as the unit of incident analysis

As part of a broader proactive approach to socio-technical risk management, the **AcciMap** method was proposed by Rasmussen and Svedung (2000, 2002). **AcciMap** is intended to encourage deeper analysis of the broader influences that may have prepared, and shaped the socio-technical landscape – both prior to, and subsequent to the ‘critical event’ of an incident situation [3]. Predicated on the starting assumption that risk management is basically a control problem, **AcciMap** construction facilitates explicit understanding of the distributed system of *influence*, *decision-making*, and *communication paths* aspects of an incident situation. Despite its popularity amongst safety researchers, practical guidance for how to go about constructing the four **AcciMap** representations we overview below is only available at a fairly minimal level of detail. While not central to the contributions of this thesis, Branford (2007) provides more in-depth discussion of difficulties in inter-analyst replicability, as well as advantages due to the flexibility of the original **AcciMap** method.

Four different forms of diagrammatic representations form the core of the **AcciMap** method – as defined by Rasmussen and Svedung (2000, 2002):

(1) A single **AcciMap**:

> represents the patterns of socio-technical influence facilitating the particular incident situation. In particular, a substantive focus of these influence graphs is to explicitly show how particular decision makers, and decision bodies across society help to both set-up, as well as manage the consequences following the ‘critical event’ of an incident. An illustrative example is shown in Figure 2.5. An individual **AcciMap** corresponds to the specifics from an individual incident situation.

(2) A **Generic AcciMap**:

> is based on multiple individual **AcciMaps**, a kind of representative ‘mega AcciMap’ can be generated. This **generic AcciMap** looks somewhat similar to individual **AcciMaps**, but embodies more abstract generalisation across individual incident scenarios. How this generalising move ought to be done is not well-defined in the method’s reference documents (see Rasmussen and Svedung 2000, 2002). Nevertheless, this second graphical

[3] In patient safety terms, such a ‘critical event’ could be an amputation of the wrong leg for example. This ‘critical event’ construct is subtly yet significantly different from the ‘incident outcome’ construct shown in Figure 2.4; in the fact that the critical event of the incident outcome is but one of many ‘events’ occurring throughout the development, progression, and possible resolution of an incident situation beyond the ‘incident outcome’.

representation seems to function as a generalised summary, of salient commonalities across the many single **AcciMaps** corresponding to individual incident situations. Through such generic representation, the idea is to obtain inductive and normative aggregation, of the analytical knowledge embodied by individual **AcciMaps**.

(3) An **ActorMap**:

is based on the analytical knowledge represented through the **Generic AcciMap**. This diagram explicitly focuses on the 'organisational actors/bodies' embodied in **Generic AcciMaps**.

(4) An **InfoFlowMap**:

is a *graph* (in the mathematical sense), showing the *normal* information channels between the participating 'actors' represented in the **ActorMap**. An **InfoFlowMap** is produced based on 'filling in' some of the possible channels of communication between participating 'actors'. Figure 2.6 shows an example, illustrating how information flows along the normal communication channels between actors, from a previously identified **ActorMap**.

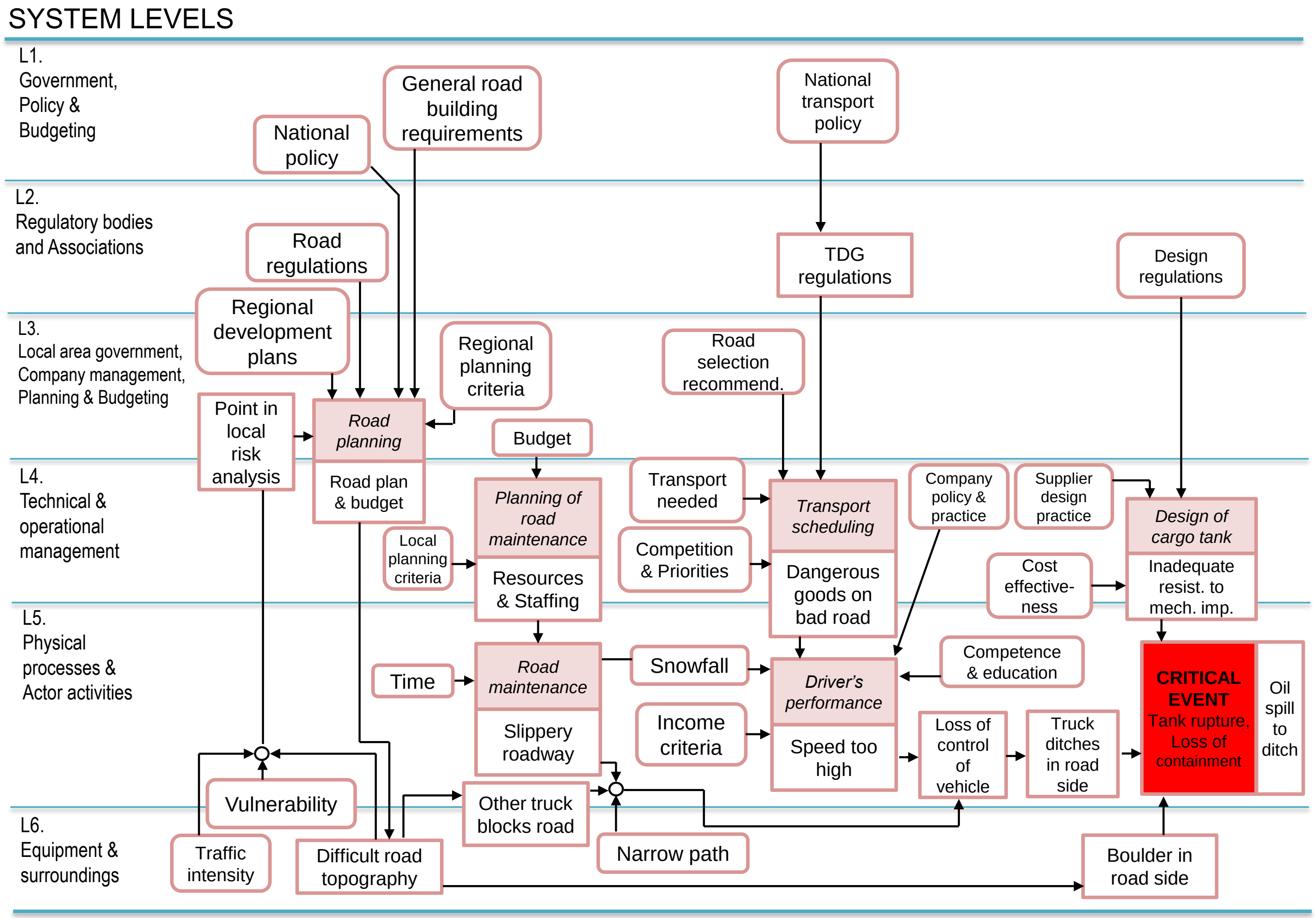

Figure 2.5: An **AcciMap** of the social-technical decision making landscape in which this transport incident situation developed, prior to the 'critical event' of a tank rupture (bottom right hand side). Similar graphical representation of the events and interactions after the 'critical event' of this incident is not included here, but proceeds in basically the same fashion. Adapted from Rasmussen and Svedung (2000, Figure 3.3A).

In Figure 2.5, square edged boxes represent identified 'consequences' of various sorts (e.g., *TDG regulations* is a consequence of *national transport policy*). Round edged boxes represent various preconditions of the situation evaluated no further in this particular **AcciMap** analysis. Arrows in this figure are supposed to denote the 'influence' relationships amongst the elements they connect together. The filled pink boxes represent various *decisions*, *functions*, *tasks* and/or *actions* that could have been done differently, and are thus potentially sensitive to improvement for safer work operation in the future.

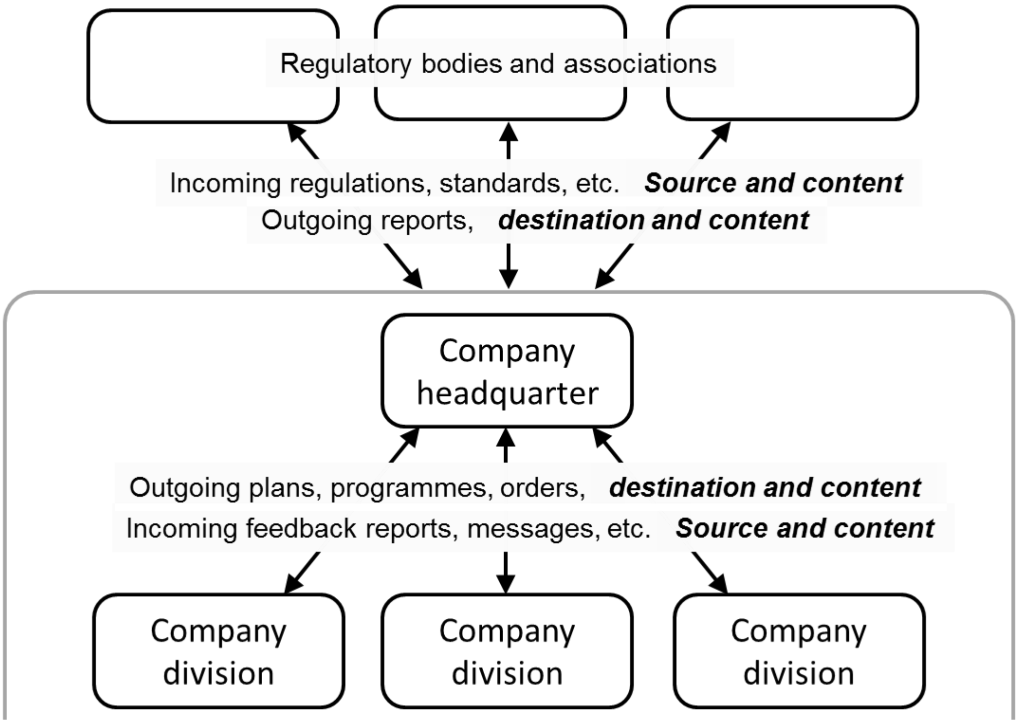

Figure 2.6: Part of an illustrative **InfoFlowMap** for a generic company headquarter. Adapted from Svedung and Rasmussen (2002, Figure 9).

The **AcciMap** method seems to stem from an 'incident as harmful energy/hazard release' metaphor (Rasmussen and Svedung 2000, Section 5 and Figure 7.9; see Kjellen 2002 for more detailed review of this kind of incident conceptualisation). Graphical representations like that of Figure 2.5 encourage analysis of the broader socio-technical 'influences' which could perhaps be intervened on, to help prevent the (metaphorical) release of (adverse) energy/hazards. As part of his broader contributions to safety scientific research (Le Coze 2015), **AcciMap** reflects Rasmussen's commitment to encourage deeper appreciation of the 'vertical' linkages and influences relating to incident development and occurrence, *across* the major traditional 'silos' of academic research and disciplines (Figure 2.7; cf. the 'system levels' in Figure 2.5). In particular, the **AcciMap** emphasis is on the need to investigate the influences across each and every one of these horizontal 'levels' of society, in dealing with the inherently multi-disciplinary problem of risk management (and incident analysis by implication).

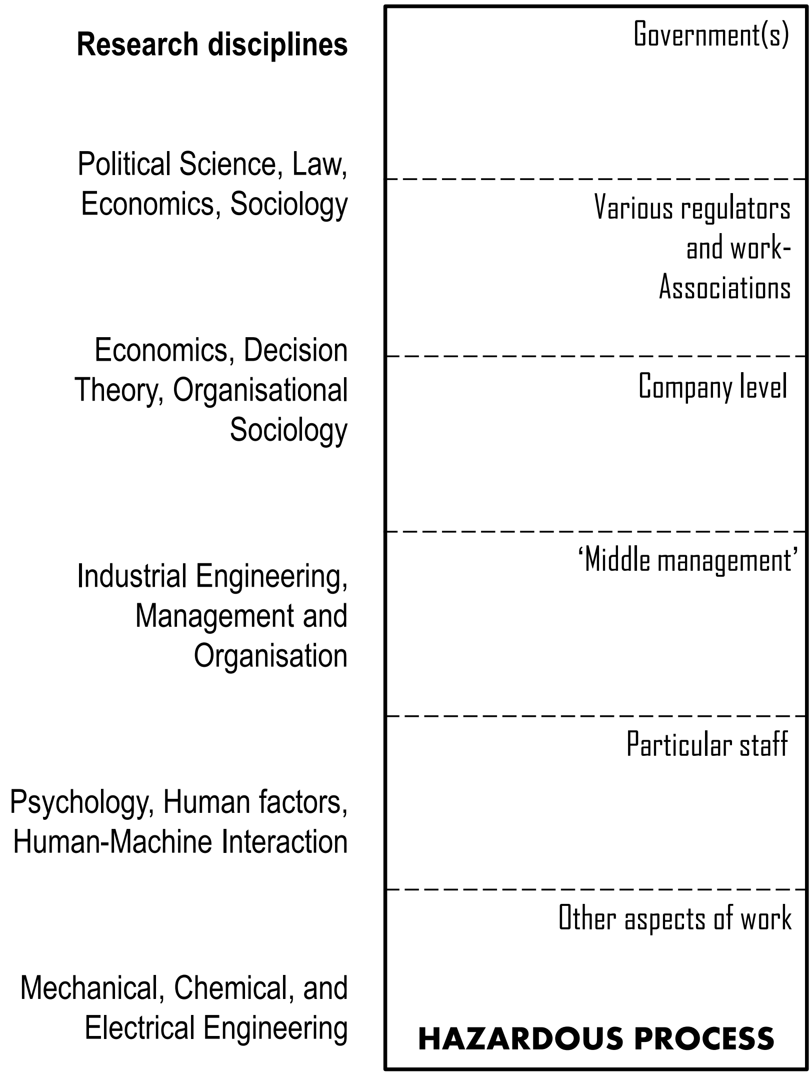

Figure 2.7: The approximate correspondence between various research disciplines, and different levels of societal control (adapted from Rasmussen 1997, Figure 1).

For the purposes of this thesis, the point to note here is that **AcciMaps** encourage a 'channel-based' conception of how information flows through society and organisations too (e.g., see Figure 2.6). Further discussions, diagrams, and method presentation relating to 'content of communication', throughout Section 7 of Rasmussen and Svedung (2000), provide further evidence for this interpretation of **AcciMap** method. The perspective naturally necessitates the conceptualisation of 'information objects' – as the 'content' which flows through channels 'in' organisations and society. In this fashion, the 'information as object' illusion is being sustained, as part of the theoretical basis of the **AcciMap** method.

2.3.3 Systems of *socio-technical hazard control* as the unit of incident analysis

Further developing Rasmussen and Svedung's (2000) analytical emphasis on societal control, Leveson (2002, 2011) proposes the ***C**ausal **A**nalysis based on **ST**AMP* (**CAST**) method, as a way to operationalise her ***S**ystems-**T**heoretic **A**ccident **M**odel and **P**rocesses* (**STAMP**) incident model to support incident analysis. The hypothesis motivating **STAMP** (and **CAST** by implication), is that 'systems theory' is a useful way to analyse incidents (Leveson 2004). More specifically, **CAST** analyses are conducted under the assumption that incidents happen due to a lack of appropriate *constraints* on the various interactions that occurred (Leveson 2011, p67). They are thus attributable to the particular safety control structure which may or may not have been in place at the time.

Leveson (2011) proposes the following 9 main steps to do, in conducting a **CAST** incident analysis. Further generic details about how to 'do **CAST'**, is not well-defined beyond the level of detail presented here:

> **CAST step 1:** Identify the system(s) and hazard(s) involved in the loss.
>
> **CAST step 2:** Identify the system safety constraints and system requirements associated with the hazards.
>
> **CAST step 3:** Document the safety control structure in place to control each hazard and enforce the safety constraints. This structure includes the roles and responsibilities of each component in the structure, as well as the controls provided or created to execute their responsibilities, and the relevant feedback provided to them to help them do this. This structure may be completed in parallel with the later steps.
>
> **CAST step 4:** Determine the proximate events leading to the loss (of the incident).
>
> **CAST step 5:** Analyse the loss at the physical system level. Identify the contribution of each of the following to the incident events:

- physical and operational controls,
- physical failures,
- dysfunctional interactions,
- communication and coordination flaws, and
- unhandled disturbances.

Determine why the physical controls in place were ineffective in preventing the hazard.

CAST step 6: Moving (recursively) up the levels of the safety control structure, determine how and *why* each successive higher level allowed or contributed to the inadequate control at the current level. For each system safety constraint, either the responsibility for enforcing it was never assigned to a component in the safety control structure, or a component or components did not exercise adequate control to ensure their assigned responsibilities (e.g., safety constraints) were enforced in the components 'below' them. Any human decisions or flawed control actions need to be understood in terms of (at least):

- the information available to the decision maker as well as any required information that was *not* available,
- the behaviour-shaping mechanisms (the context and influences on the decision-making process),
- the value structures underlying the decision, and
- any flaws in the process models of those making the decisions and why those flaws existed.

CAST step 7: Examine overall coordination and communication contributors to the loss.

CAST step 8: Determine the dynamics and changes in the system and the safety control structure relating to the loss, and any weakening of the safety control structure over time.

CAST step 9: Generate recommendations from the **CAST** analysis.

As an analyst proceeds through these steps, the general idea is to start to construct one or more **STAMP** models (which provide the main theoretical/conceptual basis underpinning these 9 steps). These investigative hypotheses thus identify the system(s) of socio-technical hazard control, which may or may not have been in place at the time. There is as yet no formalised procedure for creating these ***STAMP** based investigative hypotheses* (Underwood 2013, cf. Leveson 2011), or for providing structured presentation of them (Hollnagel and Speziali 2008, cf. Leveson 2011). Their development can therefore substantively vary across different case studies (the interested reader may wish to compare in detail the case-independent aspects of the investigative hypotheses developed: by Johnson and de Almeida (2008), Dong (2012), Leveson et al. (2012), and Underwood and Waterson (2014) for example). Despite such diversity, some commonalities seem to reoccur across different published incident analyses based on **CAST/STAMP**.

One common emphasis seems to be on the explicit identification of hierarchical systems of control. These systems are socio-technical, and to an extent cultural in nature; and their hierarchical aspects have some similarity to the six 'system levels' of **AcciMap** (compare Figure 2.5 with Figure 2.8). An illustrative 'generic model' is presented as part of **CAST/STAMP** method, based on Leveson's perspective of the key actors and control-relationships in the United States (Figure 2.8). This figure enumerates – in the abstract – some of the potential means of *exerting/communicating* 'control commands', and *monitoring* the efficacy with which the associated safety constraints (of the societal systems of control) are being satisfied. The incident analyst then goes on to instantiate some of these abstractions as they pertain to concrete incident scenarios. Under a **STAMP** perspective, the communication of control commands and monitoring of safety constraints are done through the so-called 'reference' and 'measuring' channels (as shown more concretely in Figure 2.9). For the purposes of this thesis, we assume that the *system operations* half of Figure 2.8 (i.e., the right hand side) is probably intended to be relevant to any **CAST** incident analysis. Leveson (2011) does not explicitly explain the extent to which the *system development* half of **STAMP** modelling is indeed applicable to **CAST** incident analysis, however, in the section of the book devoted to '**CAST** method'. Figure 2.9 illustrates some elements from a concrete **STAMP** model, from an analysis of the US pharmaceutical products control structure (circa 2010).

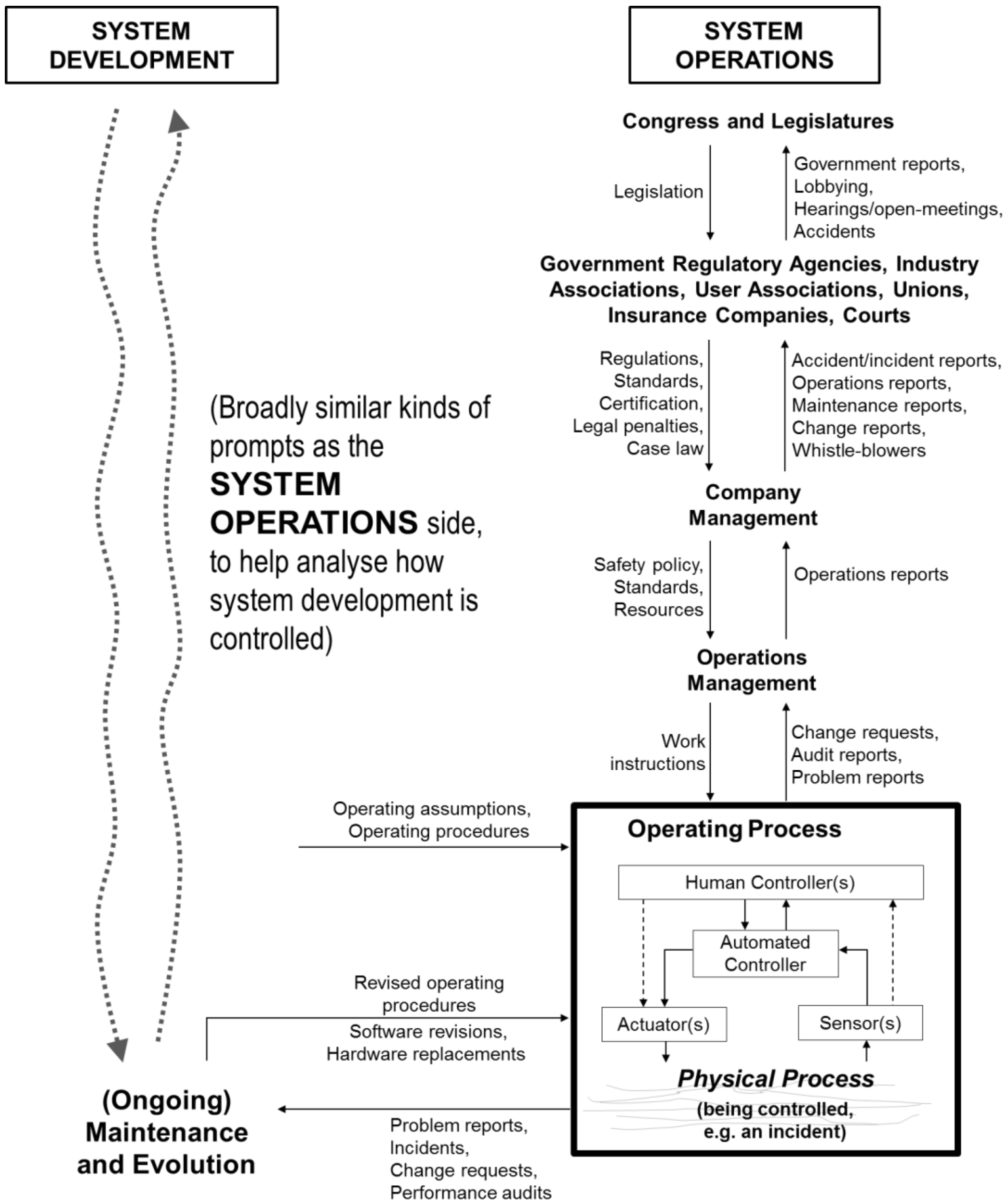

Figure 2.8: General form of a STAMP model of sociotechnical control. Adapted from Leveson (2011, Figure 4.4).

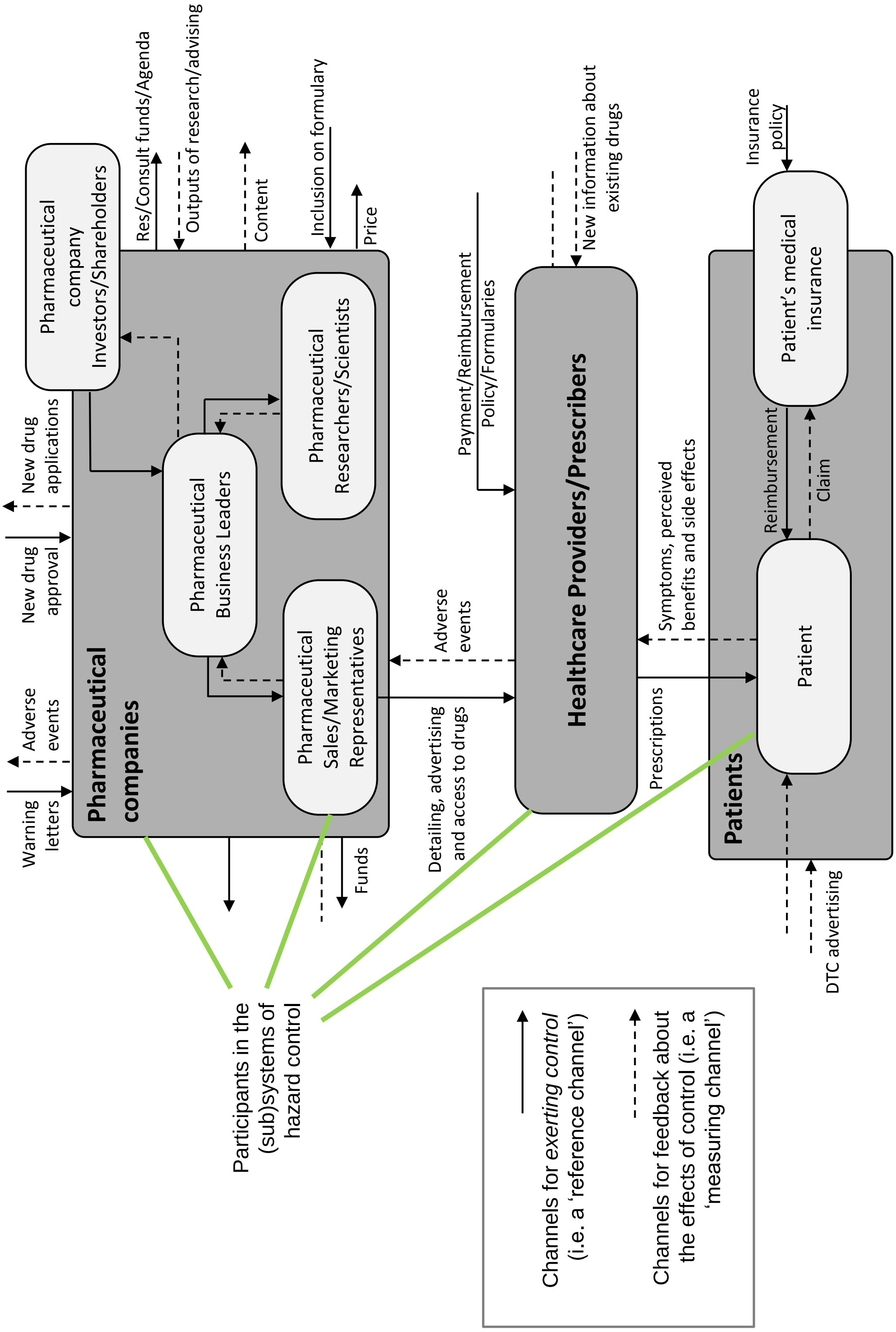

Figure 2.9: The 'bottom' part of a concrete STAMP analysis, adapted from Leveson et al. (2012, Figure 1), and annotated by myself. This is from an analysis of the US pharmaceutical products control structure conducted by one of Leveson's masters students.

Like for the **AcciMap** method, we see that the **STAMP** based investigative hypotheses underlying a **CAST** analysis also take a channel-based conceptualisation of how information flows (e.g., Figures 2.8 and 2.9). Leveson (2011, Section 11.8) does discuss issues around redundancy in information flow, however. The discussions in this part of her book again demonstrates how a channel-based conceptualisation necessitates the subsequent idea of 'information objects' – as the 'content' flowing through such conduits between actors in organised society. In this fashion, the 'information as object' illusion is also sustained as part of the **CAST** method.

2.3.4 A system of *work functions*, and *variability propagation* as the unit of incident analysis

The **Functional Resonance Analysis Method** (**FRAM**, Hollnagel 2012, Hollnagel et al. 2014) was developed to encourage explicit recognition of the everyday successes of 'safe system operation': as simply the flip side of failures. In conducting FRAM analysis, no special conceptual distinction is made between work *during* incidents, and 'normal' everyday work. In particular, incidents are considered as emergent phenomena resulting from dynamic, 'non-linear' interactions. One of the underpinning concepts of FRAM is based on the assumption that human and organisational performance is always *necessarily* variable. The idea of '*stochastic resonance* as *noise benefits*' (McDonnell and Abbott 2009) seems to be analogously applied for FRAM analysis, in order to understand both safe 'non-incident' work in the same way as work during incident situations. Figure 2.10 illustrates the conceptual analogy drawn in FRAM – between the signal processing notion of 'stochastic resonance', and FRAM's proposal of 'functional resonance'. I added the annotations down the right hand side of this figure, to make this conceptual analogy more explicit and accessible to an unfamiliar reader. As shown in this figure, the concepts of 'frequency' and 'amplitude' are used metaphorically in FRAM – to draw an analogy from these two aspects of waveforms, to the 'frequency' and 'amount' by which work may or may not vary over time.

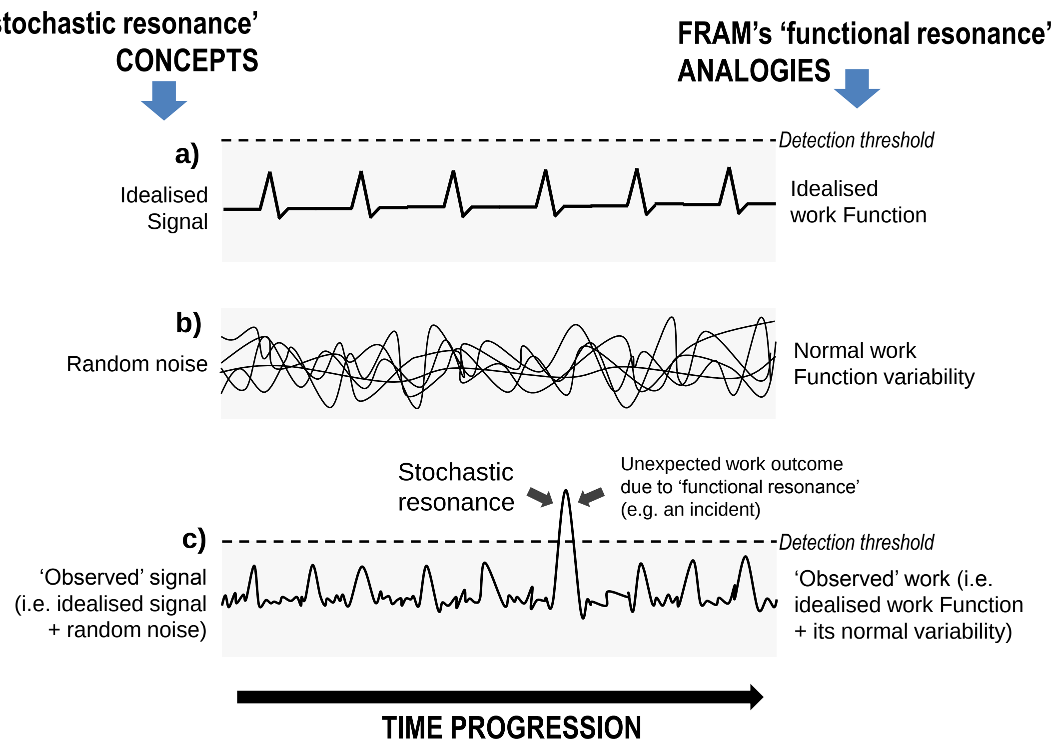

Figure 2.10: Visually illustrating the basic idea of FRAM's 'functional resonance', as applied to both 'safe' and 'incident work'. Adapted from Hollnagel and Goteman (2004, Figure 1).

Taking the 'functional resonance' metaphor further, FRAM proposes the following main analytical steps. Because work during incidents is not treated as a special case under FRAM, these main steps remain basically the same, regardless of whether FRAM is used for analysis during risk management, or incident analysis. In the rest of this section, **I**nitial **C**apitalisation will be used to distinguish between a more specific FRAM analysis concept, as opposed to the common usages and meanings of the particular word (e.g., 'FRAM **F**unction' *vs.* 'functional aspects of work', 'FRAM **F**unction **I**nput' *vs.* 'input'). Figure 2.11, Table 2.2, and Table 2.3 *together*, give an idea of what a concrete 'FRAM model' looks like. Like in the case of **STAMP**, these 'models' predefine the kind of concrete investigative hypotheses developed during incident analysis, but with respect to aspect of *functional coupling*, and *systemic variability* instead here. The analysis output shown across these three representations were generated through FRAM analysis of a surgical incident, where material was unintentionally left in a patient's abdomen. We go on to discuss aspects of FRAM specifically relevant to the contributions of this thesis, after presentation of its main steps and examples of FRAM analysis outputs.

FRAM step 1:
Identify what is required for everyday work to succeed in terms of 'FRAM Functions', through a *functional*, rather than *task*-based, or *activity*-based conceptualisation;

FRAM step 2:
Characterise both the *potential*, and *actual* variability of each of the (FRAM) Functions identified through step 1;

FRAM step 3:
Look at the specific patterns of functional coupling between parts of the system of FRAM Functions identified, to better understand how the 'variability' of individual work functions may 'resonate/propagate', potentially leading to unexpected outcomes for the system of Functions as a whole;

FRAM step 4:
Propose ways to manage the possible occurrences of uncontrolled performance variability that have been found through steps 1-3 (this step seems to be as yet largely under development, in terms of the lack of concrete guidance available to support what to do for incident analysis here).

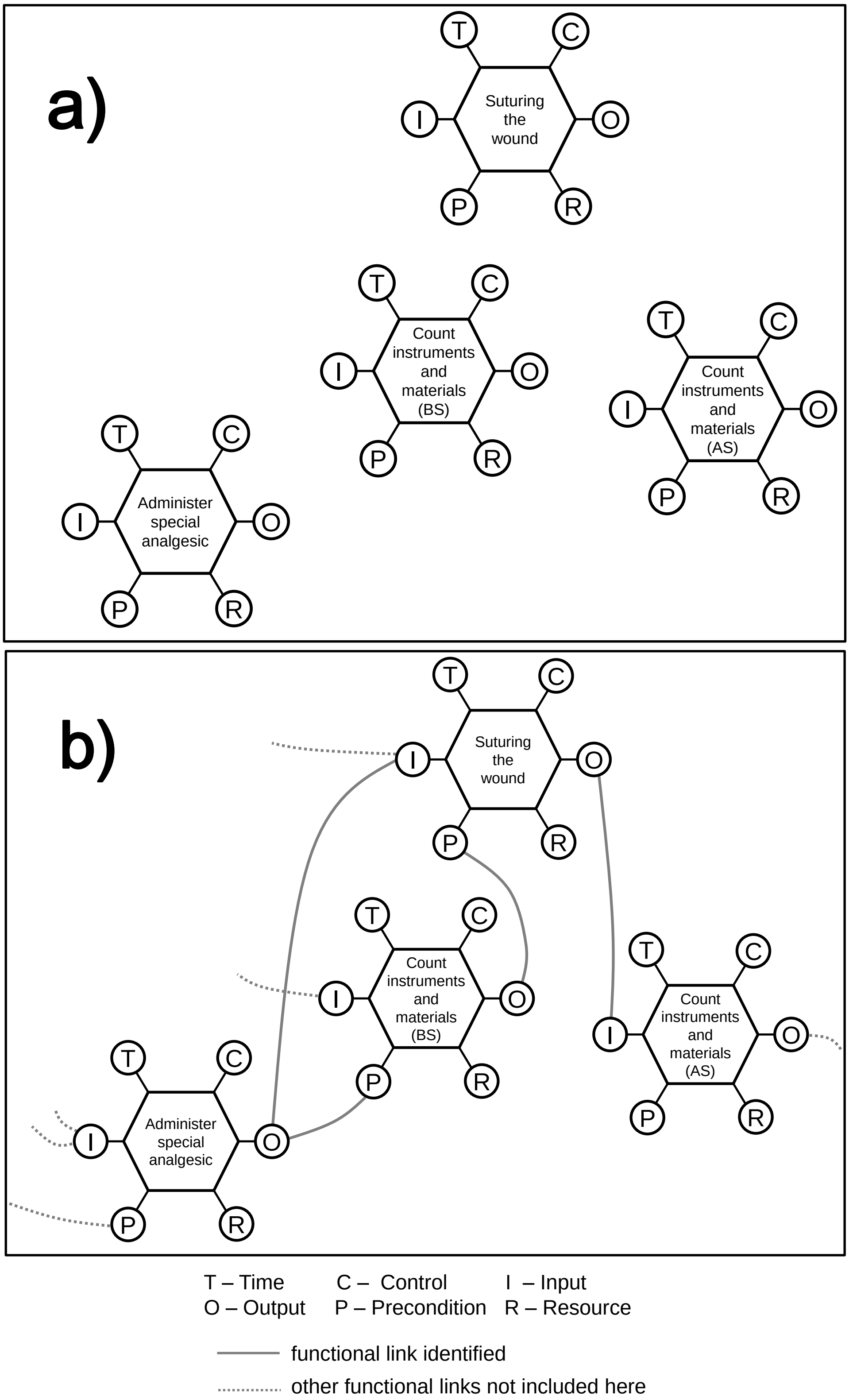

Figure 2.11: Graphical representation of part of a concrete 'FRAM model' (2.11a), and a particular instantiation of this 'FRAM model' (2.11b). In this figure, '**BS**' and '**AS**' stand for work functions ***b****efore,* and ***a****fter* **s**urgery respectively. Adapted from Hollnagel (2012, Figure 9.1).

Table 2.2: Textual representation of the 'Suturing the wound' Function shown in Figure 2.9b. Single quotes indicate adapted quotes from the original. Adapted from Hollnagel (2012, Table 9.1).

Name of the FRAM Function:	'Suturing the wound'
Description: '[Suturing the wound] is part of the completion of the surgical procedure. To be done by the main surgeon'	
Function aspect	**Description**
INPUT	'Surgical procedure has been completed'
OUTPUT	'Wound has been sutured'
PRECONDITION (two identified in this case)	'All instruments and materials are accounted for'
	'Special analgesic has been administered'
RESOURCE	'not described initially'
CONTROL	'not described initially'
TIME	'not described initially'

Table 2.3: Textual representation of the 'Administer special analgesic' Function shown in Figure 2.9b. Single quotes indicate adapted quotes from the original. Adapted from Hollnagel (2012, Table 9.5).

Name of the FRAM function:	'Administer special analgesic'
Description: '[Administering special analgesic is] to be done by the scrub nurse. Note that this was an additional task during this surgery'	
Function aspect	**Description**
INPUT (two identified in this case)	'Tissue sample has been excised'
	'Syringe with special analgesic'
OUTPUT	'Special analgesic has been administered'
PRECONDITION	'Haemostasis has been achieved'
RESOURCE	'not described initially'
CONTROL	'not described initially'
TIME	'not described initially'

Ideally, in a FRAM analysis the identification of such systems of (work) Functions should continue until no unexplained (or unexplainable) work variability remains. Although graphical representation of these Functions, and the coupling between the aspects of each Function can be used for convenient communication, it is their *textual* aspects (e.g., Tables 2.2, 2.3) which form the primary mode of FRAM based representation, of analysis outputs (according to Hollnagel). The graphical representations of FRAM analysis outcomes (e.g., Figure 2.11) conveniently complement the textual representation of the outcomes, however. In particular, the *uncoupled* system of FRAM functions (as shown in Figure 2.11a), forms the 'FRAM model' of the functional aspects of work. This *uncoupled* 'FRAM model' delimits the *potential range* of sets of functional couplings possible. One possible configuration of inter-Functional coupling in an incident context is shown, in Figure 2.11b for example.

For the purposes of the current review, the way in which these Functions are identified (**FRAM step 1**) is the focus of interest. Table 2.4 summarises the abstract coding scheme proposed by Hollnagel (2012), for this initial part of FRAM method.

Table 2.4: The range of aspects and issues – in the abstract – one could identify as part of constructing a FRAM Function. Adapted from Hollnagel (2012, Chapter 5).

The name of this FRAM Function (which must be a *verb phrase*, describing *something being done*)	
The six abstract aspects of each Function to consider in a FRAM analysis (the concrete 'instantiations' of each of these abstract Function aspects must be a *noun phrase*, describing a *state*); In terms of a (FRAM) Function's:	What should be described as part of a FRAM analysis (**C**apitalised words are used to refer to the individual abstract aspects of a FRAM Function)
Input	The analysis should identify that which is used or transformed by the Function, to produce its ***Output*** (in terms of its *matter*, *energy* or *information* ***Input(s)*** for example).
Output	An ***Output*** of a Function is the result of what it does, for instance by processing its ***Input***. Corresponding to the proposal for ***Input*** identification, *matter*, *energy*, or *information* ***Output(s)*** may be identified for the current Function.
Precondition	The analysis should identify various additional conditions of work – which are (ideally) all satisfied before the current work Function is carried out. Unlike its ***Input***, this aspect of a Function does not in itself constitute a signal that 'starts/activates' it.
Resources, and/or the ***Execution Conditions*** necessary for facilitating this Function	The analysis should identify the things that are needed or consumed while a Function is carried out. Some examples of such 'consumables' include *matter*, *energy*, *information*, *competence*, *software*, *tools*, *manpower* etc. Although *time* is in principle also a ***Resource***, it is treated as a 'special' Function aspect in FRAM (cf. the last row in this table).
Control (Input) aspects	The analysis should identify that which supervises or regulates a Function, so that its desired ***Output*** is obtained. Some illustrative examples of ***Controls*** include a particular *plan*, *schedule*, *guidelines/instructions*, *a (control) algorithm*, *exceptional work conditions to look out for*, and *work* or *social expectations*.

Time aspects	The analysis should identify the various ways in which issues relating to *time* can affect how a Function is carried out. In principle, these timing issues can alternatively also be characterised as part of the ***Input***, ***Precondition***, ***Resources/Execution-Conditions***, or ***Control*** aspect of a FRAM Function.

As shown in Table 2.4, FRAM clearly sustains the 'information as object' illusion as part of its theory and conceptualisation. A fairly traditional 'information processing' assumption is again elaborated on here, to encourage analysis of how 'information (objects)' can be both inputted into a Function, as well as outputted from it. Under this framing, *information* can naturally also be 'used up' – as part of a Function's Resources, and/or Execution Conditions.

2.3.5 Summary

In summary, Section 2.3 has shown that the 'information as object' illusion is sustained by all three of the major methods of systemic incident analysis reviewed. In the case of the *system of causes* being advocated in patient safety, however, no strong theoretical commitment can be evidenced through the methodological literature reviewed, regarding the issue of conception of *information*. We join reputable others (e.g., Lakoff and Johnson 2003, Wears 2012) in arguing that the 'information as object' illusion fundamentally misconceptualises how natural human communication occurs. This motivates the need to develop a new method to offset the misleading dominant illusion of 'objective information transmission' currently present in the field of systemic incident analysis (Aim A of the PhD project).

2.4 A Distributed Cognition perspective on ecosystems of (human) cognition

This thesis was substantively influenced by the Distributed Cognition perspective of Edwin Hutchins (cf. Hutchins 2001, 2006, 2010, 2014; Rogers 1992, 1993, 1997; and Moore and Rocklin 1998 for example). We introduce the basic principles of Distributed Cognition at this point, to provide a theoretical foundation for the rest of the thesis.

Over recent decades, Distributed Cognition has become increasingly popular. It provides an alternative to classical approaches to human cognition. As a cognitive theory, Distributed Cognition does not make strong ontological claims. It does not claim to describe what human cognition *is*. Instead, it is probably best described as providing a loose set of epistemological foci and strategies. As Hutchins notes:

> "to take the distributed perspective is not to make any claim about the nature of the world. Rather, it is to choose a way of looking at the world, one that selects scales of investigation such that wholes are seen as emergent from interactions among their parts"
> (Hutchins 2014, p36)

Moreover, a basic assumption of Distributed Cognition is that *all* cognitive activity is distributed in nature (Hutchins 2014). Taking this starting assumption, an investigator applying Distributed Cognition is encouraged to look for *how* cognitive distribution occurs, interactively. While Distributed Cognition retains the basic interest in seeking to understand and explain the organisation of cognitive situations, it differs substantively from classical cognitive science. In contrast, the Distributed Cognition emphasis is on *broader, non human-centric* units of analysis. Consequently, the boundary between 'inner' and 'outer' aspects of human cognition is softened and often dissolved: with both often treated as a single conglomerate for effecting cognition. Existing citations of the original monographs and papers articulating Distributed Cognition show interest in this 'framework theory' from a diverse range of application domains. For example, Distributed Cognition has been used as a basis for theorising about research and engineering process and practice (Giere 2002, Nersessian 2009), clinical education (Pimmer et al. 2013), safety critical situations (Masci, **Huang**, et al. 2012; Rajkomar and Blandford 2012; Franklin and Zhang 2014), and as a theoretical basis for data reduction in observation situations (Halverson and Clifford 2006, Blandford and Furniss 2006). In particular, the 'cognition as computation' metaphor of cognitive science is retained. The computation metaphor is 'stretched', however, to encompass and emphasis the broader, intersubjective contexts enabling 'distributed cognitive systems' to emerge. Whilst Distributed Cognition does not commit to how computations are actually 'implemented' inside people, a substantive focus is on how states of *representation* are *created*, *transformed* and *propagated* in naturalistic situations (Hutchins 1995a, p49). From a Distributed Cognition perspective, the world consists of constantly evolving patterns of interactive, functional couplings between participating elements – which form the distributed cognitive process and system emerging from analysis.

Two theoretical principles are distinguishing, and central to Distributed Cognition (Hollan et al. 2000).

The first principle concerns the **unit** of Distributed Cognition based **analysis**. Distributed cognitive processes are looked for wherever they may occur, on the basis of *what functional relationships emerge amongst the participating elements*. These functional, cognitive relationships delimit the bounds of the analysis done, rather than the spatial colocation of the participating elements. Such dynamically configuring cognitive systems are socio, technical, and also often cultural in nature. A canonical illustration of two such systems is demonstrated, in terms of the differing representational assumptions between Western and Micronesian ship navigation tradition and culture (Hutchins 1995a, Chapter 2). Other 'original' examples of Distributed Cognition based analysis are also available – in the context of an airline cockpit situation for example (Hutchins 1995b, Hutchins and Klausen 1996, Hutchins and Palen 1997). In each case, the *unit of Distributed Cognition based analysis* is allowed to freely vary – depending on the particular patterns of emergent interactions observed.

The second principle of Distributed Cognition concerns **the range of participants assumed to be relevant in supporting systemic patterns of cognitive activity.** Unlike the classical approaches to human cognition, Distributed Cognition is relatively agnostic, and not human-centric – about who, and/or what may participate in a particular cognitive system (Halverson 2002). Both human and non-human participants are potential candidates, for inclusion in an analysis of how systems of cognition naturally emerge. Counter-intuitively, non-human participants of such systems can include natural representation states of the world: such as states of particular islands perceived relative to the ocean and repurposed for supporting Micronesian ship navigation for example (Hutchins 1995a, Chapter 2). *States of representation* may also be more artificial in nature: in the form of states of a Western navigation chart or alidade for example (Hutchins 1995a, Chapter 2). In Distributed Cognition based analysis, the naturalistic and artificially constructed features of the world are both 'primary participants' – of the distributed cognitive process and system. While it does not reject the internal representation assumption underpinning classical approaches to cognitive science, Distributed Cognition does take a contrastive, 'outside-in' approach to systemic description and explanation. Such an explanatory strategy naturally foregrounds the mediating role of externalised aspects of cognition, and minimises the role of explanation based on traditional 'egocentric', 'inner' conjectures about how people cognize. In particular, one emphasis of Distributed Cognition is on how observable representations *must* contribute to the less observable aspects of human cognition.

When these two central principles of Distributed Cognition are applied to the observation of human activity 'in the wild', at least three kinds of cognitive distribution become apparent through analysis:

- distributed cognition across members of a social group,
- distributed cognition through coordination between internal and external (material/environmental) structure, and
- distributed cognition through time, such that the products of earlier events can transform the nature of later ones.

The Distributed Cognition theory reviewed here provides the basis for development of the Information Safety Method (chapters 3, 4). In looking for *how* cognitive distribution occurs, interactively, the developed Systematic Reanalysis Method (chapter 6, 7) provides one way of exploring how systemic incident analysis method information is actually distributed – between their tangible representation and their users when used in practice.

2.5 Learning from incidents

2.5.1 Emerging models of learning from incidents

Due to a growing interest in the area, several theoretical perspectives have emerged on *learning from incidents* in recent years. For example, Lindberg, Hansson and Rollenhagen (2010) proposed that learning from incidents may be viewed as a chain of steps. According to them, learning starts with the *reporting of incidents* (Step 1), *selection of incidents for further investigation* based on the initial reporting (Step 2), and *incident investigation* (Step 3), followed by the *dissemination and communication* of the outcomes of the investigation (Step 4), and finally the actual *prevention of (future) incidents* (Step 5). They proposed that the process as a whole can fail – if one of these links in the chain of steps fails. They also emphasised the need for the process to be self-reflective, to enable improvements to be recursively made to the learning process itself.

A different model of learning from incidents was presented by Jacobsson et al. (2010; 2011). In contrast to Lindberg et al. (2010), they see learning as a more *cyclical* process. Jacobsson et al. also frame learning from incidents slightly differently: as consisting of *data collection and reporting*, *analysis and evaluation*, *decisions*, *implementations* and *follow-up* as part of a learning cycle.

In response to the mostly theoretical nature of existing models of learning from incidents, Drupsteen (et al. 2013, 2014) developed a more elaborate model of the learning from incidents process. Her model claimed to integrate parts of the wider theoretical literature on learning. In contrast to the models by both Lindberg et al. and Jacobsson et al., the model of Drupsteen (et al. 2013, 2014) was additionally calibrated against new empirical data as part of her PhD studies, and subsequently refined in light of the resulting new understanding of key part of the learning from incidents process. Drupsteen's model of learning also takes a stepwise view, like Lindberg et al. (2010). However, it also integrates conceptual elements from the well-known Deming cycle of continual business improvement (i.e., 'Plan-Do-Check-Act', see Deming 1982), with the organisational learning theory of Argyris and Schon (1979). The most recent, revised 2012 version of Drupsteen's model is shown in Figure 2.12.

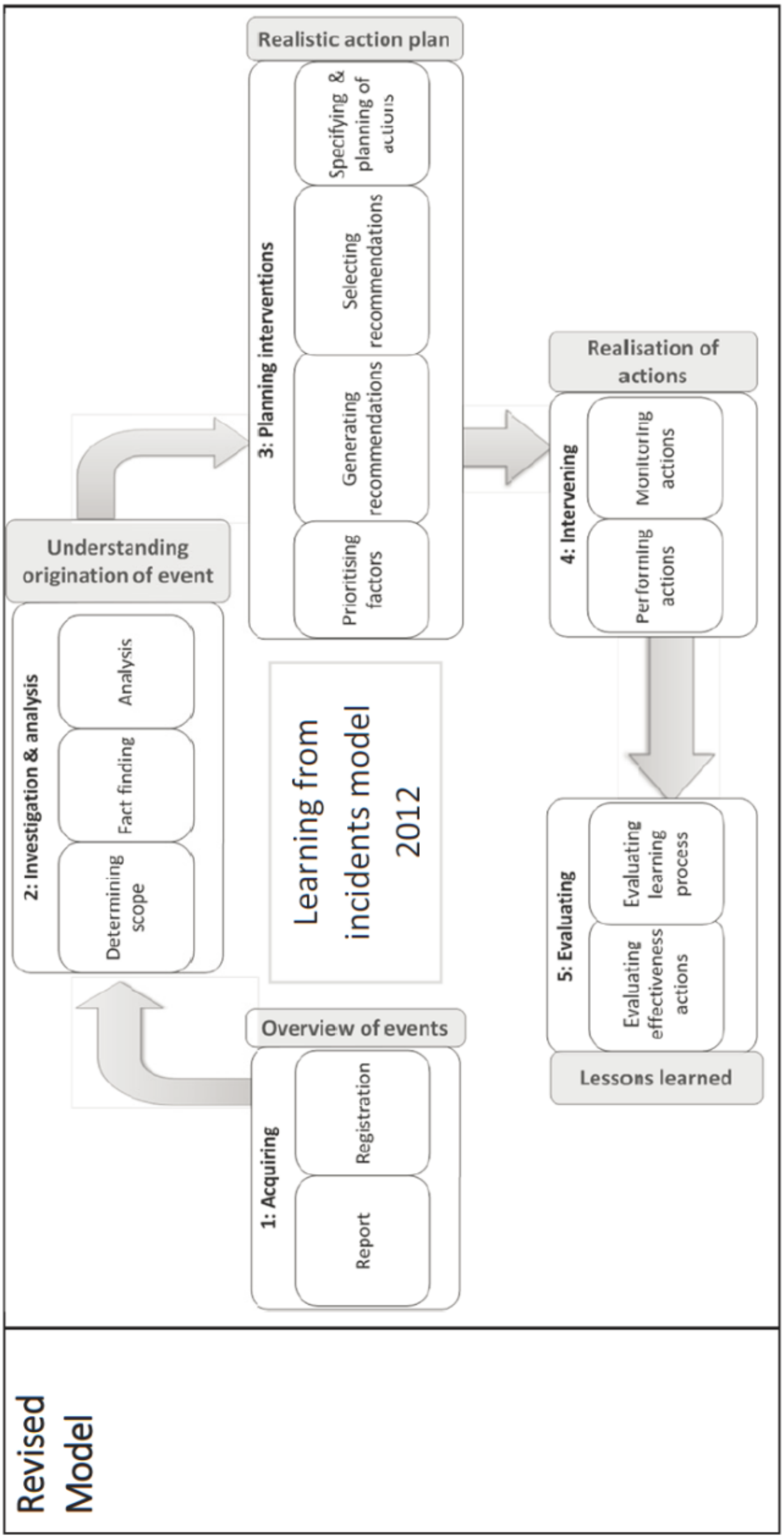

Figure 2.12 A revised conceptual model of *learning from incidents*. Reproduced from Drupsteen (2014, Figure 5) with permission.

Informed by its theoretical heritage, Drupsteen's new perspective emphasises the need for an understanding of the *complete* organisational process: from studying incidents (i.e., incident analysis and investigation), through to using the resulting knowledge outcomes to attempt prevention of future incidents. Key assumptions embodied by Drupsteen's model of the process include:

- the fact that learning from incident situations will not be effective if there is a discrepancy between what actors in organisations *say/think they do* (the *espoused theory* in Argyris and Schon's terms), and what they *actually do* (the so called *theory-in-use*),
- the recommendation that improving learning from incidents will require a philosophy of 'learning to learn', and
- the recommendation that it is useful to be sensitive to how learning from incidents may be supported or hindered by the organisational environment in which the process of learning is performed.

2.5.2 Factors potentially hindering organised learning

The various understandings of how learning from incidents occurs – embodied by the conceptual models reviewed above – are all necessarily simplified; due to the complex and contingent nature of incident evolution, occurrence, and situational progression. We now go on to review existing knowledge on a range of factors not fully captured by these simplified models of learning from incidents. As one might expect in this complex area of empirical research, many factors have been identified to potentially impact on how learning from incidents occurs.

In conducting incident analysis as part of organised work, numerous factors may hinder the enactment of organised learning from incidents in practice. In terms of the initial parts of a learning process for example, learning may be limited by too few incidents being reported, or limited knowledge about particular incidents (Mancini 1998, Sanne 2008, Rasmussen et al. 2013). A diversity of personal factors may also limit the extent of learning achieved. Personal beliefs and previous understanding and knowledge may limit how lessons for learning are identified, how remedial actions are selected, and how lessons learnt are implemented (Carmeli and Gittell 2009, Lundberg et al. 2010, Stockholm 2011, Fahlbruch and Schöbel 2011, Sanne 2012). People tend to hold on to their beliefs, despite evidence to the contrary (Reason 1990). Latent causes for incidents may therefore not be identified (Jacobsson et al., 2009; Körvers and Sonnemans, 2008), and thus impede the implementation of remedial actions (Cedergren, 2013).

Other contributing factors impeding learning include the formation of premature hypotheses, mono-causal thinking, and influences from how individuals have previously thought about and experienced work (Fahlbruch and Schöbel 2011, Sanne 2012). Safety fixes that are known to work and easy to understand can also be more likely to be implemented (Lundberg et al. 2010). The presence or lack of high quality relations among people (i.e., shared goals, knowledge and mutual respect), and 'psychological safety' (i.e., people feel that they can safely ask questions or feedback, and report errors) may also have an effect on the learning process (Carmeli and Gittell 2009).

Through qualitative interviews with 22 incident investigators across different domains in Sweden, Lundberg et al. (2010) found a wide range of factors which worked against the ideal of 'what-you-find-is-what-you-fix' (cf. Lundberg et al. 2009) during actual incident investigation. For example, in investigation practice, the prior theoretical and experiential competencies of the investigator could substantively affect the kind of data collected, and incident analysis done. This is broadly congruent with the earlier empirical research of Svenson et al. (1999) and Branford (2007), who independently found that opinion on analysing the same incident situation may vary substantively – depending on the particular backgrounds of the incident analysts (e.g., disciplinary), and leading to divergent understandings of system interactions and finding from incident analysis. Lundberg et al. (2010) also found that the cost-benefit balance projected by an incident analyst may also be significant, in shaping what remedial actions are designed for potential implementation; although investigators from different safety domains did not unanimously agree on the relevance of this particular factor in the study. Material limitations can also shape data collection and analysis during incident investigation, where limited time (e.g., for part-time investigators) or limited data (e.g., due to subsequent dissolution of a key relevant organisation after the incident occurred, or due to the voluntary nature of investigation co-operation as mandated by law or policy) may potentially constraint the depth of analysis and investigation enacted.

In attempting empirical explanation of why organisations may not necessarily effectively learn from incidents, Drupsteen and Hasle (2014) identified a number of contributing causes and conditions. These included low visibility of organised incident prevention efforts in some cases, fear of negative consequences as a consequence of speaking up for the organisational employee (i.e., extra work for the individual, or creating a negative image for management), and a systematic blind spot for recognising and discussing organisational/cultural issues. As a consequence of their empirical examination of the issue, Drupsteen and Hasle (2014) concluded that more studies are needed to identify both the differences, and broad commonalities in why organisations may fail to learn from previous incidents.

Taken as a whole, this previous research shows that many factors may influence both what an investigator finds, and the lessons identified through incident analysis. Such lessons may be acted upon, sometimes. They are however not always necessarily addressed as part of incident investigation practice. This motivates the need for incident analysis methods to be developed which more actively encourage learning from incident situations (cf. Francis 2013, Macrae and Vincent 2014, Drupsteen and Guldenmund 2014). This concern is integrated into the developed Information Safety Method (chapters 3, 4).

2.6 Emerging evidence on the gap between Systemic Incident Analysis research and practice

While many viable methods exist in systemic incident analysis research, the corresponding empirical evidence base supporting these theoretical developments is as yet nascent. In particular, there is limited rigorous evidence of any of the existing methods being adopted and incorporated into routine incident investigation practice. Underwood (2013) undertook an initial examination of the issue, and found that the current gap between systemic incident analysis research and practice is complex and multifaceted in nature: multiple issues, stakeholders, and (inter)relationships between them are involved, as shown in Figure 2.13 below.

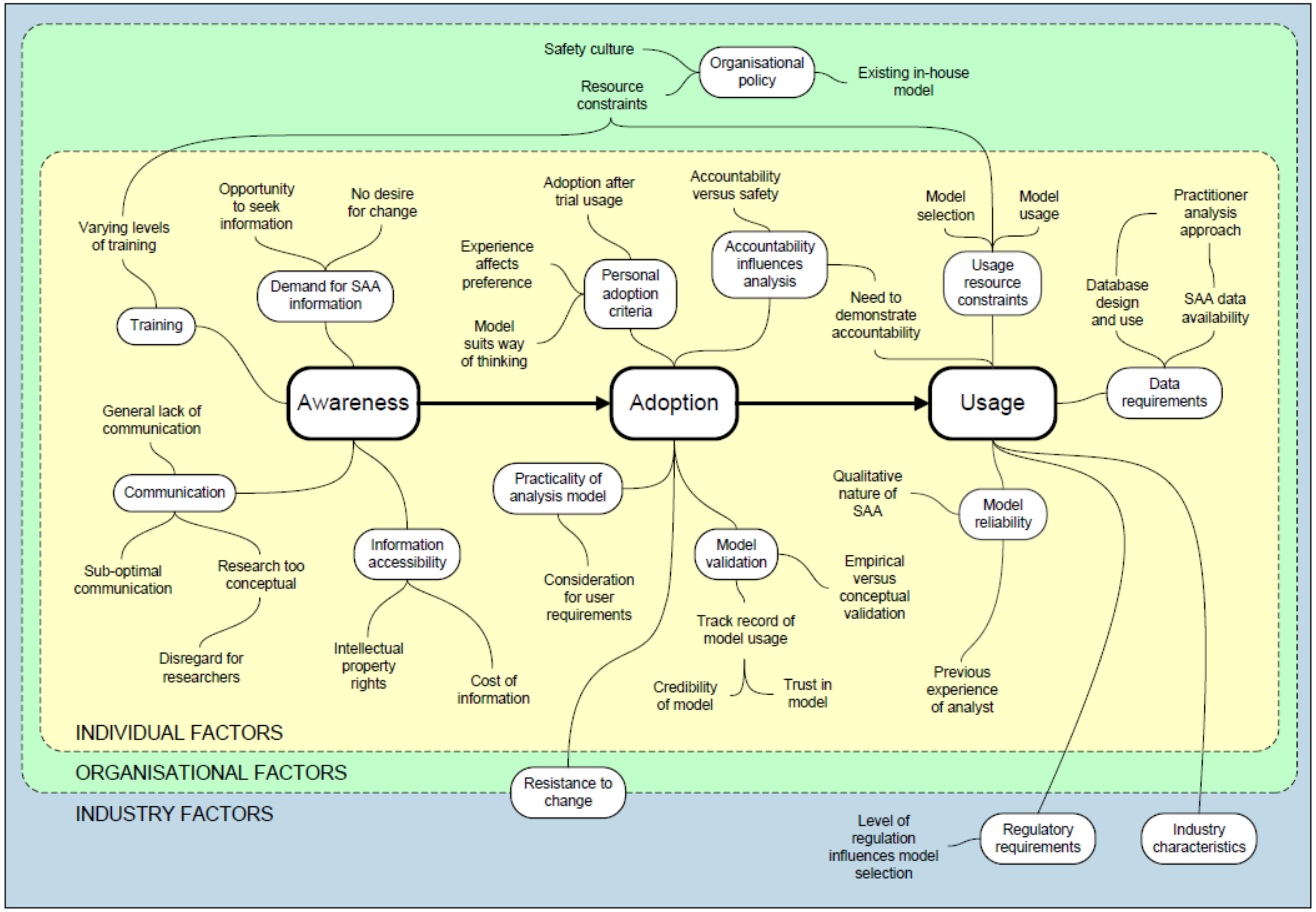

Figure 2.13: Factors contributing to the gap between systemic incident analysis research and practice, identified from an integrated analysis of research literature and semi-structured practitioner interviews. Reproduced from Underwood (2013, Figure 20) with permission.

In the specific context of patient safety, broadly congruent findings have been obtained through other detailed empirical studies. Working in the context of healthcare in the United Kingdom, the ethnographic research of Nicolini et al. (2011) observed safety incident investigation practice over a substantive period. They found multiple challenges in moving from the theoretical thinking embodied by RCA, to its practice as part of healthcare organisation. Challenges in interpreting and enacting existing methodological guidance included difficulties observed in reconciling the rational/technical conceptualisation of incident investigation (as embodied through the language and terminology of organisational RCA policy), with the substantive emotional component of the actual process. Conflicting diaries, limited resource constraints, and active resistance through organisational politics were also found to be sometimes influential. Such challenges in enactment were explained by Nicolini et al. as in part due to the need to re-establish public legitimacy, and to demonstrate appropriate forms of governance and accountability in the wake of safety events. In the two Trusts of their ethnographic study, it seemed paramount for the reporting of incident investigation to tell a comprehensive, clear and polished story, concluding with tangible, easy-to-communicate recommendations. Substantive contradictions and dissenting voices were observed as part of the investigation process, but usually edited out of the final report produced, in imitation of supposedly “good” (positivist) scientific research. This limited the potential for practicing organisational learning, through voicing the differences and disagreements arising from the investigative process.

Tamuz et al.’s (2011) serendipitous exploration of how one hospital learnt from a drug overdose identified a number of additional challenges of practice. The politics surrounding investigation of incidents were particularly highlighted, through their interviewing of healthcare workers with knowledge of or involvement in the actual incident or investigation. Following the occurrence of the incident situation, physicians, nurses, pharmacists, and quality-assurance/risk-management representatives responded in diverse ways. The same incident was classified differently by each of these four professional groups, who assessed a different segment of history in attempting to understand it. Decisions about different issues were also made, and different courses of action chosen by each group. In this particular study, the strong influence of organisational politics was evidenced by the fact that the physician, nursing and pharmacy management teams all seemed to have decided on which solutions to implement, *before* the first root cause analysis meeting was even convened (as part of initial stages of formal investigation into the incident situation). This raises doubts about the practical relevance of organisational policy in this case, for purposes of actual usage and enactment in supporting the work of incident analysis in practice.

A pair of papers by Iedema et al. (2006a, 2006b) focused around a series of five 1-hour RCA meetings, conducted as part of an evaluation of a health safety improvement practice program. As reported by the authors, both the disjunction between the ‘formal rules’ of investigation and its situated enactment (2006b), and the reflexive turn supported by the formulation and discussion of wider ‘systems solutions’ as part of these meetings are examined in some detail (2006a). In Iedema et al. (2006a), a discourse analysis of data from two of these meetings were conducted. These meetings were both conducted as part of an investigation of a ‘near-miss’: in mis-labelling a Computed Tomography scan. Despite the relatively benign final outcome of this particular incident however, staff seemed extremely wary about how they positioned themselves in relation to the issues and clinicians investigated during these analytical discussions. Consequently, the actual enactment of investigative analysis in these meetings was quite exploratory and uncertain: freely vacillating between both ideational and interpersonal issues, as well as between affective and more critical/judgemental discussion. This disjunction between the actual, and theoretical were explored in more detail by Iedema et al. (2006b), who explored the translation of the inherently uncertain and contradictory details of situated clinical activity into ‘root causes’, and then into recommendations for practice change. The data from this meeting showed considerable uncertainty about what individual staff did, knew and intended. Difficulties also arose in reconciling the formal parameters of the method used, with intuitions about the relative tradeoffs between verbal and written clinical communication; as well as in resolving the ‘philosophical conflict’ between the generalisation entailed by attempting formal rules for clinical practice, and the inherent contingent needs of such practice. Through their data analysis, Iedema et al. (2006b) found that the investigation team members acted not so much as clinical practitioners applying formal knowledge to in situ specifics, but as actors tasked with deducing organisational–managerial generalisations from the contingent practice of healthcare. Based on their empirical data, Iedema et al. (2006b) came to the conclusion that more recognition needs to be paid to the role of RCA as an *active* means to engender interpersonal debate and discussion between clinical staff of diverse backgrounds; and integrate the related cross-disciplinary relationships, thinking, and knowledge about the organisation of each others' work. In particular, Iedema et al. (2006b) argues for the need to better recognise the loosely coupled necessities of safe clinical practice, alongside the tight coupled solutions often considered in the related literature.

The empirical evidence reviewed in this section provides an indicative description of issues relating to the gap between systemic incident analysis research and incident analysis practice. This motivates the need to start to bridge the gap between systemic incident analysis methods in theory, and their usage and utilisation in practice. This is done through examination of empirical data on contemporary safety incident analysis and investigation practice (Chapter 5); as well as through empirical analysis of the move from systemic incident analysis methods in theory, into their practice as part of real incident investigation (chapters 6, 7). Such efforts may help to better inform designers of systemic incident analysis methods, of the diverse situational needs which may be demanded of a particular systemic incident analysis method when enacted in practice.

2.7 Conclusions

In this chapter, we have reviewed related literature for the PhD project. We began by setting out and illustrating the four foundational assumptions of the thesis work. The chapter then went on to review the latest major developments in systemic incident analysis research, the basic principles and precepts of Distributed Cognition, and existing research on learning from incidents. Through this review, we have shown that the 'information as object' illusion is sustained by all three of the major methods of systemic incident analysis reviewed. Given that the 'information as object' illusion fundamentally misconceptualises how natural human communication occurs (Lakoff and Johnson 2003), a new method is needed to offset this misleading dominant illusion of 'objective information transmission' during incident situations. This is Aim A of the research project, met by the work conducted in chapters 3 and 4.

In the penultimate section of the chapter, we reviewed emerging evidence on the gap between Systemic Incident Analysis research and practice. To date, there is little evidence of routine and wide usage of systemic incident analysis research in practice. In the context of patient safety specifically, the small body of empirical evidence so far indicates diverse and many potential challenges in moving from systemic incident analysis research into organisational practice. This motivated Aim B of the research project, which is to start to bridge the gap between systemic incident analysis methods in theory, and their usage and utilisation in practice. To increase the potential for theorists in the area to better account for the demands of incident analysis as practiced, further data is needed. This is the work of Chapter 5. To allow closer research scrutiny of the empirical phenomena of using systemic incident analysis methods, more detailed examination of the point at which the relevant research theory moves into practice is needed. We develop and trial a new research method for this purpose in chapters 6 and 7.

Chapter 3 – A new method of systemic incident analysis

The review of Chapter 2 motivated the need to develop a new method to offset the misleading dominant illusion of 'objective information transmission' during incident situations (Aim A, Objective 1), this chapter:

- Develops a method of systemic incident analysis based on Distributed Cognition
- Describes how the new method focusses on the flow of information through representations and their propagation
- Explains how the new method aims to improve learning from incidents, through building into its core design the process of dynamic, ongoing investigator and data triangulation
- Shows how the new method facilitates systemic integration and comparison of data and analytical insights *across* incident investigations

3.1 Introduction

As shown through the literature review of Chapter 2, the misleading illusion of 'objective information transmission' during incident situations is dominant in the field of systemic incident analysis. In this chapter, a new method for systemic incident analysis is developed to offset this misleading dominant illusion, based on Distributed Cognition precepts. This also addresses the current lack of Distributed Cognition based methodology in the field. And codifies Distributed Cognition precepts for incident analysts in describing and reasoning about *how systems of cognition* emerge as a function of *communication* during incident situations. In particular, incidents are examined and explained, through the Distributed Cognition focus on *propagation of representation states*.

To develop this basic focus of Distributed Cognition into a full and explicit method of analysis, two new concepts for systemic incident analysis are proposed here. The first new concept synthesises the notion of ***correctness*** with the Distributed Cognition focus on ***representation***. This new concept prompts the incident analyst to assess for **correct representation** of information in analysing incident situations. The second new concept is to prompt an incident analyst to assess for **consistent coordination** of representations during incident situations. This second concept synthesises the Distributed Cognition notion of ***coordination***, with the notion of ***consistency***. Together, these two new concepts of **correct representation** and **consistent coordination** are designed to offset the common analytical bias shown in Chapter 2: where the conceptualisation of *information* as objective representation is sustained by all three major alternatives from the general systemic incident analysis literature. The new analysis method presented here is intended to rebalance the theoretical toolbox available to systemic incident analysts. It is designed to heighten awareness of the deeply subjective, and context-bound aspects of natural communication and inter-subjective representation during incident situations. Here, the *unit of incident analysis* is on how patterns of information representation and coordination naturally arise. In the context of the new method presented here, all of the relevant aspects of incident situations interact – to constitute the patterns of communication identified through incident analysis.

To improve the likelihood of learning from incidents in practice, the new analysis method views the *development* of investigative hypotheses as a process of distributed cognition. This *intersubjective* design philosophy treats the doing of incident analysis as a predominantly systemic phenomena, following from the *interaction* between two or more minds across time and space. In Distributed Cognition terms, these two or more minds may be considered *distributed*, in terms of the thoughts of a *single* person across different points in time and space. Under Distributed Cognition, this counter-intuitive idea sits alongside the more standard conception of *two* minds between *two* individual people. This Distributed Cognition interpretation of *intersubjectivity* informed the conceptualisation of how relevant factors are to be identified, developed, and scoped in an ongoing fashion. The method of systemic analysis developed here therefore encourages a process of ongoing definition, calibration, and constant comparison for each emerging factor – to encourage dynamically ongoing investigator and data triangulation across diverse incident analysis settings (cf. Rothbauer 2008). This is reflected in the design of the '*safety functions*' part of the new method, presented later in Section 3.3.4. Due to its focus on **information** in the context of analysing **safety** incident situations, the new **method** is called the **Information Safety Method**.

The conduct of Information Safety Method analysis consists of two main parts. The first part is primarily concerned with *descriptive analysis* of incident situations. Here, the new method provides generic abstractions and procedures for generating concrete investigative hypotheses. About *what* natural information systems arise during incident situations, and *how* they result from the particular context (Section 3.3). The second part of the Information Safety Method is more *inferential* rather than factual in nature, providing four inferential questions to ask of the concrete investigative hypotheses generated through the descriptive incident analysis (Section 3.4). Four questions are provided as part of the new method: for both *formative* and *summative* use to support the ongoing, distributed process of incident analysis. Provisional interpretations of answers to these four questions are also developed and provided, as part of the Information Safety Method.

In the following sections, we present the abstractions and procedural elements of the new method of systemic incident analysis in a stepwise fashion. The abstract constructs introduced by the Information Safety Method are illustrated using analysis of data from a concrete, real incident situation (**Huang** et al. 2014a). A synopsis of the incident situation analysed is presented next, based on factual material from Toft's (2001) patient safety incident investigation report.

3.2 An illustrative incident situation (Toft 2001)

To demonstrate Information Safety Method analysis of a real incident situation, the incident scenario reported by Toft (2001) was chosen. We perceived the empirical reporting of Toft (2001) to be both *comprehensive* and *exhaustive* in reporting relevant contextual details. This seemed therefore to be a good initial basis for initial experimentation with core ideas of the Information Safety Method.

At approximately 17.00hrs on Thursday 4th January 2001, a day case patient on Ward E17 at the Queen's Medical Centre Nottingham (QMC) was prepared for an *intrathecal* (i.e., spinal) administration of chemotherapy. This chemotherapy was given as part of the patient's medical maintenance programme following successful treatment of leukaemia (a type of cancer). After correctly administrating a cytotoxic drug (Cytosine), a second cancer treatment drug was administered to the patient.

However, this second drug, Vincristine, should never be administered by the *intrathecal* route – which is almost always fatal to the patient. Unfortunately, whilst emergency treatment was provided quickly in an attempt to rectify this error, the patient died at 8.10am on the 2nd of February 2001. Following an internal inquiry at QMC into the circumstances surrounding this death, Professor Brian Toft was commissioned by the Chief Medical Officer for England and Wales to hold an external investigation, with a remit:

> "To investigate the circumstances leading up to an intrathecal, rather than intravenous injection of Vincristine into a patient at the Queen's Medical Centre Nottingham (QMC) on 4 January and to report findings to the Chief Medical Officer.
>
> To advise the Chief Medical Officer on the areas of vulnerability in the process of intrathecal injection of these drugs and ways in which fail-safes might be built in."
> (Toft 2001)

This incident situation, and the analysis results obtained are used here to illustrate, and help explain the main aspects of the Information Safety Method. The names of incident participants are taken 'as is' from the publically available external investigation report (Toft 2001). We refer to this as the 'Vincristine incident situation' throughout the rest of this chapter.

3.3 Forming explicit investigative hypotheses using the Information Safety Method

3.3.1 Selecting the *information representation*

As a cognitive activity, any information use may be understood from a Distributed Cognition perspective. In characterising cognitive processes in terms of the *propagation* and *transformation* of *representations* (Hutchins 2001), one can naturally ask (Hutchins 2000):

- *what information is represented?*
- *where and how it is represented?* and
- *what patterns of information flow are formed?*

In line with this Distributed Cognition perspective, the Information Safety Method can be used to analysis the propagation and transformation of *any* representations *informative* to work during incident situations. We use the term '**information representation(s)**', to refer to natural classes of representations that inform. An example of such a class is the set of *route of administration* representations, used during the Vincristine incident situation.

The choice of which specific class of information representations to analyse is left up to the discretion of the incident analyst, to be decided depending on the specific needs and interest of the incident analysis situation. The particular class of information representation chosen may impact on how subsequent parts of the analysis play out. In the case of the running example here, the *route of administration* was chosen as a focus for Information Safety Method analysis. But a more specific and different class could also have been chosen – of ***intrathecal*** *route of administration* representations (*intrathecal* meaning through the spine), leading to a different Information Safety Method analysis potentially different in form to the illustrative example presented here. A formal empirical study is presented in the next chapter, where we conduct Information Safety Method analysis for 7 different natural classes of information representation (Section 4.3).

To help an analyst understand and use the method, we also provide an explicit ***information representation selection heuristic***. This heuristic is adapted from Liu et al. (2008), and intended to help an analyst double check that their interpretation and understanding of Distributed Cognition is sufficiently close to the one underpinning the method being developed here. Additionally, the heuristic may also act as a quick sanity-check on the compatibility of the candidate information representation(s) being considered, for Information Safety Method analysis.

Information representation selection heuristic:

> "*propagation of* **<?>** *information* as *representation states* across a series of *representational media* that are brought into *coordination* with one another" (adapted from Liu et al. 2008, original emphasis).

The **<?>** symbol is used to stand for a candidate information representation of interest. The meaningful substitution of a candidate information representation in place of **<?>**, indicates understanding of the Information Safety Method by the prospective user. The *route of administration*, and *intrathecal route of administration* mentioned above are two example (classes of) information representations. Both examples are regarded by us as meaningfully substitutable in place of **<?>**, in the capacity of method designers. If you cannot meaningfully substitute any candidate information representations into the heuristic above, the Information Safety Method probably shouldn't be used. Apart from the added **<?>**, all other parts of this heuristic are from Liu et al.'s interpretation of Distributed Cognition.

The *representation states* of this heuristic exist in both unobservable and observable form. Both the human and non-human participants in a work-process are the *representational media* that are brought into *coordination* – coordinated ***through*** the particular information used, and its contextually constituted movement as part of the work done during incident situations. The analysis of particular classes of information representation is the new and general method developed here, for answering the initial question posed by Hutchins (2000): of ***what information is represented?***

3.3.2 Mapping out the patterns of representation coordination during an incident situation

Having answered the *what information is represented* question through identifying relevant classes of information representations, the incident analyst next needs to answer the two remaining questions (Hutchins 2000), of:

- *where and how the information is represented?* and
- *what patterns of information flow are formed?*

The Information Safety Method analyst identifies how representations were used and coordinated through the following two mapping heuristics:

Two 'information flow' mapping heuristics:

> *"Where did the* **<?>** *information in* **<PARTICIPANT>** *come from?"*
> (for 'upstream' exploration of how patterns of information flow form during the incident situation)
>
> *"Where did the* **<?>** *information in* **<PARTICIPANT>** *go to?"*
> (for 'downstream' exploration of how patterns of information flow form during the incident situation)

The general aim here is to map out the contextual interactions effecting the 'flow' of information – based on the incident data available. Selected significant 'non-flows' may also be included in an Information Safety Method analysis – as cases of *inconsistent* information flow. Simple directed graph representation should be used together with corresponding textual explanation, to author this part of the incident analysis. Starting with any participant involved in the propagation and transformation of information representations, answers to the two questions above may help the analyst to map out the patterns of information flow. In using these questions, each '**<PARTICIPANT>**' part should be substituted for participants already identified through the ongoing systemic incident analysis, with **<?>** again substituted for each of the classes of information representation, identified to be of interest by the analyst earlier.

For example, part of an Information Safety Method analysis is shown in Figure 3.1, for the Vincristine incident situation. This figure shows two interactions through which the *route of administration* information seems to have 'flowed' – as part of the interactions of this particular incident situation. Table 3.1 provides the corresponding textual descriptions and explanations. Together, such conjunction of graphical and textual elements forms the kind of investigative hypotheses entailed by using the Information Safety Method of systemic analysis. In conducting such incident analysis, the analyst assumes information to 'flow' only through an inherently *fallible* process of attempted replication, reproduction, and/or reconstruction. Communicative inconsistencies may thus *naturally* arise, routinely, as part of the formation of natural systems of representation propagation and transformation.

Table 3.1: Textual representation of the information flow pattern shown in Figure 3.1 and Figure 3.2.

Links in the information trajectory **(these are the arrows in the figures)**	**Associated interactions leading to the propagation and transformation of *route of administration* representations**
Dr Morton *to* the patient	Dr Morton administered the Vincristine drug intrathecally (i.e., via the spine) – which was the wrong route of administration.
Dr Mulhem *to* Dr Morton	Dr Morton confirmed the route of administration with Dr Mulhem.
Dr Musuka *to* prescription chart	Dr Musuka wrote out the patient's prescription chart.
Nurse Vallance *to* Dr Morton	Nurse Vallance remarked to Dr Morton about an intrathecal injection.

Pharmacy database *to* the syringe label	Pharmacy database generates syringe label [4].
Pharmacy database *to* the syringe packaging label	Pharmacy database generates syringe packaging label.
Prescription chart *to* Dr Morton	Dr Morton consulted the prescription chart.
Prescription chart *to* Dr Mulhem	Dr Mulhem consulted the prescription chart.
Syringe label *to* Dr Morton	Dr Morton read from the syringe label before administering the Vincristine injection.
Syringe label *to* Dr Mulhem	Dr Mulhem read from the syringe label prior to handing the syringe to Dr Morton.
Syringe packaging label *to* Dr Mulhem	Dr Mulhem took the package containing the syringe with the Vincristine drug from Nurse Vallance. We assumed that he also looked at the syringe packaging label at this point.

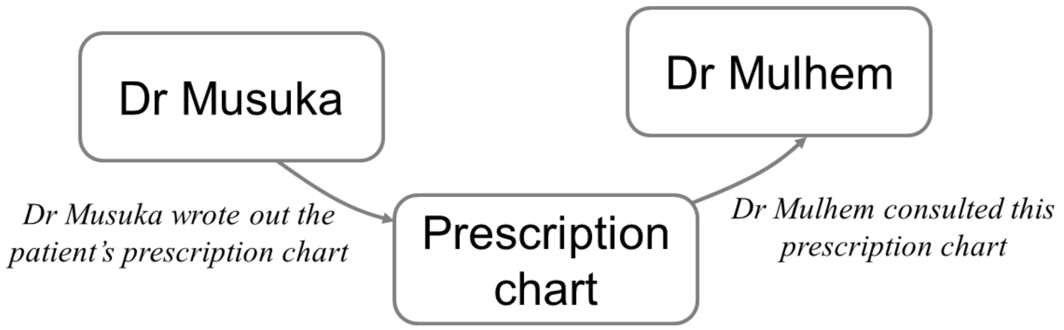

Figure 3.1: Two interactions in the Vincristine incident effecting the flow of *route of administration* information. In this case involving the coordination of three different representation states across the three participants shown.

Such investigative hypotheses (e.g., Figure 3.1 and Table 3.1 *together*) may be obtained from answering the two 'information flow' mapping heuristics just outlined. Sometimes, neither of these two mapping heuristics may seem to be applicable or relevant. In this situation, a natural stopping point in exploring part of the information flow patterns may have been reached. No further use of the particular class of information representations is perceived to have occurred during the incident situation, or is unknown due to natural data limitations perhaps. In terms of the method of analysis being developed here, the actual point at which to stop mapping these flows is

[4] The *syringe label* is directly attached to the syringe containing the Vincristine drug, and different from the *syringe packaging label* – which is attached to the packaging containing one or more syringes.

a discretionary decision by the incident analyst. In the example shown in Figure 3.2, the incident participant of *Nurse Vallance* formed one such ‘stopping point’, due to lack of incident data for further upstream analysis in this particular case. Figure 3.2 shows the final pattern of coordination identified – for the flow of *route of administration* information during the Vincristine incident situation. We refer to such patterns as the **information trajectory** associated with a particular class of information representations. In this case Figure 3.2 and Table 3.1, together, present an information trajectory for *route of administration* information representations. By virtue of their nature, patterns such as the one shown in Figure 3.2 are describing ephemeral phenomena, rather than phenomena of a static or permanent nature.

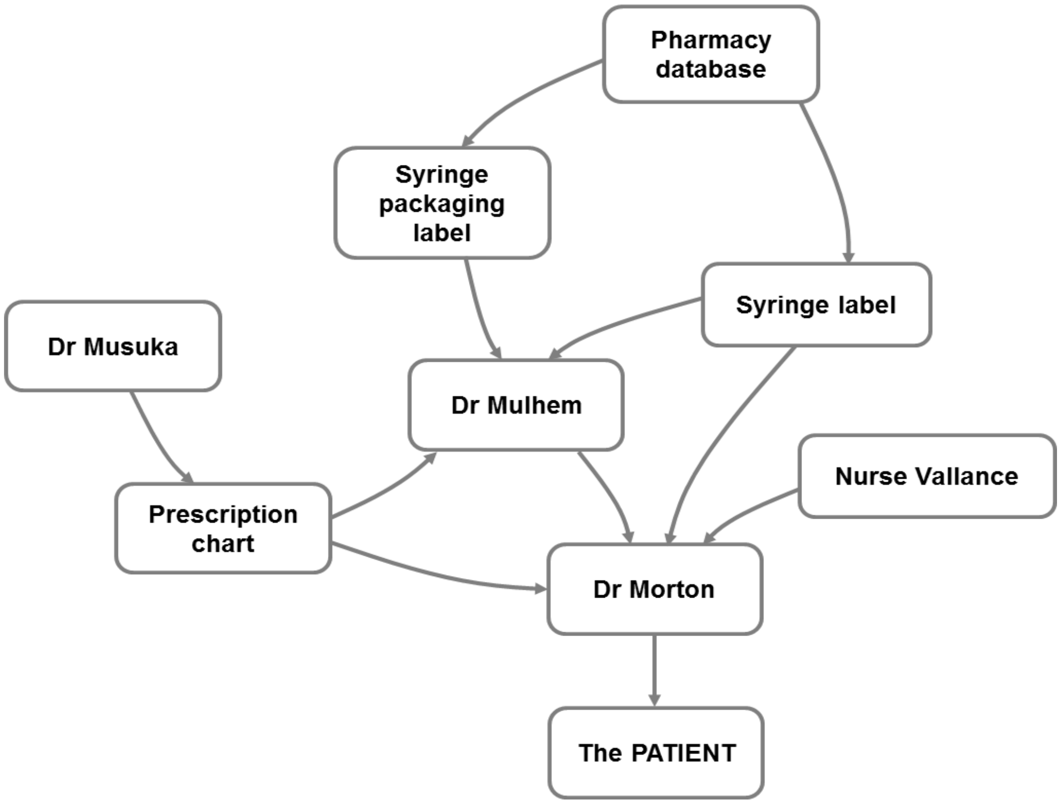

Figure 3.2: The pattern of *route of administration* information flow formed during the Vincristine incident.

So far, we have referred to information movement predominantly using the term ‘information flow’. The use of this term is because we have been unable to find a single convenient term to unambiguously and simultaneously express both:

1) how information moves in a directed way (as time progresses, across individuals); yet ‘moves’ only through
2) coordinative (re)representation and (re)construction (i.e., through the propagation and transformation of representations which inform).

Hutchins points out that the illusion of *meaning* being *contained in* a *message* is a hard-won social and cultural accomplishment (1995a, p238-9). In terms of this thesis, the illusion of *information* being *contained in* a *representation* is **rejected** as a basis for the new incident analysis method being developed here (cf. the 'Social implications' section from Reddy 1979; 'Interpersonal Communication and Mutual Understanding' section from Lakoff and Johnson 2003; 'Cooperation fallacies' section from Artman and Garbis 1998). The important conceptual distinction between 'information as object', and the Distributed Cognition alternative of 'information as consequence of interaction' is further clarified in the next section. Since the Information Safety Method is intended as a means of understanding systems of natural communication; the interactive, 'de-objectified' view of how information 'moves' is thus the one advocated and embedded into its design.

3.3.3 Illustrating how the information *as object* conception radically differs from conceiving information *only as a consequence of interaction*

In discussing human communication through the use of English representations, the linguist Michael Reddy presents two contrastive perspectives at odds with each other. Reddy (1979) proposed that English users commonly conceive communication in terms of a 'conduit metaphor'. Under this model, *what is being communicated* (commonly referred to as 'information' in everyday parlance) can be literally inserted *into* English inscriptions. Such an 'information parcel' can then be freely 'given' or 'transferred' to others – akin to the physical movement of a tangible object along some conduit or channel (e.g., like a boat in a river, with the boat being analogous to the 'information' that is moving). As shown in Chapter 2, **CAST/STAMP**, **FRAM**, and **AcciMap** all sustain forms of such 'information as object' illusion, through their theoretical conceptualisation of the incident situation.

Reddy than goes on to explain and substantiate his argument – which is that the provisions of English language systematically biases its users towards conduit-metaphoric modes of thinking, making it very difficult to omit such modes of expression altogether in using English intersubjectively. The **two 'information flow' mapping heuristics** given earlier (Section 3.3.2) further illustrate this embedded biasing effect. We have found it difficult to negate this biasing effect in presenting the Information Safety Method (cf. Reddy 1979, Appendix). Under the 'objective information' illusion, information *can* indeed be literally 'sent' and 'received' by individual participants, as highlighted graphically in Figure 3.3. In this figure, the light blue boxes visually embody the empirically problematic notion of '*route of administration* information parcels' being created, packed up, ejected into a subject-independent 'ideas space', and 'sent' to participants of the emerging natural information system. The 'objective information' illusion is one rejected rather than maintained by the user of the Information Safety Method.

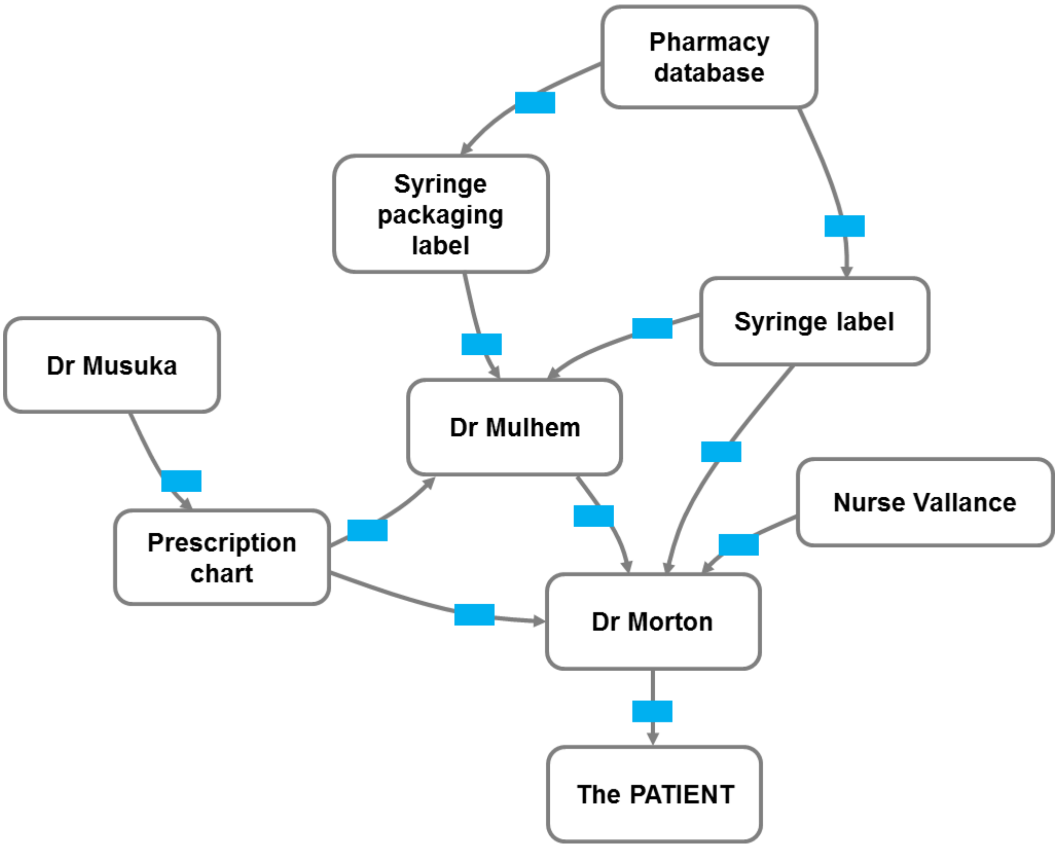

Figure 3.3: A *conduit-metaphoric* conceptualisation of how *route of administration* information is 'sent/received' around the information system identified for the Vincristine incident (based on Figure 3.2).

As a means of contrastive explanation, Reddy (1979) proposes an alternative 'toolmakers paradigm' for conceptualising how we communicate through representation. His detailed explanations are somewhat involved, but effectively highlight the *reconstructive*, *mediating* and *contextual* nature of English communication: intersubjective meaning making is dependent on both *who* is *'sending'*, and *who* is acting in the capacity of *'receiver'*. To illustrate his 'toolmakers paradigm', a physical compound is the analogy chosen by Reddy. This compound is totally physically segregated, and the local environment within each segment of the compound is similar, but non-identical to other segments (Figure 3.4). Crucially, individuals can only communicate about useful tools through the exchange of intermediary representations between each segment of the compound. No direct exchange of physical 'samples', or the tool itself is possible in this scenario.

This compound metaphor is used by Reddy to highlight the usually non-identical mental life shared by two or more individuals. Relatedly, the example also draws explicit attention to the fact that intersubjective understanding is only ever achieved through indirect inference and naturally fallible interactions – through intermediating systems of symbolic representation. From this starting perspective, some miscommunication is the expected *norm* of any human-to-human communication, rather than the exception. Reddy's toolmakers paradigm draws clear attention to the fact that 'information' only ever *moves* as a *consequence of interactive and intersubjective* activity between minds in practice; *never*, as context-free objects and streams – as conceived under the illusion of the conduit metaphor.

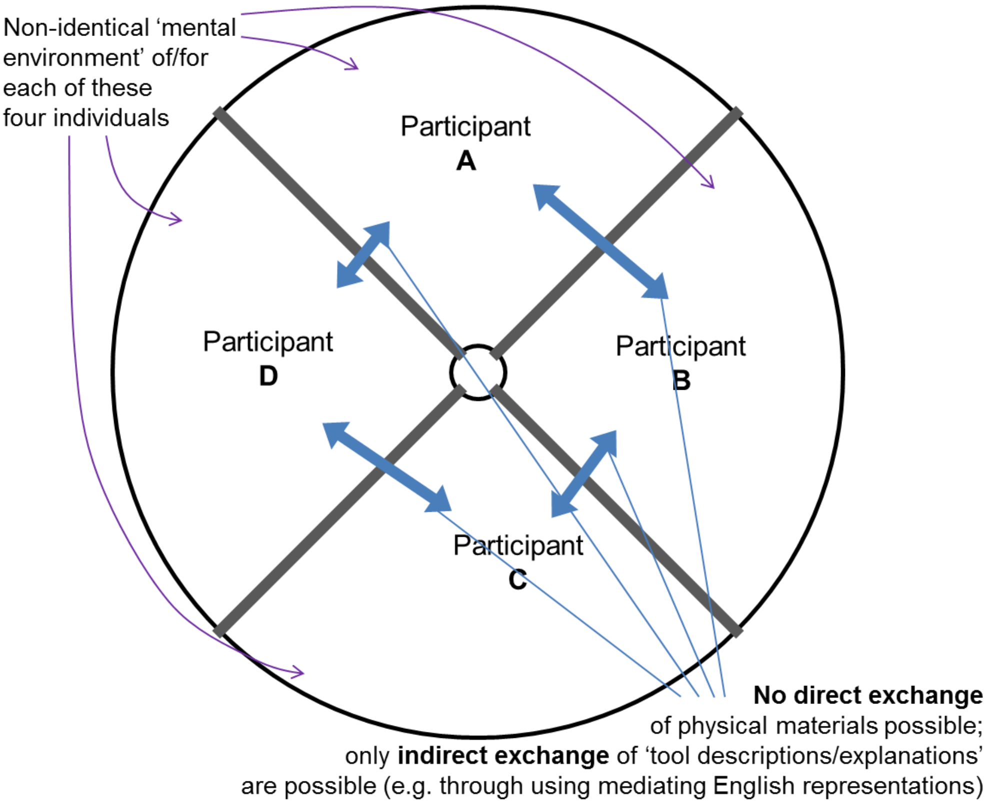

Figure 3.4: A 'toolmakers' paradigm of human communication, in contrast to the conduit-metaphoric one show in Figure 3.3. Adapted from Reddy (1979, Figure 9).

There are additional reasons to reject a 'conduit-metaphoric' conceptualisation of 'information flow'. A basic conduit-metaphoric treatment could encourage the mapping of information flows (Section 3.3.2) to terminate prematurely, and discourage substantive systemic analysis beyond the first point of 'failure' in flow along the conduit. Figure 3.5a illustrates such a situation graphically, where the flow of *route of* *administration* information 'stops' with its 'rejection' by participant B (between participant A and B in Figure 3.5a). This may counterproductively restrict the scope of incident analysis, in situations where (different?) *route of administration* information continued to be used further downstream (e.g., between participant B and C in Figure 3.5a).

Particularly in cases of miscommunication, the conduit metaphor can bias thinking to focus on why participants somehow failed to appropriately *pack/unpack* the *objective* information being *given* to them (Reddy 1979, p295-6). This framing of the situation deemphasises the considerable background resources, and contextual factors effecting any communication attempt. Such background resources and factors may include nature and degree of education, knowledge of the symbolic language being used, specialist training, shared vision, culture, and so on. This 'outside-in' perspective is precisely what Distributed Cognition argues *for* – in its emphasis on prioritising explanation in terms of the external context in which cognition occurs (Hutchins 1995a, Chapter 9). The relatively context-free conceptualisation of how information moves (Figure 3.5a) also to an extent contradicts the broad emphasis on context-sensitivity in contemporary safety literature.

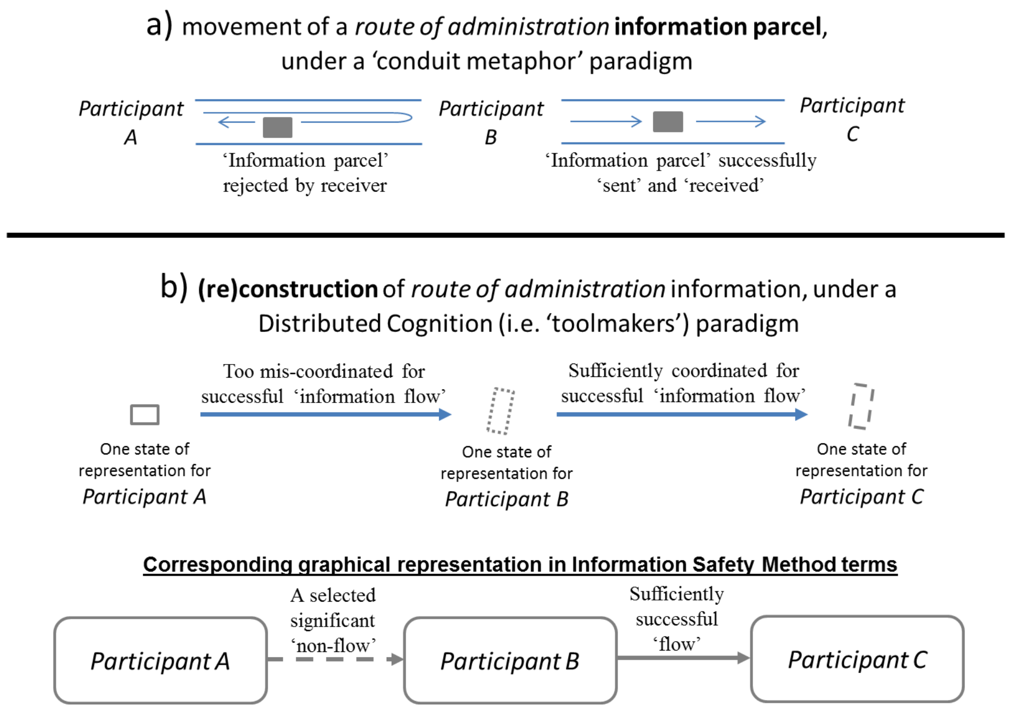

Figure 3.5: Illustrating two alternative paradigms of how information moves through the socio-technical substrate (up to and including cultural/societal factors). The second one (Figure 3.5b) is the one advocated by the Information Safety Method.

Having had this explicit illustration, we can now more accurately reframe the two information flow mapping heuristics given earlier. In the interest of succinct expression, use of conduit-metaphoric expression is still retained in the following reframed definitions (notably in using the terms ‘receiving’ and ‘sending’). In conjunction with Figure 3.5b however, a better understanding of the *coordinative* conception of information flow (of the Information Safety Method) – *as consequence of interaction* – should now be possible. As before, each ‘**<PARTICIPANT>**’ part should be substituted for participants already identified through analysis (e.g., those in Figures 3.2, 3.5), with **<?>** substituted for the particular information representations of interest:

A more accurate statement of the two ‘information flow’ mapping heuristics from Section 3.3.2:

> *Which interactive co-ordinations involved* **<PARTICIPANT>** *in a ‘receiving’ capacity, to effect the flow of* **<?>** *information?*
> (for ‘upstream’ exploration of how patterns of information flow form during the incident situation)
>
> *Which interactive co-ordinations involved* **<PARTICIPANT>** *in a ‘sending’ capacity, to effect the flow of* **<?>** *information?*
> (for ‘downstream’ exploration of how patterns of information flow form during the incident situation)

Despite the conduit-metaphoric connotations of ‘*information flow*’, we continue to use such terminology in the rest of the thesis. In attempting intersubjective explanation and presentation of the new method developed here, we have so far been unable to omit conduit-metaphoric language use altogether. While its designers are not professional linguists, experience of many repeated attempts at written representation of the Information Safety Method seems to further support Reddy’s statement, that:

> “Practically speaking, if you try to avoid all obvious conduit metaphor expressions in your usage, you are nearly struck dumb when communication becomes the topic.” (Reddy 1979, p299)

To offset this presentational complication, alternative graphical representations have been liberally used in this chapter to provide some redundancy, in attempting communication of the main ideas of the Information Safety Method. Compared with a term like 'information coordination', talking about 'information flow' also helps to preserve the Information Safety Method emphasise on the *temporally directed* nature of representation propagation and transformation. In doing Information Safety Method analysis, information movement should be conceptualised as a *consequence of interaction* (e.g., Figure 3.5b), and *not* as object-transfer along a conduit (e.g., Figure 3.3, Figure 3.5a). Analysts can choose to model these coordinative information movements at variable levels of detail using the new method. Figure 3.6 shows two equally valid Information Safety Method analyses of the same situation, based on factual details from the Vincristine incident situation. While both Figures 3.6a and 3.6b are based on the same extended series of incident interactions, Figure 3.6b is at a less detailed level of analysis than the interpretative analysis of Figure 3.6a. In particular, Figure 3.6b shows how Information Safety Method based investigative hypotheses can abstract over an extended series of 'informational interactions'. The level of detail in the available incident data may also inform and constrain the level of detail chosen.

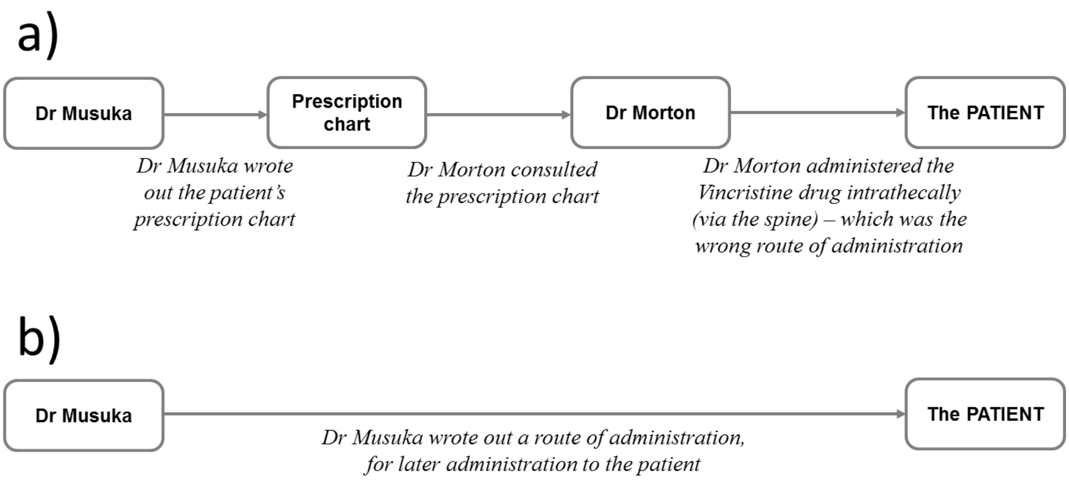

Figure 3.6: An example of two *equally valid* Information Safety Method analyses of the same aspects of the Vincristine incident situation. In both cases a *coordinative*, rather than *conduit-metaphoric* interpretation is the one intended.

3.3.4 Mapping out factors potentially effecting information coordination and representation

In an incident situation, many contextual factors may impact on the emergence of information trajectories and representations. This part of an Information Safety Method analysis involves the identification of such factors, and their explicit association to the information trajectories identified. Four functional relationships are prioritised in particular, in relation to the specific information trajectories identified in systemic incident analysis. These are defined below, and named '**safety functions**' (for convenient future reference to these abstract constructs). The four type of relationships defined here should be used to identify, and 'instantiate' specific concrete factors of interest, in analysing actual incident scenarios. The 'interaction context' refers broadly to the various interactions of an incident situation:

Four types of 'safety function' for the Information Safety Method:

CAPACITY 1 – A **correctness-enhancing** safety function [**+**]

... is an aspect of an interaction context that can increase the probability of **correct** information representation in one or more interacting participants.

A concrete example of a safety function acting in such a capacity could be the taken for granted ***rules of grammar****, which are currently in use, accepted, and adhered to by both the writer and reader of a language, in successfully enacting unity of communication between them.*

CAPACITY 2 – A **correctness-reducing** safety function [**-**]

... is an aspect of an interaction context that can reduce the probability of **correct** information representation in one or more interacting participants.

A concrete example of a safety function acting in such a capacity could be ***a particular and substantively different set of background education:*** *Between the writer and reader of the symbolic representation presented to facilitate meaning communication.*

CAPACITY 3 – A **consistency-enhancing** safety function [**+**]

... is an aspect of an interaction context that can increase the probability of **consistent** information flow between two interacting participants.

A concrete example of a safety function acting in such a capacity could be a ***nice quiet room for reading****, which for many people improves their understanding and comprehension of what they are reading (but not necessarily in all situations and not necessarily for everyone).*

CAPACITY 4 – A **consistency-reducing** safety function [**-**]

... is an aspect of an interaction context that can reduce the probability of **consistent** information flow between two interacting participants.

A concrete example of a safety function acting in such a capacity could be the ***substantively different aspect of grammatical expectations from two different***

> ***languages****, such as between elements of Chinese and English language for example.*

As suggested by the examples here, a ***safety function*** may act on both the **correct representation** of information, and **consistent coordination** of such representations during parts of the same incident situation, simultaneously. The concrete and relevant safety functions, and their specific scoping, will depend very much on both the incident data, and the specific nature of the safety function identified. Safety functions relating to *emotion* for example: may be relatively tightly scoped, to reflect their relatively proximal effects on the incident situation, and their typically shortish durations. A contrastive example would be the profound influences of elements of culture (including scientific cultures), which can often remain largely invisible until it is resisted or otherwise rejected by a member of society. Together, the four abstract safety function definitions just presented express the totality of the Information Safety Method perspective: on how particular aspects of an incident may effect information trajectories in one or more of the four different capacities defined above. *Any aspect*, at *any level of abstraction* may be related in principle to the *information trajectories* identified, through these four kinds of functional relationships. Such 'safety functions' may include both constructed aspects of the situation (e.g., an artefact design feature), as well as more naturally arising issues (e.g., various 'latent' conditions of society).

The identification of safety functions should be predominantly inductive, based on knowledge of the incident situation as much as possible. A single safety function may act in several of its four capacities simultaneously, across different parts of information trajectories. For example, a specific checking protocol may act as a *correctness-enhancing* safety function for particular nurses, who routinely follow such a protocol faithfully; At the same time, the same protocol may be perceived as an unnecessary bureaucratic burden by others involved in effecting the information flows – thus perhaps acting negatively (as a *correctness-reducing* safety function), to reduce the likelihood of serendipitous self-checking and self-correction. In this case the same safety function – *of the particular checking protocol used* – may simultaneously have two effects that are converse and opposite, when compared with the prior likelihoods of correct information representation in each participant if the checking protocol hadn't been there. Multiple safety functions acting on the same part of the information flows may not always act at the same time. An example of this is provided by safety function 5 (*the separation of packaging and supply of drugs*) and safety function 7 (*avoiding* *compromising patient care*), presented in Table 3.2 and graphically depicted in Figure 3.7. The red links in Figure 3.7 correspond to safety functions acting in **capacity 2** and **capacity 4**. The green links correspond to ones acting in **capacity 1** and **capacity 3**. Here safety function 5 did not seem to have actually happened at the time of the specific incident situation. This possibility of *non-concurrent*, *potential* functional impact is reflected in the specific wording chosen, through using the word '*can*' in the four types of safety functions defined earlier in this section.

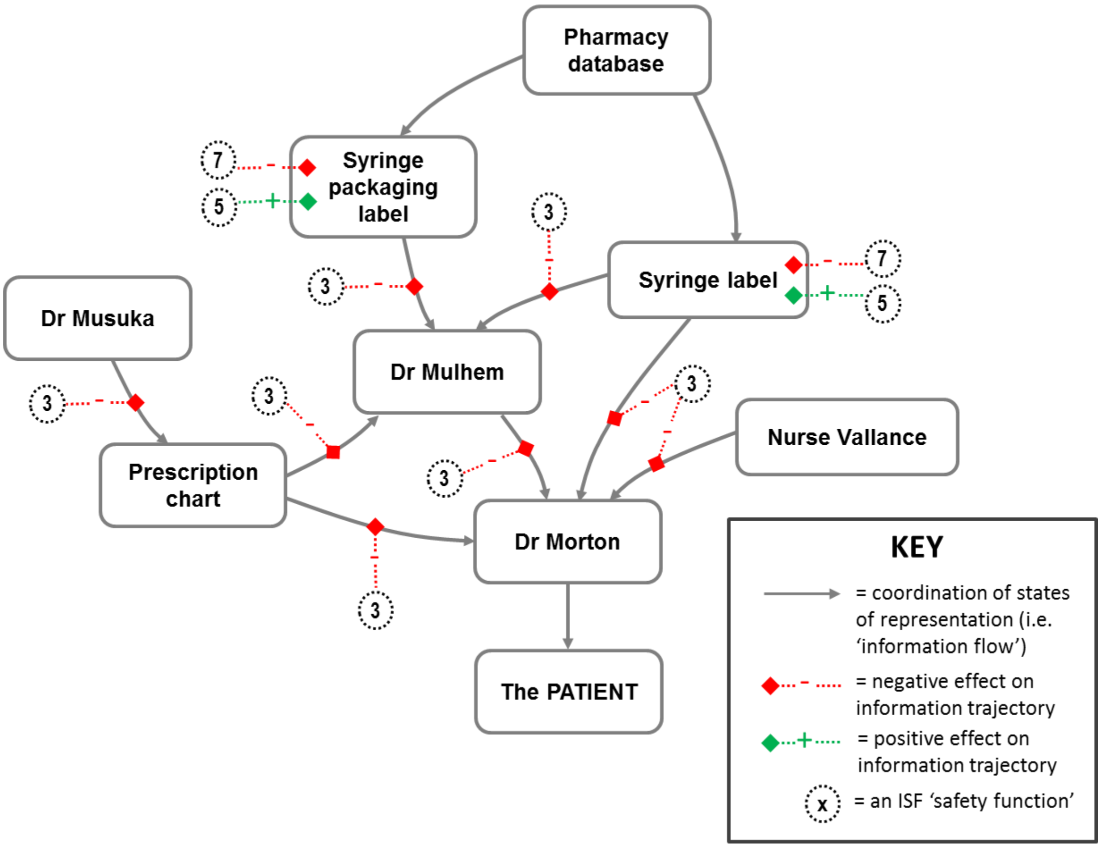

Figure 3.7: Showing how three safety functions (3, 5, and 7) are associated with the *route of administration* information-trajectory.

Table 3.2: Textual representation of the safety functions shown in Figure 3.7.

Safety Function identified (the numbering corresponds to the identifiers shown in Figure 3.7)	**Brief description**
3: Fallible human transcription (an 'old' safety function identified from Information Safety Method analysis of a prior incident situation, see Figure 3.8 below for the general idea behind this kind of analytical move)	Human 'transcription' of information is a fallible process. Any information flows to/from humans will be potentially effected by this.

5: Physical and temporal separation of the packaging and supply of drugs to the wards	The practice of separating the packaging and supply of intrathecal and non-intrathecal drugs reduced the chance of inadvertent mix-ups. Therefore increasing the chances that the *route of administration* information displayed on the syringe and syringe packaging label would be correct.
7: Avoiding compromising patient care	In this particular incident, both intravenous and intrathecal drugs were in fact sent at the same time to the wards. This directly contradicted the purpose of safety function 5. In the report not much more detail is provided about this workaround, other than that it happened in the interests of not compromising patient care. This safety function increased the chances that inadvertent mix-ups between the labelling of drugs intended for different *routes of administration* may occur.

In some cases, it may be more convenient to represent a participant of the incident situation directly as a safety function, instead of as part of information trajectories. This choice is intentionally left underspecified here, and up to the judgement of the analyst using the Information Safety Method. The scopings of '**old**' safety functions, developed through prior investigative hypothesising using the Information Safety Method, may also be extended as part of the new ongoing incident analysis. This occurs when an explicit link is authored: between the current set of investigative hypotheses, and other investigative hypotheses constructed using the Information Safety Method.

Through extended scoping of the **fallible human transcription** safety function, to the analysis of the Vincristine incident situation (safety function 3 in Table 3.2), a concrete example of this kind of integration of previous knowledge about incident situations is provided as part of the current explanation. This example shows how the integration of previous (articulated) knowledge about incident situations was concretely integrated, as part of the analytical knowledge derived from the new Information Safety Method analysis (of the Vincristine incident situation). This kind of *extension of scoping* – across incident analyses – is obviously dependent on the informed assessment of the incident analyst (as in the coding of incident data done for any incident analysis using a pre-defined method). Such informed assessment is again based on the known facts of the case, representing the analyst's informed judgement of whether each safety function is sufficiently relevant to each new incident situation and analysis. Figure 3.8 graphically illustrates this kind of ongoing scoping process, across the contingencies of individual incident situations and their analysis.

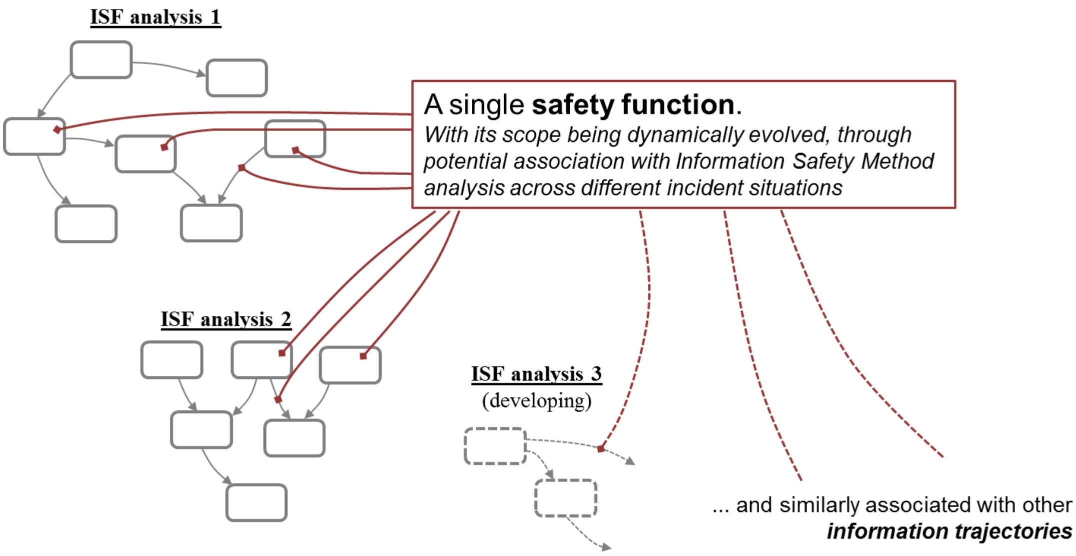

Figure 3.8: A visualisation of how a safety function is dynamically developed over multiple incident analyses.

3.3.5 Indicative generalisations to illustrate possible concrete configurations of Information Safety Method information flows and safety functions

To show how the various concepts introduced so far fit together more generally, Figure 3.9 generically illustrates a variety of relationships which may be identified using the new method. This figure presents a small set of investigative hypotheses in the abstract, developed using the Information Safety Method. The relationships depicted in this figure are not exhaustive. As for other incident analysis methods, infinite unique sets of investigative hypotheses are potentially identifiable in practice – depending on the particulars of the incident situation (e.g., future investigative hypotheses currently unknown and not yet needed). Together, the various concrete **information trajectories** and **safety functions** delimit the scope of Information Safety Method based investigative hypotheses, and the *representation coordination systems* they describe. In the interests of concise generic illustration, not all of the relationships shown in Figure 3.9 necessarily have a realistic gloss in terms of a real situation. A minor point of the Information Safety Method is in its suggestion of an optional distinction – between the human and non-human participants of incident situations (**Huang** et al. 2014a, Section 4.2.3); this distinction is illustrated now in Figure 3.9, but was not utilised in the previous figures in this chapter.

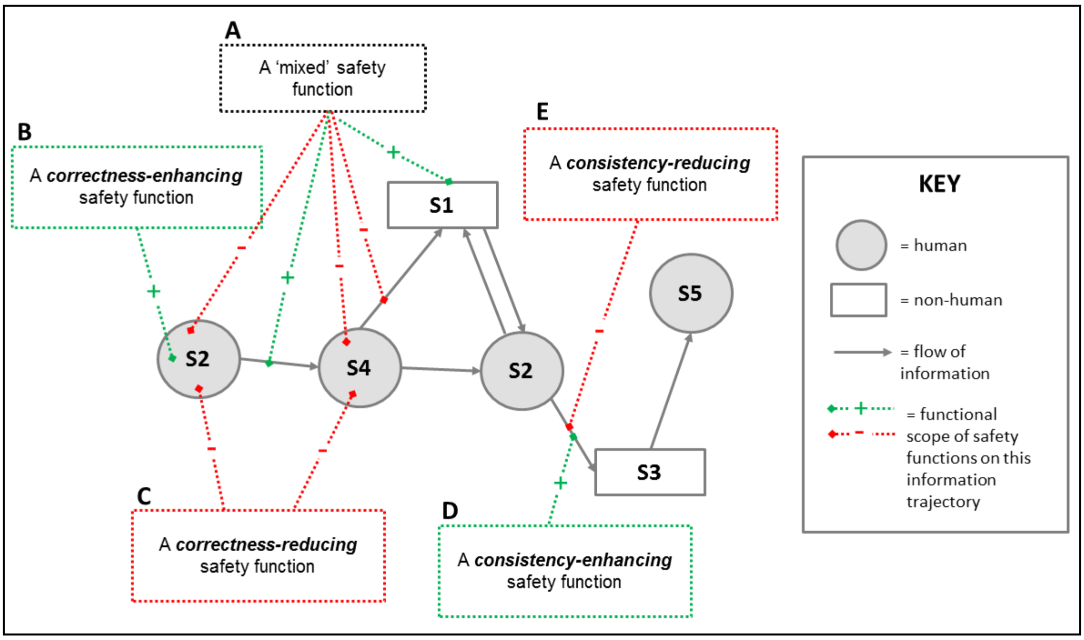

Figure 3.9: A generic illustration of an Information Safety Method **information trajectory**, with related generic **safety function** associations.

Using the ideas described so far in this chapter, Figure 3.9 shows generalisations of some of the possible configurations of *participants*, *information flows* and *safety functions* that may be found through incident analysis done using the Information Safety Method. In this particular case, five generic safety functions (labelled A to E), and five unique human and non-human participants (labelled S1 to S5) are shown.

In terms of the four types of safety functions (discussed in the previous section):

- **B** is a *correctness-enhancing* safety function,
- **C** is a *correctness-reducing* safety function,
- **D** is a *consistency-enhancing* safety function,
- **E** is a *consistency-reducing* safety function.

Safety function **A** provides a generic example, of a safety function perceived as acting both positively and negatively, on both the *correctness* of information, and *consistency* of information flow at different parts of the information trajectory. The figure shows how safety function **A** may reduce the *correctness* of information representation 'in' S2 and S4, and the *consistency* of flow from S4 to S1. Safety function **A** may also simultaneously enhance the *consistency* of the flow of information from S2 to S4, and the *correctness* of information in S1. Different flows of information between the same two participants may also be compactly represented as a pair of uni-directional arrows – shown between S1 and S2 in Figure 3.9. In principle, different safety functions and their combinations may be perceived to act separately and independently, on such a pair of flows. Each safety function may in principle be simultaneously associated with one or more information trajectories, as shown generically in Figure 3.9. The specific relationships coded for in analysis are in terms of the four possibilities: of the safety function's *correctness-enhancing*, *correctness-reducing*, *consistency-enhancing* and *consistency-reducing* effects (as perceived by the incident analyst). These effects may be on information trajectories of the same information representations (e.g., *route of administration* information flows in other incident situations), or on different symbolic representations of information. This aspect of the Information Safety Method will be concretely demonstrated in detail later in Section 4.3.2.

3.4 Systematically exploiting the investigative hypotheses generated to support formative and summative investigative reasoning

The information flows and safety functions identified constitute the descriptive investigative hypotheses generated using the Information Safety Method (e.g., Figure 3.7, Table 3.1, and Table 3.2 collectively). Once created, the following four questions, and some possible interpretations of their answers are suggested as part of the new method presented in this chapter. These questions and interpretations are intended as a starting, rather than ending point for systematically exploiting the investigative hypotheses thus constructed. Other questions and interpretations may also be 'applied' to these hypotheses at the analyst's discretion. Figure 3.10 provides an 'example answer' for **Question 2**, based on the final set of investigative hypotheses identified through analysing the Vincristine incident situation using the new method.

Four starting questions for interacting with Information Safety Method based investigative hypotheses:

> **Question 1**: Which parts of the information flows have neither **positive** (i.e., *correctness/consistency-enhancing*) nor **negative** (i.e., *correctness/consistency-reducing*) safety functions acting on them?
>
> **Question 2**: Which parts of the information flows have only **negative** safety functions acting on them?
>
> **Question 3**: Which parts of the information flows have both **positive** and **negative** safety functions acting on them?

Question 4: Which parts of the information flows have only **positive** safety functions acting on them?

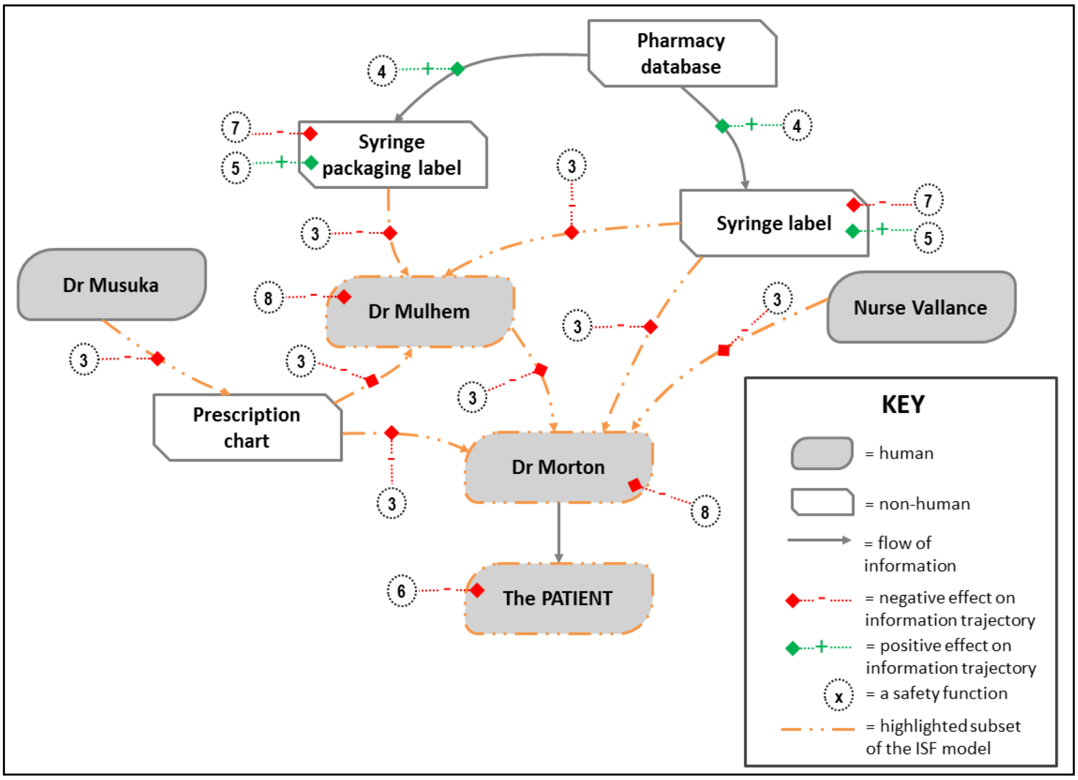

Figure 3.10: The subset of a full set of investigative hypotheses developed using the Information Safety Method which answers **Question 2** (parts of the same investigative hypotheses were shown earlier in Figure 3.7). The optional human/non-human distinction of the new method was used in the case of this particular analysis.

3.4.1 Interpreting the developing investigative hypotheses to support their iterative generation and refinement

As a way to support formative understanding, answers to **Questions 1, 2 and 4** may identify areas particularly needing further investigation. Areas of apparent interactional simplicity are systematically identified through answering these three questions; in terms of how the use of *correct*, and *consistent* information representations are shaped in these parts of the work-system. The absence of safety functions (i.e., through answering **Question 1**), or very unbalanced ones (i.e., through answering **Questions 2 and 4**), help highlight where investigative understanding of factors effecting information movement may perhaps be particularly incomplete, and/or one-sided. The analyst may wish to double-check the completeness of their incident understanding for these areas of apparent simplicity. Further data collection may help to give a more thorough understanding of these aspects of an incident situation.

3.4.2 Interpreting a set of Information Safety Method based investigative hypotheses on conclusion of an investigation

When the answers to these same four questions are interpreted summatively, **Question 1** (i.e., no positive or negative safety functions acting) helps to localise places where there may be substantive system performance variability. If the investigative understanding embodied by the investigative hypotheses reflect reality accurately, then there is a total lack of contextual shaping factors in these parts. This implies only weak enforcement of robust communication in these parts. Under a summative interpretation, the answers to **Question 1** indicate where system performance is apparently predisposed neither towards 'good', nor 'bad' patterns – and is likely to be largely uncontrolled and unpredictable. If viewed as a control problem (e.g., Leveson 2011), robust information flow in these parts cannot be assured with confidence, in the absence of actual controls and constraints, and/or knowledge of them. Under a control based starting perspective, future similar 'breakdowns' in information use is thus likely to unpredictably (re)occur in these under-controlled parts of the work-system.

Answers to **Question 2** (i.e., only negative safety functions acting) helps to localise areas of obvious weakness in assuring robust information flow. The fact that there are negative safety functions, yet apparently no positive safety functions to offset them, indicate where information representation(s) may be incorrect, or be inconsistently propagated through the work-system. These are areas of high priority, for understanding how to assure/improve robust communication for the future.

Answers to **Question 3** (i.e., both positive and negative safety functions acting) helps to localise areas of high complexity. The answers to this question highlight where multiple competing shaping factors may or may not concurrently act, in shaping the ideally correct and consistent flow of information. For these areas of a work-system, reasoned judgement and expertise is particularly needed from investigators. To weigh up the on-balance likelihood, of information being incorrectly represented, or inconsistently propagated again in the future. Relatedly, investigators may also wish to assess whether areas with only positive safety functions acting are sufficiently safe, in answer to **Question 4** (i.e., only positive safety functions acting) – bearing in mind the particular forms, and degree of ephemerality of each positive safety function identified.

3.5 Summary

This chapter has developed a new method of systemic incident analysis based on Distributed Cognition ideas and its worldview, called the **Information Safety Method**. This new incident analysis method is based on the Distributed Cognition focus on *propagation of representation states*. Two new concepts are proposed based on the Distributed Cognition worldview, as part of the new analysis method: the incident analyst is prompted to assess for both ***correct*** *representation*, and ***consistent*** *coordination of representation states* during incident situations. Through doing this, we are able to systematically analyse how information 'flow' is *constitutive* of the formation of distributed cognitive systems. The incident analysis using the new method identifies the *systemically interactive*, *emergent*, and *naturally fallible* acts of communicative representation during incident situations. Communication during incident situations is understood as a direct function of the communication *context*, irrespective of the degree of success or failure in attempting communication.

As is often the case for qualitative methods of analysis, the individual 'steps' of the Information Safety Method are unlikely to be strictly sequential, but more iterative/recursive in practice. As a means of generating analytic representations, the new method's outputs are intended as *focused* and *selective* additions *on top of* the available incident data. These analysis outputs are not intended to lead to a *single*, *true*, and *complete* representation of incident situations, but are instead designed to enrich human discourse in this area (as is standard for much of qualitative modes of inquiry). Interpreting systemic incident analysis outputs as a *single*, *true*, and *complete* representation of the incident situation is only likely to lead to a false sense of security, given the often highly complex and context-specific nature of incident situations (cf. Shojania 2010). As recognised by contemporary social scientists as well as some cognitive linguists for example, the assumption of a *single*, *true*, and *complete* reality is also unfeasible, and very difficult to defend in practice from a technical perspective, when seeking to account for issues of human action and sociality (Ragin and Amoroso 2011, Lakoff and Johnson 2003).

To provide an alternative means of explanation, the Information Safety Method embodies a strong interpretation of Distributed Cognition concepts (cf. Pea 1993). The new method is based on a disbelief of the possibility of cognition residing solely in people, and the flow of objective information between them in communicating (Lakoff and Johnson 2003). Instead, the incident analyst is prompted to focus on *interactive co-ordination*, as the *sole and only* means of empirically evidencing *any* of the communicative and cognitive aspects of incident situations. The new method also seeks to improve the likelihood of actual *learning from incidents*, through treating incident analysis as a distributed cognitive process; of ongoing *incident analyst and data triangulation* (cf. Rothbauer 2008). This explicitly reflects the heavily qualitative nature of systemic incident analysis, as both conceived and practiced.

Like other existing alternatives, the new systemic incident analysis method developed in this chapter is intended to be generalised and generative in nature. To play a part in enriching constructive discourse about incident situations regardless of the particular safety domain in question. The new method represents an *advance in theory*, through codifying Distributed Cognition ideas for the specific empirical purposes of systemic incident analysis. This follows through on the recognised promise of Distributed Cognition based safety explanations (cf. Busby and Hughes 2003, Sweeney 2009), for explaining problems of communication during contingent incident situations in this particular case. In advancing safety science *methodology*, a new method of systemic incident analysis is contributed to the field.

Chapter 4 – Analysing five patient safety incident situations using the Information Safety Method

To explore the new systemic incident analysis method developed in Chapter 3 (Aim A, Objective 2), this chapter:

- Describes an initial validation of the new method, using five diverse and relevant patient safety incident situations
- Illustrates some of the original and productive insights resulting from the use of the method
- Illustrates how these insights lead to better understanding of how communicative fragilities develop, as *natural information systems* form during incident situations
- Shows how active distribution of knowledge across individual incident situations could be achieved through the new analysis method, to improve learning from incidents through distributed incident analysis

4.1 Introduction

Chapter 3 presented a new method for analysing how *systems of interactive information coordination and representation* form during incident situations. In order to study the new method, this chapter presents an application of the Information Safety Method to five patient safety incident situations. This study was designed to enable an initial understanding of whether the Information Safety Method *does what it is supposed to do*, and also explore empirical consequences following from controlled use of the new method of systemic incident analysis.

The particular aims of the study were threefold, to:

> Aim 1: Determine the extent to which the **Information Safety Method** can be used to analyse diverse patient safety incident situations.

Aim 2: To explore whether analysis using the new method can generate additional knowledge to extend/enrich the existing incident investigations.

Aim 3: To explore what potential operational difficulties may unfold – in moving from the abstract theory of the new method, to concrete incident analysis in practice.

The study procedure is first presented in Section 4.2. Section 4.3 then presents some indicative examples, to give a detailed idea of the kind of concrete outputs generated from the Information Safety Method analysis done. We then go on to discuss broader implications of these analyses in Section 4.4. The study limitations (Section 4.5) and conclusions (Section 4.6) are finally presented.

In the lead up to the current study, substantive preparatory work was done. The main goal of this preparatory period of work was to try to represent the core ideas and details of the Information Safety Method into a form suitable for rigorous, demonstrable, and exploratory research investigation. A technical report was therefore written to tangibly represent our Information Safety Method (**Huang** et al. 2014a), involving a sustained design effort over the course of around 1½ years. The technical report was then used interactively, for the current study. To improve the representation of the new method through it, diverse efforts were used to calibrate the construction of the technical report. These efforts included conference presentation of some of the core ideas of the Information Safety Method at the 2013 Communicating Medical Error conference (**Huang** et al. 2013d), informal discussions with a variety of patient safety stakeholders, extended detailed correspondence with an incident-investigator/safety-researcher experienced in the safety domains of transport and aviation. During this period, pilot Information Safety Method analysis was also conducted, and reported on, based on incident data from two publically available reports of patient safety incident situations (**Huang** et al. 2014a).

4.2 Methods

In this study, five recent patient safety incident situations (from 2010 onwards) were analysed using the Information Safety Method. The incident data was provided by collaborating incident investigators from a large Foundation Trust in the United

Kingdom [5]. This represented access to previously unseen incident data. The data was drawn from reports of the corresponding internal incident investigations – used in the capacity of primary data for the incident analysis of the current study. Appendix A.1 shows one of these data sources, as an indicative example. The two collaborating incident investigators from the Trust were on hand, to clarify significant details where necessary.

The five incident situations to be analysed using the new method were selected by the collaborating investigators, from their existing catalogue of completed investigations into *Serious Untoward Incidents*. This is the most serious category of patient safety incident situations internally investigated by the Foundation Trust. The incident investigators selected for relevance based on our inclusion criteria, where an incident scenario was a suitable candidate if:

- It involved inappropriate patient care information being used, *and/or*
- It involved inappropriate information used in work with interactive medical devices, *and/or*
- It involved one or more of the 'five *rights*' of medication administration not being fully discharged (i.e., the *right patient*, *right drug*, *right dose*, *right route*, and given at the *right time*; cf. Federico 2011), *and*
- Either of the two collaborating incident investigators was closely involved in investigating the particular incident situation.

These inclusion criteria were used to scope the scenario selection process to include only incident situations *relevant* to the Information Safety Method. At the same time, they would enable potential operational issues to be discovered, when the new method was used to analyse concrete and diverse incident scenarios.

For the current study, the author acted as scientific investigator and incident analyst, with expert knowledge about the analysis method used. Although not a professional incident investigator, he had conducted a small scale incident investigation using 'systemic Root Cause Analysis' prior to the current study (reported in Chapter 7).

The Information Safety Method analysis was conducted over a period of 43 working days, taking place over 230 person-hours of analysis work. Analysis of each of the five

[5] These are the two incident investigators interviewed in the next chapter.

incident situations proceeded one-by-one. For each *information representation* chosen for analysis, the descriptive analysis parts of Information Safety Method analysis was conducted (as described in Section 3.3). The descriptive incident analysis was continued using the new method, until the investigative hypotheses generated had stabilised in each case, and no longer changed. This process is analogous to one of the standard stopping heuristics for coding qualitative data: when nothing substantial is being added or revised through revisiting the emergent analysis (as in Braun and Clarke's 2006 *thematic analysis* for example). The emerging analytical structures here are the investigative hypotheses generated – which were constantly compared and coordinated with the available data, and revised and refined as understanding of each incident situation developed throughout their analysis. There were no *a priori* time constraints for completing the incident analysis reported in this chapter.

Through a separate pilot Information Safety Method analysis prior to the main study reported here, a custom recording scheme was developed for recording the investigative hypotheses. The textual elements of the recording scheme are illustrated in detail in Appendix A.2. Its graphical aspects are shown as part of the analysis results presented later in the chapter.

In the next four subsections, we describe the steps common to the Information Safety Method analysis of each incident situation. As typical in practicing qualitative data analysis, these distinct incident analysis steps did not proceed completely sequentially, but in a more iterative, overlapping fashion in practice (cf. Miles and Huberman 1994). 43 daily 'snapshots' of the developing investigative hypotheses and related background material were taken, using 7-zip archives (http://www.7-zip.org/) throughout the study. These 7-zip files provided an archival record of how the investigative hypotheses developed from day to day, across the different incident data and incident situations for Information Safety Method analysis.

4.2.1 Developing an initial understanding of each incident situation

Prior to analysis using the new method, an initial understanding of each incident situation was developed. The original internal incident investigation reports were used as the primary source of incident data here (e.g., Appendix A.1). Background biomedical literature was also consulted to help understand the patient safety work taking place during each incident situation. This helped the incident analyst understand the various healthcare work concepts and processes involved in each incident situation.

Sources ranged from pedagogical online sources written by reputable clinicians (e.g., http://www.ccmtutorials.com/cvs/Shock/page_01.htm for understanding the meaning of 'clinical shock'), to published research literature (e.g., reading Stevens et al. 2006 to better understand the role of *Creatinine*, and *Glomerular Filtration Rate* measurement in assessing kidney function). Initial incident understanding also came about through completing the full anonymisation of each internal investigation report. The specific people and organisations involved were anonymised, as a data preparation step by the incident analyst.

As in the studies of de Carvalho (2011), Salmon et al. (2012), and Underwood and Waterson (2014), narrative accounts from investigation reports provide only indirect representation of the interactions and events of an incident situation. Since our collaborating investigators were directly involved in investigating each of the incident situation considered in this study, they were able to clarify details where necessary. The bulk of these internal reports also seemed to focus on *detailed description* of various interactions and events which occurred. They were thus substantively richer in terms of details and specifics, than the two public incident investigation reports (Toft 2001, ISMP Canada 2007) used earlier to pilot the Information Safety Method (**Huang** et al. 2014a). We were therefore able to gain an accurate and comprehensive understanding of the events and interactions of each incident situation – within the scope of the incident and investigation situations as reported by the collaborating incident investigators.

4.2.2 Identifying information representations

Based on the initial incident understanding gained, the analyst considered various candidate *information representations*. Particular candidates were then taken forward for 'full' Information Safety Method analysis – based on all of the following criteria being satisfied:

- The incident situation was compatible with the purposes of the Information Safety Method (Section 3.1),
- The candidate information representation can be sensibly substituted within the *information representation selection heuristic* of the new method (Section 3.3.1),
- Based on the initial incident understanding (Section 4.2.1) the candidate information representation was relevant to the particular incident situation,

- There was likely to be a substantive amount of available data from the corresponding investigation report, about the actual role played by the candidate information representation.

This identification of candidate information representations was contingent, on the very fluid period of evolving initial understanding of each incident situation.

4.2.3 Identifying the information trajectories and safety functions

For each *information representation* chosen and taken forward for 'full' analysis, the analyst identified its associated *information trajectories*, and the various *safety functions* associated with these trajectories (cf. sections 3.3.2, 3.3.4). As consistent with the design of the Information Safety Method, both graphical and textual representations were coordinated as part of the incident analysis process. *Microsoft PowerPoint 2010*, and *Microsoft Word 2010* were the main tools repurposed here, for authoring and recording the Information Safety Method investigative hypotheses developed (for the graphical and textual representation).

The identification of relevant safety functions consisted of two main parts (as described in Section 3.3.4). The first was to identify 'new' safety functions – based on 'freestanding' analysis of the particular incident situation. The second part was to attempt generalisation of each of the safety functions identified in the previous Information Safety Method analysis, based on the data from the new incident situation. This process was conducted on a rolling, cumulative basis. As in the pilot study of the Information Safety Method (**Huang** et al. 2014a), investigative hypotheses identified included all of the 'old' safety functions identified to be relevant to each new incident analysis.

4.2.4 Answering the four 'starting questions' about the investigative hypotheses

After the investigative hypotheses had stabilised, the four systematic questions of the Information Safety Method (as described in Section 3.4) were applied to highlight subsets of these investigative hypotheses. The time taken to do this step was brief, and spent largely on a straightforward mechanical process of highlighting parts of the investigative hypotheses. The analytic understanding of the incident situation did not change during this study step. Broader implications of the answers to the four systematic questions are discussed in Section 4.4.

4.3 Outcomes of Information Safety Method analysis

4.3.1 An overview of the Information Safety Method analysis conducted

Table 4.1 presents the seven *information representations* identified, from the five incident situations.

Table 4.1: Basic details of the analysis done, showing the sequence in which the incident situations were analysed.

Sequence followed for the incident analysis	The incident situation	Information representation(s) identified	Approximate time taken for analysis
1	... involved a wrong drug being dispensed	***drug identity***	25 hours
2	... involved the wrong '*direction of venting*' during heart transplant	***direction-of-blue-pump-tubing*** ('blue pump tubing' refers to one of the sets of tubes for the heart/lung bypass machine)	40 hours
3	... involved a late diagnosis of Acute Kidney Injury	***creatinine-level***, and ***glomerular filtration rate*** (Both are significant physiological indicators for detecting and monitoring Acute Kidney Injury, see Stevens et al. 2006 for more detailed explanation)	37 hours
4	... involved a late detection of cancerous tumour in the lung	***Dr I's interpretation of Mr G's chest x-ray*** (Dr I's interpretation of Mr G's x-ray image was important to this incident situation, since it explicitly highlighted potential cancerous tumour – at a perhaps nascent and treatable stage of development. *Dr I's x-ray interpretation* was missed early on, as part of the development of this incident situation)	38 hours
5	... involved the late detection of patient physiological deterioration	***blood pressure***, and ***Modified Early Warning Score*** (Both are useful indicators for detecting patient physiological deterioration, see Gardner-Thorpe et al. 2006 for more detailed explanation)	88 hours

For five of these seven natural classes of information representation, a single, holistic information trajectory was identified. The exceptions were the information trajectories for the last two classes identified: of the **blood pressure** (**BP**), and **Modified Early**

Warning Score (**MEWS**) information representations from the 5th incident situation. Multiple 'sub' information trajectories were identified for the BP and MEWS information representations, reflecting the 12 separate BP readings, and 9 separate MEWS readings taken over the course of a single weekend.

In total, 47 safety functions were associated with the various information trajectories identified in the study. Safety functions 1-8 were ones previously identified through initial piloting of the Information Safety Method (see Appendix A.3 for details). These 8 safety functions were used as the point of departure for the new incident analysis of the current study.

4.3.2 Two detailed contrasting examples

To avoid a very lengthy chapter, we now present two contrasting examples from the Information Safety Method analysis. Some of the safety functions presented in the figures are explained in the corresponding tables; for full details see **Huang** (2014c). The first example relates to incident situation 4 (i.e., as shown in Table 4.1), demonstrating how ***a doctor's interpretation of a patient's chest x-ray*** was propagated through a distributed cognitive system of representations. Examples from the analysis are presented to give an idea of the concrete incident analysis outcomes – in the context of very loosely standardised systems of representation. In this first case, natural language representations of the *doctor's interpretation* were used during the incident situation.

In contrast to the systemic analysis of incident situation 4, a strongly standardised system of representation underpins the second of the two illustrative incident situations (incident situation 5). This second set of examples serves to illustrate a contrasting case of Information Safety Method analysis – in the context of how distributed cognitive systems formed around representations of ***blood pressure***, and ***Modified Early Warning Scores***. In comparison to the case of the ***doctor's interpretation***, both the blood pressure, and Modified Early Warning Scores are underpinned by much more standardised means of representation: in terms of numbers and pre-set levels of seriousness, respectively.

In each case, the presentation of example investigative hypotheses is prefaced by a brief synopsis of the incident situation. Unlike in the case of FRAM (Hollnagel 2012), both the textual and graphical aspects are equally important for presenting Information

Safety Method based investigative hypotheses. This is because textual and graphical representations complement each other (Hill 2001). The textual parts of the investigative hypotheses are presented in Tables 4.2 through to 4.5. Figures 4.1 through to 4.5 present the corresponding graphical parts. The same numbers are used between the tables and the graphics for cross-referencing each safety function. Further examples from the other three incident situations are available in Appendix A.4.

Analysis of an incident situation involving late detection of cancerous tumour in the lung

In this incident situation, the patient (Mr G) had a total *laryngectomy operation* (i.e., separation of the food, and air passageways; see Cancer Research UK (2013)). A speaking valve was inserted to enable him to speak after his operation. Shortly after, it became apparent that the speaking valve had become dislodged, and its whereabouts could not be located. A chest x-ray was requested by Mr H, the consultant caring for Mr G. This x-ray was intended to rule out the possibility of the speaking valve having been dislodged into the lungs. This x-ray imaging was completed, reported on, and initially filed by a radiologist 'external' to the hospital (Dr I). The associated report was filed electronically by the 25th of July, 2012: documenting advice to the referring clinician (Mr H) of a suspicion of underlying chest lesion which may need further investigation. This was not however responded to promptly at the time. Later on, the patient presented to his GP (Dr J) with symptoms of breathlessness. After further delays, the patient was eventually diagnosed with lung cancer, which was found to be inoperable upon attempted surgery to remove it. An investigation was conducted into the incident situation, to try to enable more timely detection of cancer in similar care situations in future.

Figure 4.1, Table 4.2, and Table 4.3 together show examples take from the full set of investigative hypotheses developed: about how ***Dr I's interpretation of Mr G's chest x-ray*** was represented and coordinated. The investigative hypotheses include the various relevant safety functions, together with their scoping across the participants of this emerging natural information system.

Abbreviations and acronyms used in interpreting the incident situation

ENT – **E**ar, **N**ose, and **T**hroat (a clinical specialty)

GP – **G**eneral **P**ractitioner

ICE system – **I**ntegrated **C**linical **E**nvironment system (an electronic system used at the Trust as part of x-ray requests, imaging, and reporting)

PACS system – **P**icture **A**rchiving and **C**ommunication **S**ystem (another electronic system used at the Trust as part of x-ray requests, imaging, and reporting)

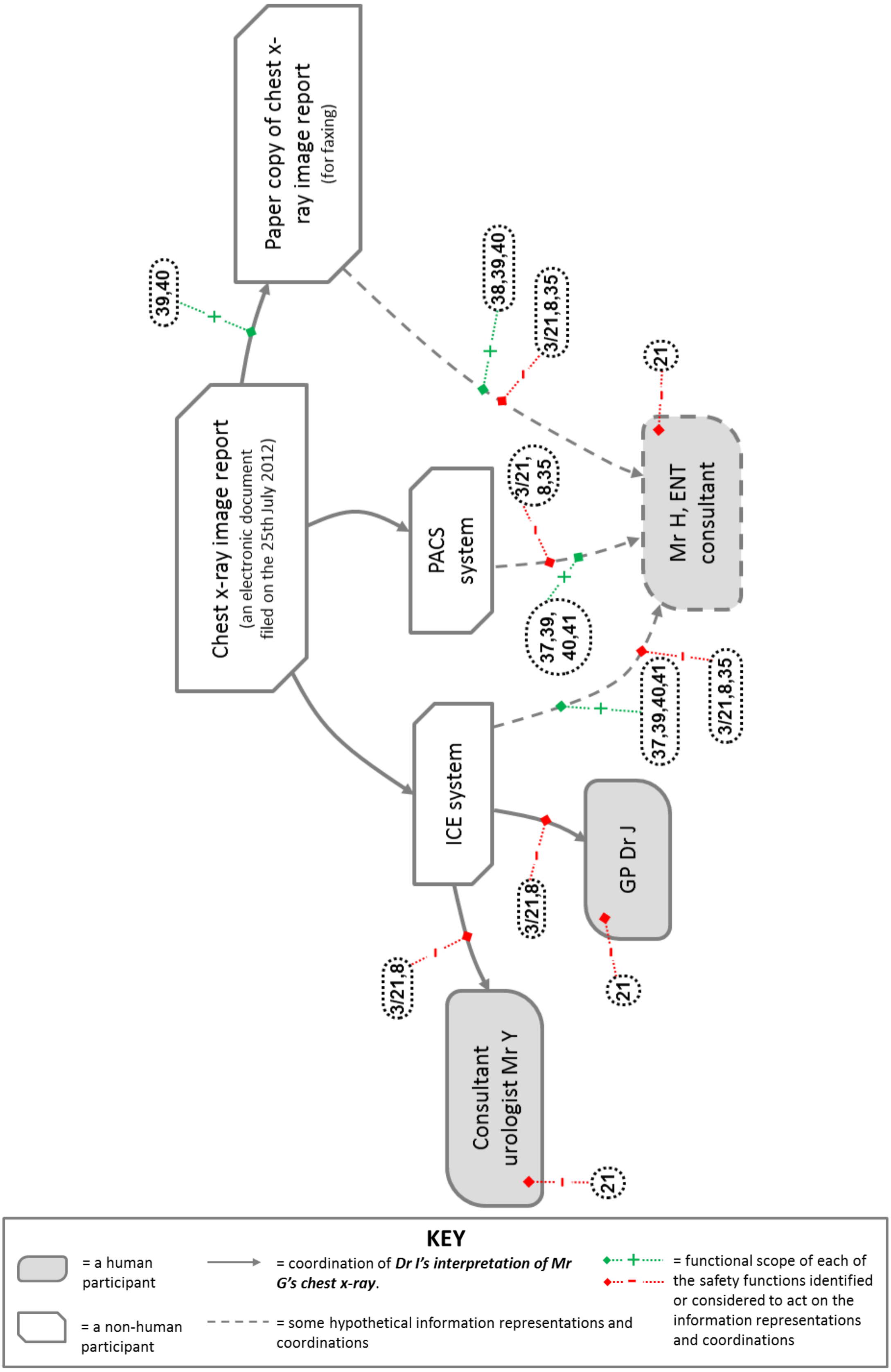

Figure 4.1: Graphical part of the final investigative hypotheses generated. Showing both the information trajectory, and scoping of the safety functions relating to ***Dr I's interpretation of Mr G's chest x-ray***.

Table 4.2: Corresponding textual counterpart to the information trajectory shown in Figure 4.1 (for each arrow in the figure, alphabetically ordered).

Links in the information trajectory (hypothesised inconsistent coordination of information representations are marked with ***CF***)	**The interaction(s) leading to the propagation and transformation of representations of *DR I's INTERPRETATION OF MR G's CHEST X-RAY*** (the two participants in each interactive 'flow' are indicated in **bold**)
Chest x-ray image report (an electronic document filed on the 25th July 2012) *to* ICE system	**Dr I's report on Mr G's chest x-ray image**, was put onto the **ICE system**.
Chest x-ray image report (an electronic document filed on the 25th July 2012) *to* PACS system	**Dr I's report on Mr G's chest x-ray image**, was put onto the **PACS system**.
Chest x-ray image report (an electronic document filed on the 25th July 2012) *to* Paper copy of chest x-ray image report (for faxing)	A **paper copy of the electronic version** of **Dr I's report on Mr G's chest x-ray image** is made; in preparation for faxing to Mr H, ENT consultant.
ICE system *to* Consultant urologist Mr Y	**Consultant urologist Mr Y** reviewed **Dr I's report on Mr G's chest x-ray image** from the ICE system.
ICE system *to* GP Dr J	**Dr J** was Mr G's GP, and reviewed **Dr I's report on Mr G's chest x-ray image** from the ICE system.
ICE system *to* Mr H, ENT consultant ***CF***	**Mr H** was an ENT consultant, and was the clinician who requested Mr G's chest x-ray on the 6th July 2012. This link represents Mr H's timely review of **Dr I's report on Mr G's chest x-ray image** – also through accessing the ICE system.
PACS system *to* Mr H, ENT consultant ***CF***	**Mr H** was the ENT consultant who requested Mr G's chest x-ray on the 6th July 2012. This link represents Mr H's timely review of **Dr I's report on Mr G's chest x-ray image** – through accessing the PACS system.
Paper copy of chest x-ray image report (for faxing) *to* Mr H, ENT consultant ***CF***	Ideally, **Mr H** would have reviewed the paper copy of **Dr I's report on Mr G's chest x-ray image** in a timely manner.

Table 4.3: Textual representation of an illustrative selection of safety functions. Corresponding to the numerical identifiers shown in Figure 4.1.

Safety function 'newly identified' [I], or extended [E]	**More elaborate description and explanation** (positive safety function to information trajectory associations are highlighted with **[+]**, and negative ones with a **[-]**)
38: Procedures for 'double-checking the information channel', from the Trust Information Security Policy [6] (in particular the part regarding "safe havens", in the case of this incident situation). **[I]**	According to the organisational information security and safe haven policy in use at the time of this incident situation, the National Health Service has used so-called 'safe havens' for many years to ensure the secure transfer of personal identifiable data. Part of this policy describes a number of specific procedures, designed to help ensure that the fax number used is the correct one. In the case of this particular incident situation, this safety function did not apparently take effect. **<u>Operationalising the Information Safety Method safety function definitions</u> [+]** This is a *consistency-enhancing* safety function, which can increase the probability of consistent information flow, from the *Paper copy of chest x-ray image report (for faxing)* participant, to *Mr H, ENT consultant*.
41: Expected 'organisational norm' of x-ray imaging follow-up for requesting clinicians. **[I]**	In the particular Trust where this incident situation occurred, there is an expectation that clinicians review the electronic report for investigations that have been requested for patients under their care. **<u>Operationalising the Information Safety Method safety function definitions</u> [+]** This is a *consistency-enhancing* safety function, which can increase the probability of consistent information flow to *Mr H, ENT consultant* – from both the *PACS* and *ICE systems* (these are the 'standard two routes' of information propagation, for x-ray imaging electronic reports).
Extending the scope of safety functions from Information Safety Method analysis prior to this current study (**8**, see Appendix A.3 for the original context of identification)	
8: Lack of a rigorous checking procedure for the doctors. **[E]**	As for the Information Safety Method analysis of the 3rd incident situation (and for much the same reasons), this safety function is treated as a *consistency-reducing* safety function here. **<u>Operationalising the Information Safety Method safety function definitions</u> [-]** This is a *consistency-reducing* safety function here, which can reduce the probability of consistent information flow to any 'doctors' involved in the information trajectory identified here.

[6] We do not name the specific trust policy here, to preserve a high level of organisational confidentiality in reporting the results of the incident analyses.

Extending the scope of safety functions from Information Safety Method analysis of the 3rd incident situation	
35: The substantively different nature of the original illness requiring entry to the hospital. **[E]**	Somewhat similar to its treatment in the Information Safety Method analysis of the 3rd incident situation, this safety function also applies to this incident situation. Here Mr G originally presented to the outpatient clinic (of Hospital A) because his speaking valve (inserted after his earlier laryngectomy) had disappeared. This initial presentation of Mr G's illness is perhaps not too closely related to a 'new' cancer developing in his lung; This situation may thus reduce Mr H's sensitivity to the possibility of a new cancer developing in Mr G – and thus not consulting **Dr I's interpretation of Mr G's chest x-ray image** in a timely way. **<u>Operationalising the Information Safety Method safety function definitions</u> [-]** Here this acts as a *consistency-reducing* safety function, which can reduce the probability of consistent information flow to *Mr H, ENT consultant*. **<u>Additional comments</u>** In principle, we would need to double-check the validity of this Information Safety Method hypothesis through further conversation/discussion with Mr H.

<u>Analysis of an incident situation involving the late detection of patient physiological deterioration</u>

The patient (Mrs R) originally presented at hospital for a jaw fracture, due in part to her ongoing cancer of the jaw. She was kept in hospital for further assessment and tests. During the course of her weekend in hospital, her physiological condition deteriorated, eventually leading to a heart attack. A report of this situation was filed on the hospital system, presumably in part due to a hypothesis that the patient's bad physiological condition could have been responded to earlier. The actual clinical response was mostly late on the Sunday of that weekend.

Figures 4.2, 4.3, 4.4, and 4.5 show four out of the many 'sub' information trajectories identified – corresponding to the many **blood pressure (BP)** and **Modified Early Warning Score (MEWS)** readings taken over the weekend Mrs R spent in hospital. While their specific details are not identical, each information trajectory involved mostly fairly mundane interactions. In the interests of succinctness, only the detailed interactions for Figure 4.2 are presented here in Table 4.4. As similar to the previous example, Table 4.5 details some of the safety functions shown graphically, and their specific instantiation and scoping across each of the four ‘sub’ information trajectories presented in the following figures.

Abbreviations and acronyms used in interpreting the incident situation

Max Fac – **M**axillo **F**acial (A specialty which deals with medical issues around the mouth, jaw, face and neck)

SHO – **S**enior **H**ouse **O**fficer

SpR – **Sp**ecialist **R**egistrar

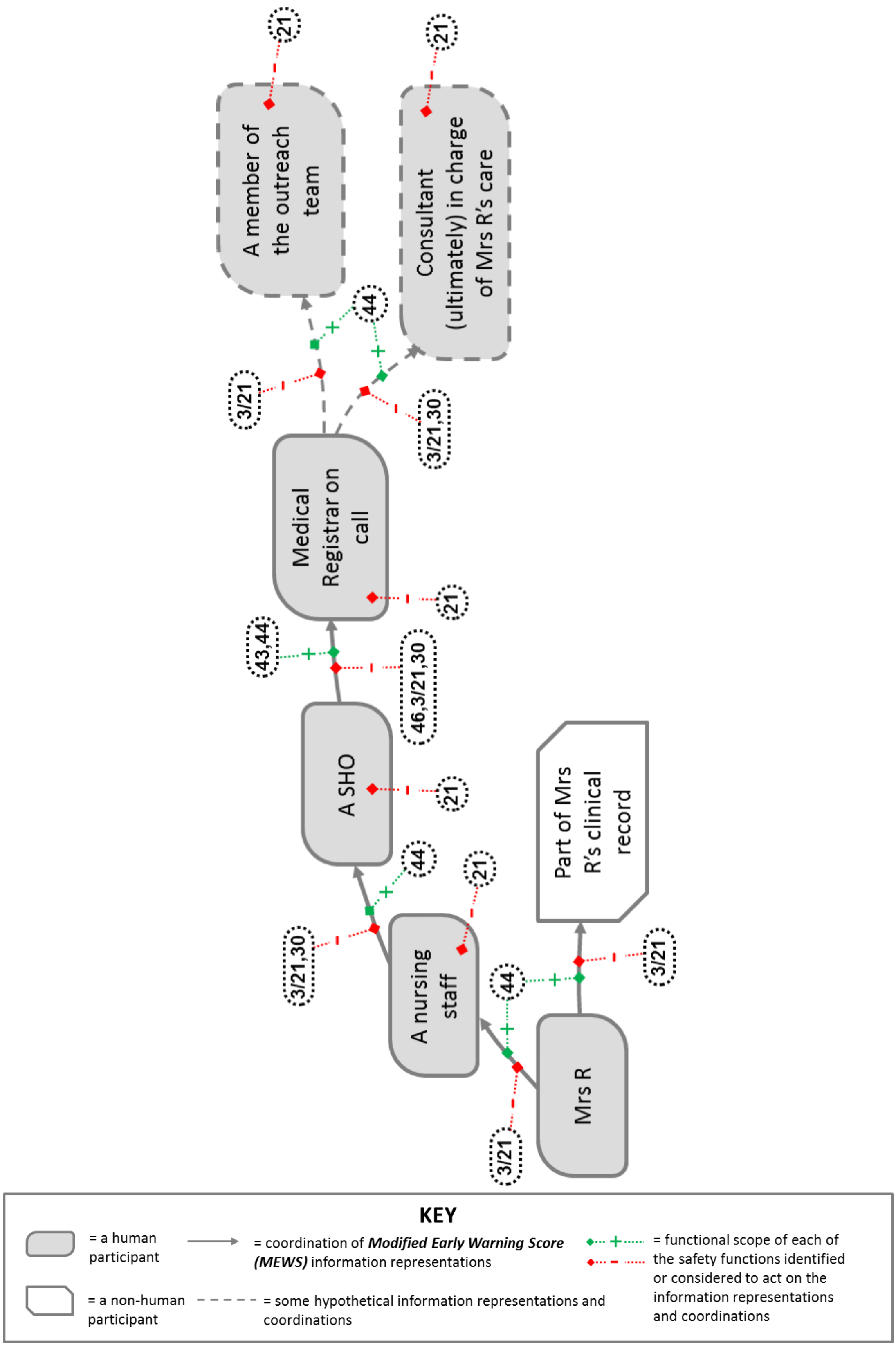

Figure 4.2: Graphical part of the final investigative hypotheses generated. Showing both the information trajectory, and scoping of the safety functions relating to the 6th **MEWS** reading taken on the Sunday of that weekend (MEWS = 11, suggesting severe physiological deterioration).

Table 4.4: Corresponding textual counterpart to the information trajectory shown in Figure 4.2 (for each arrow in the figure, alphabetically ordered).

Links in the information trajectory (selected 'inconsistent information flows' are marked with ***CF***)	**The interaction(s) leading to the propagation and transformation of *MEWS* representations** (the two participants in each interactive 'flow' are indicated in **bold**)
A nursing staff *to* A SHO	**A (generic) member of nursing staff** communicated Mrs R's MEWS to the **on-duty SHO**.
A SHO *to* Medical Registrar on call	**An on-duty SHO** discussed Mrs R's condition with the **medical registrar on call**.
Medical Registrar on call *to* A member of the outreach team ***CF***	**The medical registrar on call** 'escalates' Mrs R's MEWS score to the **outreach team**.
Medical Registrar on call *to* Consultant (ultimately) in charge of Mrs R's care ***CF***	**The medical registrar on call** informs **Mrs R's consultant** of Mrs R's MEWS score.
Mrs R *to* A nursing staff	**A (generic) member of nursing staff** calculated and took note of **Mrs R's MEWS score**.
Mrs R *to* Part of Mrs R's clinical record	**Mrs R's MEWS score** is recorded onto **part of her clinical record** by clinical staff.

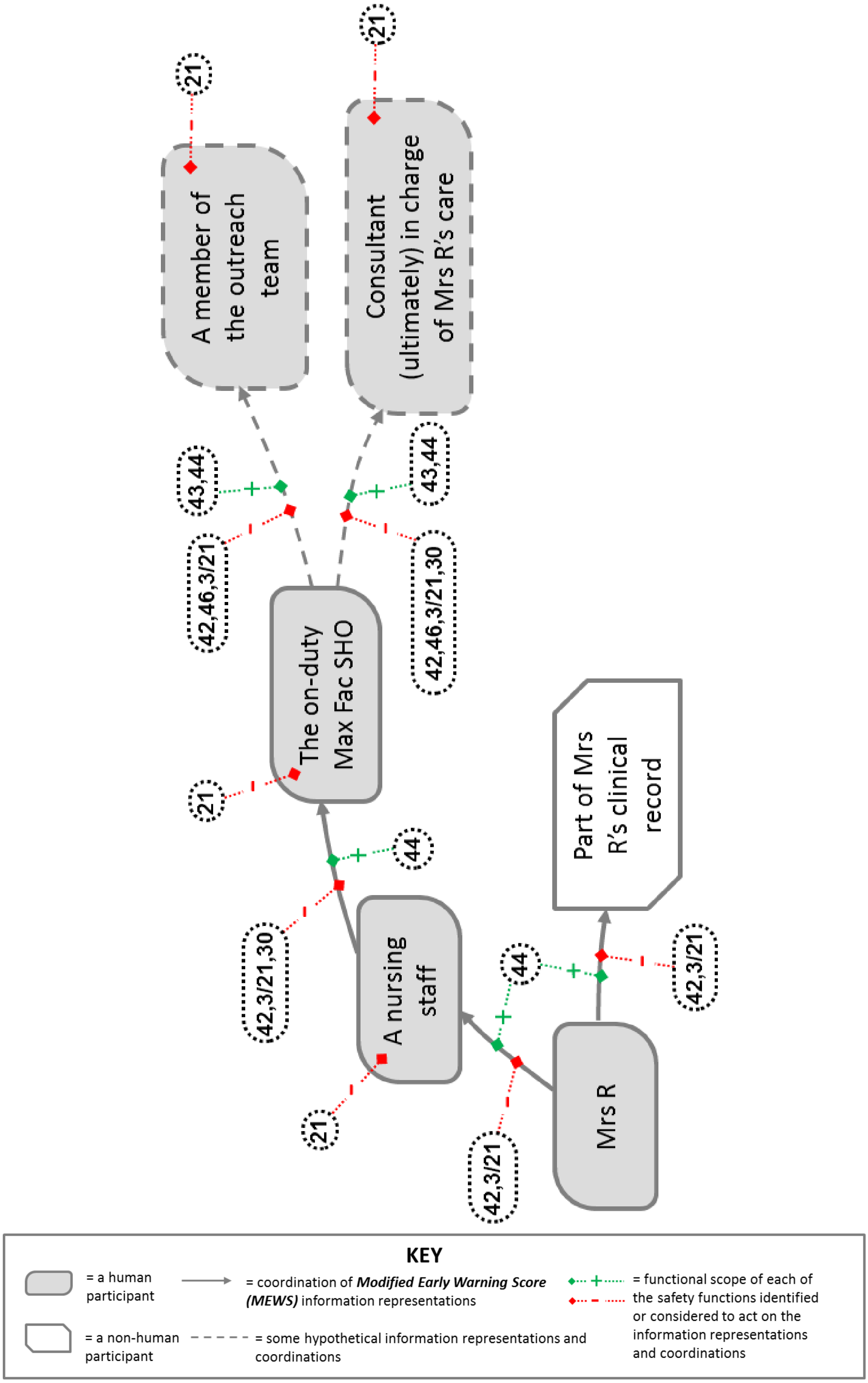

Figure 4.3: Graphical part of the final investigative hypotheses generated. For the 1st **MEWS** reading taken on the Saturday of that weekend (MEWS = 3, which should be escalated to the outreach team according to the policy in effect at the time).

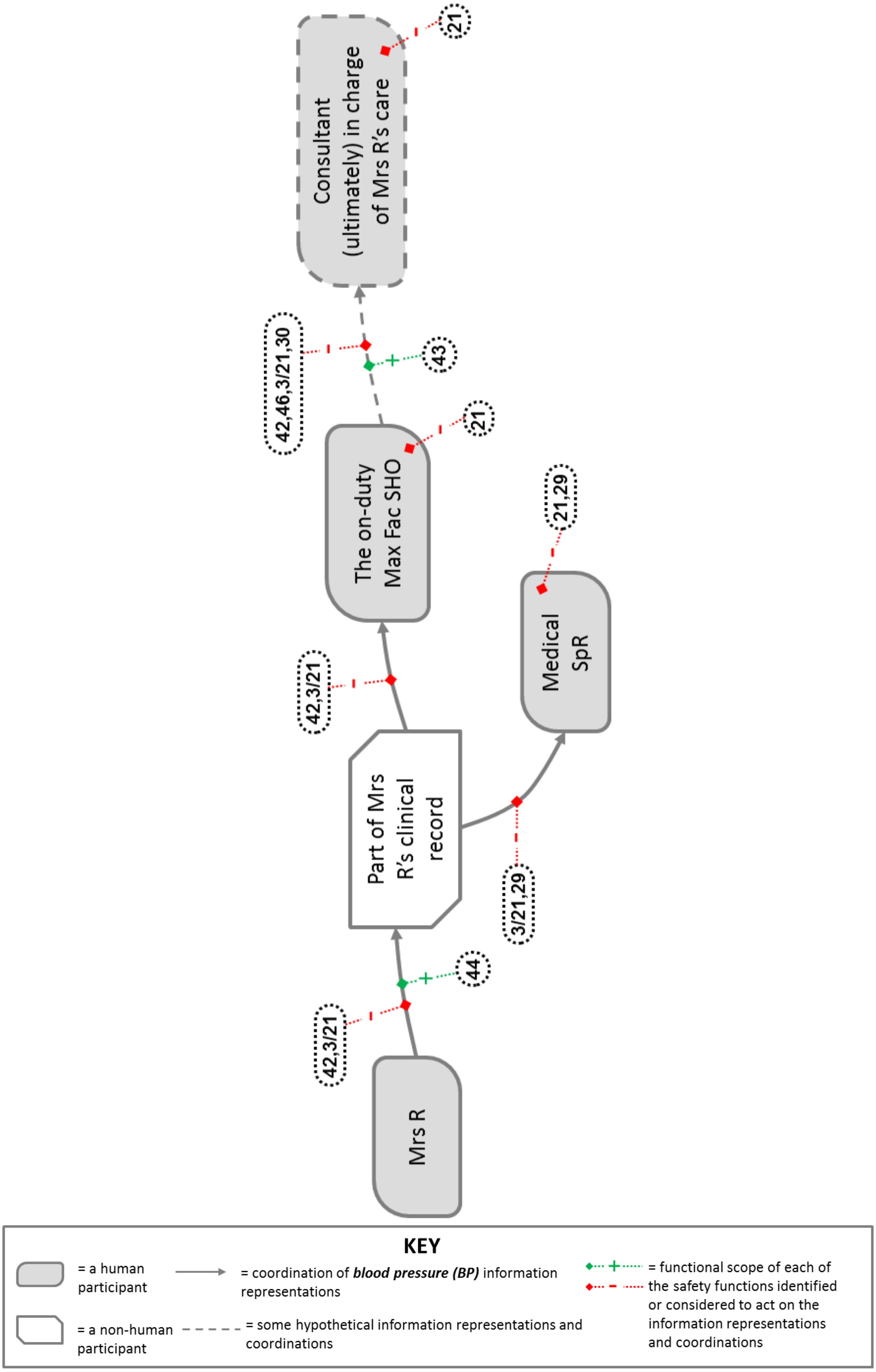

Figure 4.4: Graphical part of the final investigative hypotheses generated. For the 3rd **BP** reading taken on the Saturday of that weekend (BP = 76/54, indicating low blood pressure).

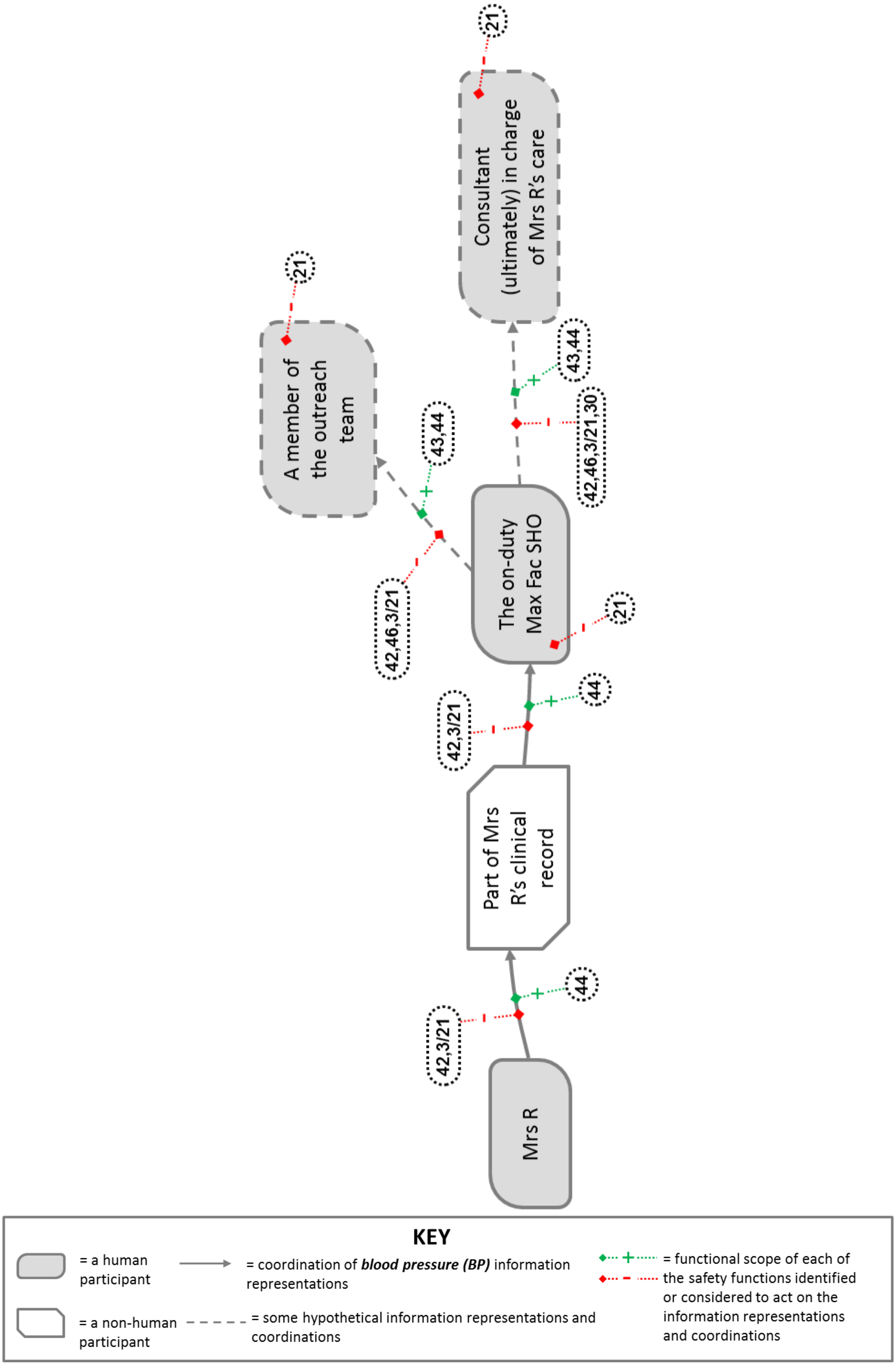

Figure 4.5: Graphical part of the final investigative hypotheses generated. For the 1st **BP** reading taken on the Sunday of that weekend (BP = 68/50, indicating low blood pressure).

Table 4.5: Textual representation of an illustrative selection of safety functions. Corresponding to the numerical identifiers shown in Figures 4.2 through to 4.5.

Safety function 'newly identified' [I], or extended [E]	**More elaborate description and explanation** (positive safety function to information trajectory associations are highlighted with **[+]**, and negative ones with a **[-]**)
42: Perception of a patient (e.g. Mrs R) as being 'asymptomatic' (i.e. the patient is not showing symptoms of illness). **[I]**	In this incident situation, Mrs R was perceived by medical staff as 'asymptomatic' for a time, and thus probably reasonably ok physiologically; This is despite many of the **BP/MEWS** readings suggesting that she could be deteriorating. This perception of 'asymptomaticness' could be partly explained by the fact that most of the **BP/MEWS** readings were not taken in conjunction with a systematic review of the prior **BP/MEWS** readings taken. **<u>Operationalising the Information Safety Method safety function definitions</u>** **[-]** This is a *consistency-reducing* safety function, which can reduce the probability of consistent information flow between two interacting participants, in the form of either: 1) reducing the chance for proper/timely observation or recording of **BP/MEWS** (for a patient perceived to be somewhat ok); and/or 2) reducing the likelihood that patient physiological status would be 'escalated' to the other medical staff in an information trajectory. In terms of its temporal scope, this safety function is interpreted to potentially effect all information trajectories occurring between 17.00 on Saturday of that weekend, to 18.00 on Sunday of that weekend (inclusive). Concretely, this scope includes information trajectories for the 3rd, 4th and 5th **BP** readings taken on Saturday, and the 1st and 2nd **BP** readings taken on Sunday. All but one of the information trajectories for *MEWS* readings on Saturday/Sunday are also included within the scope of this safety function. The exception is the trajectory corresponding to the 6th **MEWS** reading taken on Sunday (Figure 5.5), as Mrs R's poor physiological status was finally fully recognised and addressed.
43: Outreach training. **[I]**	Outreach training occurs at Hospital A – in the form of training on the use of **MEWS** scores on hospital induction, and an Acute Illness Management course. This could positively effect the timeliness with which the two SHOs involved in this incident situation could/would escalate relevant **BP** and **MEWS** information to others. **<u>Operationalising the Information Safety Method safety function definitions</u>** **[+]** This is a *consistency-enhancing* safety function, which can increase the probability of consistent information flows – from each of the two SHOs involved in this incident situation, to either 1) members of the outreach team, or 2) other 'higher' clinicians (such as registrars and consultants).

44: Patient physiology monitoring and escalation policy. **[I]**	To help consistently detect and catch patient deterioration, the Trust's 1) *minimum standards of observation policy*, and 2) ***MEWS** escalation policy*, are both designed to facilitate timely recording and escalation of patient physiological status. Only the ***MEWS** escalation policy* in effect at the time of this incident situation was readily accessible during the Information Safety Method analysis (the specific reference for this document is not provided here, to preserve organisational anonymity); the *minimum standards of observation policy* was not readily accessible. Thus here this safety function is only explicitly with respect to the potential effects of the ***MEWS** escalation policy*. However, inferring from a later version of the Trust's *minimum standards of observation policy*, there is substantive overlap in the functional roles of Trust policies for ***MEWS** escalation* and *minimum standards of observation*. **Operationalising the Information Safety Method safety function definitions** **[+]** This is a *consistency-enhancing* safety function, which can increase the probability of consistent information flow along each 'potential escalation pathway'. -- **Qualifying criteria for scoping this safety function with respect to 'escalation':** Based on reading it, the Trust ***MEWS** escalation policy* (as a safety function) is supposed to help effect 'escalation' when a 'medium' or higher **MEWS** score is obtained (of score 3 or above); the other physiological condition of substantial concern is when one or more 'red parameters' are obtained for a patient. A **BP** of 70 systolic or below is regarded as such a 'red parameter'. -- Based on these qualifying criteria, this safety function effects 'escalation' for the 4th and 5th **BP** information trajectories on Saturday, and the 1st and 3rd **BP** information trajectories on Sunday; all the **MEWS** information trajectories identified through the Information Safety Method analysis are also included under these qualifying criteria. This safety function also increases the probability of the patient **BP** or **MEWS** being initially measured, as part of the 'initial information flow' link from Mrs R in each figure, prior to further 'escalation' to other healthcare professionals. **Additional comments** If the Trust's policies were followed strictly, many counterfactual 'potential escalation pathways' would need to be visually depicted here for completeness. For simplicity here, we only visualise how safety function 44 effects the information trajectories actually identified in the current study.

45: Routine close communication between medical staff. **[I]**	The Max Fac SHOs in this incident situation communicated with the registrar on call every shift, either in person or via the telephone. This close communication could increase the chances of consistent flow of patient physiological information between these medical staff. **<u>Operationalising the Information Safety Method safety function definitions</u> [+]** This is a *consistency-enhancing* safety function, which can increase the probability of consistent (**BP** and/or **MEWS**) information flow, between a SHO and a registrar. **<u>Additional comments</u>** There is however basically insufficient detail in the corresponding incident investigation report, to support explicit investigative hypothesising about how this safety function 'attaches' to the various **BP/MEWS** information trajectories identified. The precise pattern of attachment would depend on more detailed knowledge of the shift times of, and number of times each Max Fac SHO communicated with the registrar on call; this knowledge would allow precise cross-referencing with the interaction patterns corresponding to each information trajectory. **This safety function was therefore NOT APPLIED to the various information trajectories identified.**
46: Dental, rather than medical training of clinical staff. **[I]**	The two SHOs involved in this incident situation were both dentally qualified, with limited prior exposure to critically ill patients like Mrs R. This may negatively effect the likelihood of them perceiving the need to appropriately escalate **BP/MEWS** information to other (possibly more senior) clinicians – such as a registrar, consultant or the outreach team for example. **<u>Operationalising the Information Safety Method safety function definitions</u> [-]** This is a *consistency-reducing* safety function, which can reduce the probability of all information flows 'outgoing' from the SHOs involved in this incident situation.

47: Signs of renal failure. **[I]**	Renal failure is a serious illness, where **blood pressure** and **MEWS** readings are both of relevance; when a patient develops signs of renal failure, this could increase the chance for these two patient physiological statuses to be communicated to others (as part of clinical discussions). **<u>Operationalising the Information Safety Method safety function definitions</u> [+]** This is a *consistency-enhancing* safety function, which can increase the probability of consistent information flow – in terms of Mrs R's **BP** and **MEWS** readings being 'escalated' to other (possibly more senior) clinicians; This escalation is by members of the medical staff who know about Mrs R's potential renal failure. With the possible exception of the Medical SpR, there is basically no detail in the corresponding incident investigation report to support convincing investigative hypothesising about precisely who was aware of Mrs R's potential renal failure. **This safety function was therefore NOT APPLIED to the various information trajectories identified.**
Extending the scope of safety functions from Information Safety Method analysis of the 2nd incident situation	
29: Busy and high-pressured working-environment. **[E]**	**<u>Operationalising the Information Safety Method safety function definitions</u> [-]** Like for the Information Safety Method analysis of the 2nd incident situation, this safety function similarly acts here as a *consistency* and *correctness-reducing* safety function. In the case of this incident situation, this safety function is likely to have acted on parts of the information trajectories around the time just after Mrs R's **MEWS** spiked up to 11 (i.e., from 22.40 to around midnight on Sunday the 15th of May); here the working-environment is likely to also have been similarly busy and high-pressured, in caring for a patient in dire physiological condition. Concretely, parts of the information trajectories for the 5 **blood pressure readings** taken on Saturday (i.e., the parts where these **blood pressure readings** were later consulted by the *Medical SpR* on Sunday); and parts of the trajectories for the 5th, 6th and 7th **blood pressure readings** on Sunday are effected by this safety function. The extent to which this safety function effects the trajectory for the 6th **MEWS** reading on Sunday is unclear from the corresponding incident investigation report; where there was insufficient detailed timing information to relate this safety function specifically to the corresponding information trajectory. **<u>Additional comments</u>** The precise scoping of this safety function across the various interactions in this incident situation is perhaps debatable (e.g., it does *not* currently extend to the information trajectories shown in Figures 4.2, 4.3, or 4.5). Mrs R is also not included within the scope of this safety function, since as a patient she is not 'working' in this incident situation.

30: (Perceived) surgeon/doctor 'dominance', over 'lower' parts of the medical hierarchy (e.g., nurses, junior doctors, perfusionists etc.). **[E]**	**Operationalising the Information Safety Method safety function definitions [-]** Like in the Information Safety Method analysis of the 2nd incident situation, this acts as a *consistency-reducing* safety function here, which can reduce the probability of consistent information flow between two interacting *human* participants – where the 'receiving participant' is 'higher' in terms of their perceived 'clinical seniority'.

4.4 Discussion

We now discuss some of the broader implications from the Information Safety Method analysis, taken as a whole across analysis of all five of the incident situations. Many incident-specific issues and ideas were raised through this work, like the examples shown in Section 4.3.2. Here, we discuss and illustrate some broader *kinds* of issues arising which may be replicated in future similar studies. These discussions serve to give indicative insight, into some of the more *situation-independent* properties of the Information Safety Method. Most of the issues raised in the following discussion were not treated in any depth by the original incident investigation reports. This study outcome shows that Information Safety Method analysis *can* support the generation of additional analytical knowledge, to extend and enrich the work of existing incident investigations (Study aim 2).

4.4.1 Fragilities of natural information systems

Analysis using the Information Safety Method consistently enabled additional insight into *how* the natural information systems forming during various the incident situations were fragile. The Information Safety Method facilitated insights going beyond an abstract statement of 'communication problems' (as discussed by Taylor-Adams et al. (1999), Tighe et al. (2006), Alvarez and Coiera (2006), and Kripalani et al. (2007) for example). We discuss the two main types of insights obtained below, using examples from the study for illustration.

A type of fragility consistently identified in the study was that of the low number of information coordinations involving the same participant as 'receiver' (see Section 3.3.3 for the substantive caveats around the word 'receiving'). Figure 4.6 illustrates this, based on the analysis results obtained. In the figure, *Accuracy checker (Ms F)*, *Mr P*, and the *Dispensing technician (Mr E)* are the participants doing the 'receiving'. Each of these three participants are 'receiving' two co-ordinations of ***drug identity*** information. These 'receiving' interactions are highlighted with thick orange lines in the figure. Further details of these investigative hypotheses can be found in Appendix A.4. Similar examples were also discovered for the other four incident situations.

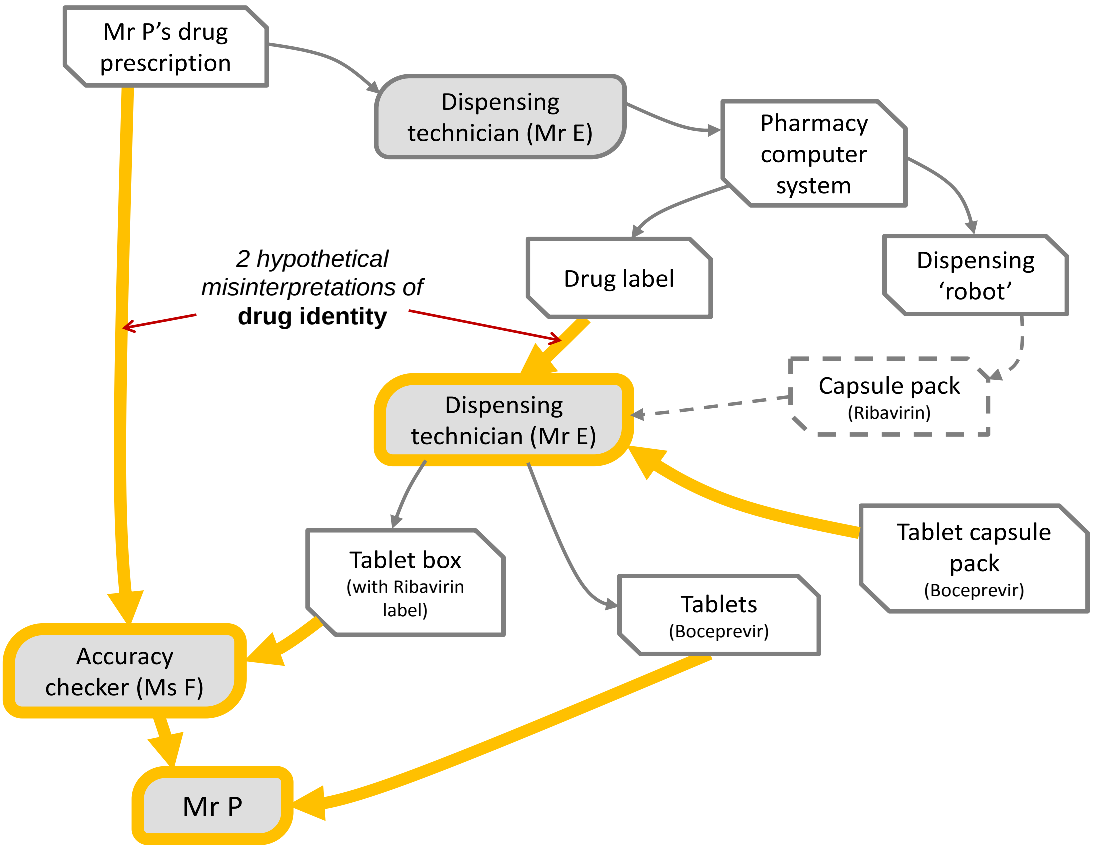

Figure 4.6: Two 'incoming flows' to each 'receiver' interpreting ***drug identity*** information. From analysis of the 1st incident situation relating to drug dispensing.

Taken at face value, such patterns of interaction suggest a lack of potential redundancy. 'Mis-coordinations' through one part of this system of informative interactions could allow unchecked downstream propagation: of one or more divergent interpretations and forms of representation. Due to a lack of alternative lines of informative representation coordination, divergent interpretations/representations could occur in spite of otherwise consistent 'good' coordinations elsewhere in this system (e.g., prior to the creation of *Mr P's drug prescription* for instance). Hutchins (2000, p58-9) has already discussed similar such issues of representational redundancy – in the context of the various socio, technical, and cultural interactions effecting information flow in an airplane cockpit. In contrast to the work of this and Chapter 3 however, Hutchins (2000) did not describe a specific, generic analysis method for identifying such issues of representational redundancy. He only took a relatively less defined Distributed Cognition *perspective* of the cockpit interactions (as is commonly done in Distributed Cognition based analysis).

The annotation in Figure 4.6 also suggests one way in which the overall robustness of this emerging system may be easily reduced, in the form of two potential misinterpretations of ***drug identity*** which may arise in practice. This kind of systemic weakness is particularly acute for the system corresponding to the ***drug identity*** example, since none of the explicitly identified incident participants were the original prescribing doctor. The human participants were predominantly the pharmacy staff in this incident situation. They were therefore heavily dependent on the communicative functionality of the ***indirect*** *drug identity* representation(s) informing their work. Like in the situation shown in Figure 4.6, all of the other information trajectories in the current study showed no occasions where the same participant 'received', as part of more than two 'incoming' information coordinations.

The three junctures highlighted in Figure 4.6 centre around the *Accuracy checker (Ms F)*, *Mr P*, and *Dispensing technician (Mr E)* participants. The interactions highlighted with thick orange lines represent situations where the representation coordinations are 'temporally dispersed' (i.e., each interaction denoted by an arrow occurs across a different point in time). Such Information Safety Method analysis provide a means of systematically highlighting opportunities for error-checking and detection, based on highlighting where communicative interactions may be amended to occur closer in time. In the case of the current example, the *Dispensing technician (Mr E)* could read the ***Ribavirin*** drug label at around the same time as he looked-at the ***Boceprevir*** capsule pack from the fridge in the dispensary (see Appendix A.4, Table A.4.1 for technical details). This amendment to the work process could have positively contributed towards preventing the particular drug dispensing incident situation.

Here the junctures identified are in the form of three different *people*. Such junctures may also be more generally in the form of *artificial artefacts*: such as the relevant part of a *pharmacy computer system* for example. Simultaneous comparison by a *single participant* of the emerging natural information system may thus be enacted for the future, whether by a person or artefact. Compared with the *collaborative cross-checking* perspective proposed by Patterson et al. (2007), this aspect of the Information Safety Method facilitates an alternative, generalised, and different Distributed Cognition based method, of generating ideas for improving the validity of the information representations used.

A second type of information fragility was also identified through the current study, relating to the second of four systematic questions proposed as part of the Information Safety Method (see Section 3.4):

> **Question 2:** Which parts of the information flows have only **negative** safety functions acting on them (i.e., *correctness/consistency-reducing*)?

Figure 4.7 shows an example answer to this question, illustrated using the ***drug identity*** information trajectory. Applying this question resulted in a focused understanding, to identify where consistent information coordination and correct information representation is as yet poorly supported by the ***drug identity*** natural information system. Some details of Figure 4.7 are discussed next.

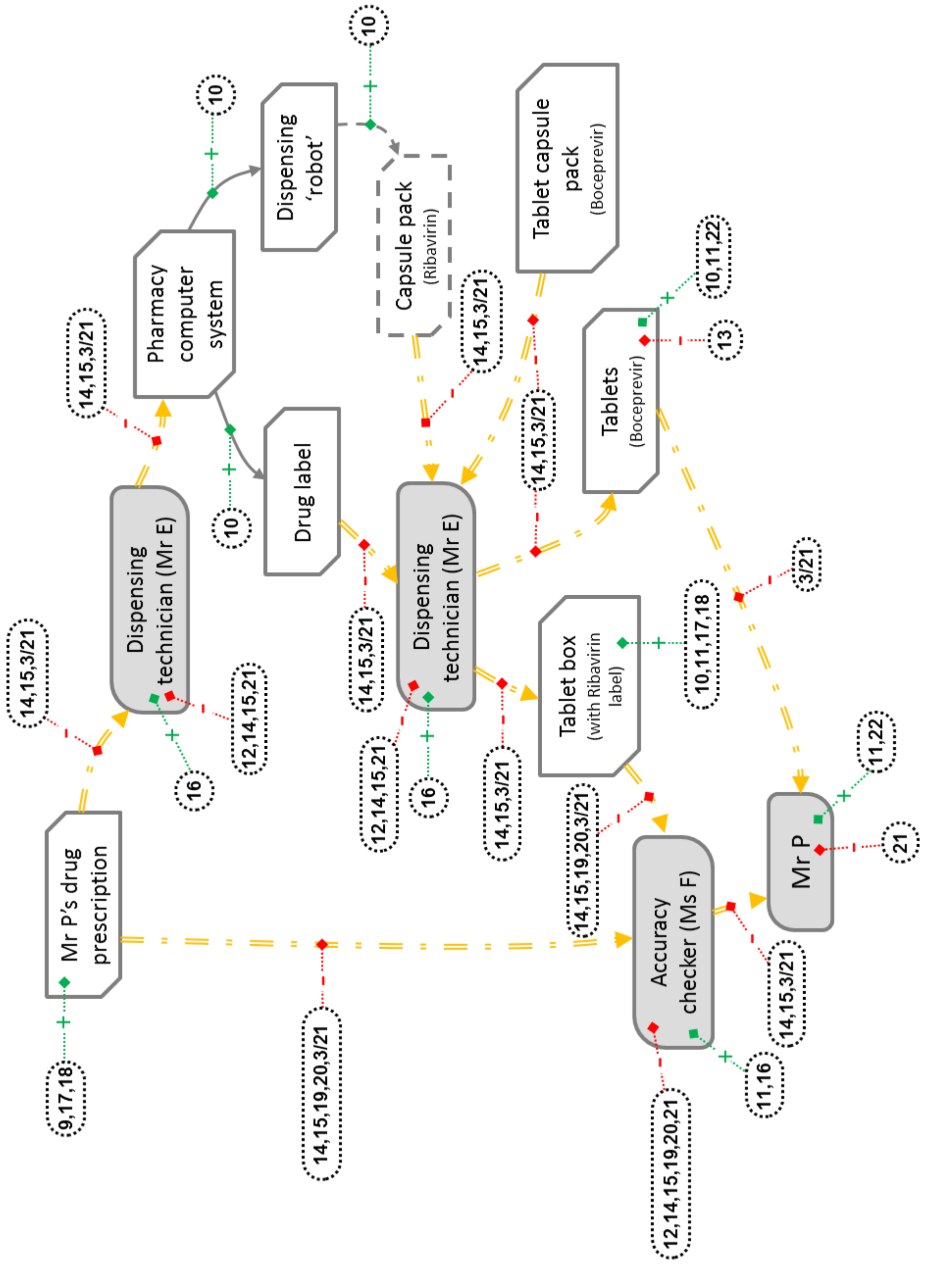

Figure 4.7: The answer to **Question 2** of the Information Safety Method, for the ***drug identity*** information trajectory. Answers are highlighted using the orange double-lined arrows.

As part of the information trajectory associated with ***drug identity***, safety functions 14, 15, 19, 20, 3, and 21 (as explained in **Huang** 2014c) were identified to potentially effect the information coordination between *Mr P's drug prescription* and *Accuracy checker (Ms F)*. This information coordination corresponds to *Ms F* looking at *Mr P's drug prescription* (details in the 8th entry of Appendix A.4, Table A.4.1). As shown in Figure 4.7, all six safety functions associated with this particular part of the natural information system were identified to act in a *consistency-reducing* capacity. Here, consistent coordination of ***drug identity*** information between *Ms F* and *Mr P's drug prescription* could be reduced. For example, the association between safety function

14 (potential interruptions from junior staff), and Ms F's looking at Mr P's drug prescription, was part of the following analytical statement:

> That *potential interruptions from junior staff* (safety function 14) can reduce the probability of consistent ***drug identity*** information coordination in any part of the ***drug identity*** information trajectory involving a pharmacy staff.

In a similar way, safety function 15 reifies 'a busy work environment', which was also judged by the analyst to have a similar reductive role and impact with respect to the information co-ordination aspect of Ms F looking at Mr P's drug prescription. While particular details and scopings vary, similar systematic identification of the fragile parts of existing natural information systems can be done: through asking **Question 2** of similar Information Safety Method based investigative hypotheses.

4.4.2 Active learning through understanding systemic causes potentially effecting information coordination and representation

The study also showed that the Information Safety Method can be used to understand how *systemic* causes potentially effect information coordination and representation across different incident situations (and analysis contexts). The safety functions mentioned in Section 4.3 give an idea of the kind of systemic causes which may be identified using the Information Safety Method. These systemic causes may be used to better understand part of the structuring of future incident situations. We go on to illustrate how these systemic causes may be accumulated, in the form of the safety functions of the Information Safety Method.

The first example is safety function **29**, originally identified through Information Safety Method analysis of the 2nd incident situation (see Table 4.1). This identified the "*Busy and high-pressured working-environment*" as a safety function significant to the natural information system emerging around the ***direction-of-blue-pump-tubing*** for a key piece of machinery used during heart transplant. As part of the analysis of the 5th incident situation (involving the late detection of patient physiological deterioration), the scope of safety function **29** was then extended to other parts of the various incident analyses. Through doing this, its scope was extended to the various natural information systems forming around the various ***blood pressures*** and ***Modified Early Warning Scores*** – both relevant to the 5th incident situation (see Figure 4.4, together with the 7th entry in Table 4.5, for details).

Safety function **21** serves as our second detailed example. This safety function was identified as the "*'fallible human' assumption*" in the current study: as an embodiment of the assumption of the inevitability of human mistakes underpinning much of contemporary safety scientific thinking (cf. Reason 1990 from instance). Unlike most of the other safety functions identified, safety function **21** was one of the few not explicitly grounded in particular incident data. It was 'identified', in response to reading a particular part of the discussions in the corresponding incident investigation report of the situation involving *a wrong drug being dispensed* (see Appendix A.4 for details: Table A.4.2 and Table A.4.6). Translating this into the specifics of the incident analysis, safety function **21** *can* negatively affect *all* human participants of an incident situation, and the various natural information systems they become part of. The scope of safety function **21** was therefore extended across the human parts of *all* of the information trajectories identified in the current study. In the case of the ***drug identity*** information trajectory, safety function **21** was identified to potentially affect Mr P the patient as well; because Mr P was an *active* rather than passive participant in the incident situation analysed (see Figure 4.7).

By making a 'background hypothesis' like safety function **21** explicit, the Information Safety Method helps to remind a future incident analyst of the need to mitigate against the *expected* potential systemic failure represented by the safety function. In the case of safety function **21**, the future incident analyst is reminded of the *assumption of human fallibility* amongst safety scientific academics. Through using the Information Safety Method, the incident analyst is explicitly required to reconsider the 'old' analytical knowledge base against the details of a new incident analysis situation. Analysts are thus required to explicitly reconsider the precise extent to which particular old lessons are relevant to new incident situations. In such a fashion, it is hoped that the intersubjective aspects of the Information Safety Method could encourage improved retention, and more *active* learning from past knowledge about incident situations. Thus actively encouraging enhanced 'collective safety memory', as part of the incident analyst's participation in a *transparent* and *systemic* learning process (cf. Department of Health 2000, Wrigstad et al. 2014, UK Department of Health 2013).

The third and final example discussed here is safety function **43** (Table 4.5, second entry). This safety function was identified as "*outreach training*". It reflects the fact that the Foundation Trust provided training for staff on their ***Modified Early Warning***

Score through a hospital induction, alongside staff training through an Acute Illness Management course. Two Senior House Officers were involved in the related incident situation. Both officers had received this staff outreach training. In this light, safety function **43** could *positively* effect the timeliness with which these two Senior House Officers could or would escalate ***blood pressure***, and ***Modified Early Warning Score*** information to others. Safety function **43** was not in the end associated with *all* of the many 'sub' information trajectories occurring over the weekend of the 5th incident situation; because the two Senior House Officers had participated in only *some* of the emergent natural information systems forming around the various ***blood pressures*** and ***Modified Early Warning Scores***.

In terms of the examples shown in Section 4.3, information trajectories relevant to safety function **43** corresponded to the 3rd ***blood pressure*** reading on Saturday (Figure 4.4), and the 1st and 4th ***blood pressure*** reading on Sunday (e.g., Figure 4.5). At least one of the two Senior House Officers were involved in all three of the associated information trajectories for the ***Modified Early Warning Score*** readings taken on Saturday (e.g., Figure 4.3), and the 2nd, 5th, and 6th readings on Sunday (e.g., Figure 4.2).

The Information Safety Method analysis of the 5th incident situation therefore gives a more nuanced analysis; it substantively further developed the original investigation's recognition of a 'lack of escalation' of such physiological readings to more senior doctors. A 'lack of escalation' is a relatively abstract statement providing little insight into the particulars of which escalations didn't occur, or possible explanations for the situation. The Information Safety Method analysis therefore encouraged clearer understanding, and detailed explication, of the variable extents to which a particular aspect of the incident situation (e.g., 'outreach training' in the case of safety function **43**) can effect each of the many information trajectories emerging.

Through using the Information Safety Method, the general idea is to dynamically develop ongoing broader patterns of causal explanation, through *systemic* explanation of diverse incident data, collated through their distributed incident analysis. The Information Safety Method provides one way through which such distributed knowledge building could start to be done. This could help to dynamically build evidence based *analytical understanding* – of the scope of potential systemic factors (a safety function) and an approximation of the extent to which each potential factor is of *systemic* relevance across diverse incident data.

4.4.3 Other implications from Information Safety Method analysis

In this section, we discuss other generative implications from the Information Safety Method analysis, and how such analysis results can lead to lines of productive enquiry.

Before commencing the incident analysis of the current study, we expected that we would be able to associate all the safety functions identified with the various information trajectories identified. However, an unexpected outcome of the incident analysis was in the form of safety function **45** (*routine close communication between medical staff*) and safety function **47** (*signs of renal failure*) (Table 4.5). Both safety functions were identified from the available incident data; neither could be concretely associated to the various ***blood pressure***, and ***Modified Early Warning Score*** information trajectories, however. In the case of safety function **45**, more detailed knowledge about the shift times, and the number of times each Senior House Officer communicated with the registrar on call was needed, to fully instantiate the Information Safety Method analysis. This would have enabled an evidenced judgement about which specific parts of the information trajectories were potentially effected by safety function **45**. In the case of safety function **47** (*signs of renal failure*), it was unclear from the available incident data which medical staff were in fact aware of the patient's potential renal failure during the incident situation. In both cases, further lines of reasonable inquiry were prompted by the attempt to associate a concrete safety function to specific parts of the information trajectories identified. In principle, the incident details thus prompted may help facilitate more thorough understanding of the potential causes of information (mis)coordination and (mis)representation.

Figure 4.8 shows part of the analysis of the ***drug identity*** incident situation, involving the *accuracy checker*, *tablet box*, and *tablets*. This also raised an interesting question of fact about ***drug identity*** information coordination.

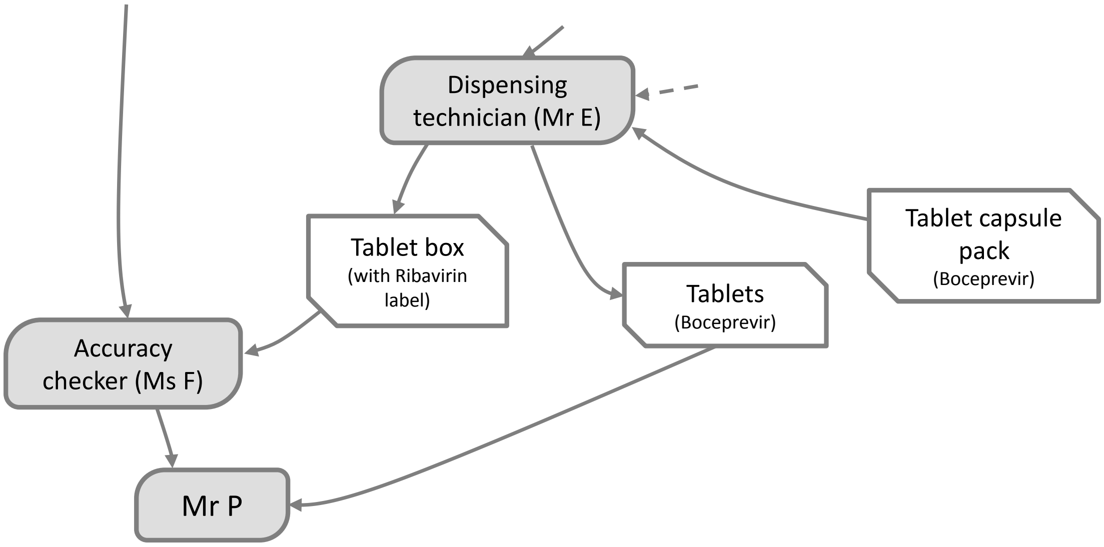

Figure 4.8: Highlighting the bottom part of Figure 4.6, omitting the safety functions for clarity here.

Figure 4.8 implies that no coordination of ***drug identity*** information occurred between *the accuracy checker Ms F*, and the Boceprevir tablets in *the tablet box with a Ribavirin label*. This fact may or may not be true, depending on the details of the incident situation. This particular aspect of what happened was beyond the scope of the available incident data. It remains unknown in this particular case, but does suggest a line of possible further safety inquiry about the coordination of ***drug identity*** information. Through systematically explicating the information coordinations supported by available incident data, the Information Safety Method analysis has also highlighted an aspect of the situation which may be changed in principle, to facilitate more robust systems of ***drug identity*** information coordination and representation in future. If the accuracy checker *had* taken the tablets out of the enclosing box and had looked at them, this would have added further redundancy to the system of ***drug identity*** information coordinations formed through the work. This is equivalent to adding an arrow from the *Tablets (Boceprevir)* incident participant, to *Accuracy checker (Ms F)* in Figure 4.8. In this amended working scenario, the Boceprevir tablets themselves would have then formed a third comparative source; for a three way *consistency-check* of ***drug identity*** by the accuracy checker *Ms F*, against:

1) the *tablet box with a Ribavirin label*,
2) the *patient Mr P's drug prescription* (the omitted end of the top left arrow in Figure 4.8, see Figure 4.7 also), and
3) the perceived ***drug identity*** of the *Boceprevir tablets*.

Such a modification to the interactions of the work system would increase the likelihood of detecting a drug dispensation error [7]. This point is made without the intention of promoting hindsight bias here. The point is not that the checker *ought* to have taken the tablets out of the box at the time of this incident situation. Instead, the point is that the structure of the investigative hypotheses developed here (through using the Information Safety Method) can naturally lead to some relatively practical ideas for enhancing the robustness of future information coordination. If this suggestion for work modification was found to be already implemented upon further investigation, the corresponding investigative hypotheses can then be revised to better represent the more complete state of knowledge about the incident situation. Similar discussions could be conducted with respect to other parts of the various information trajectories developed from this study, where the 'missing' arrows between various incident participants could prompt creative discussions around additional redundancy paths worth considering for the future. The lack of more than one outgoing arrow from the *capsule pack for Boceprevir tablets* on the right-hand side of Figure 4.8 provides a further example.

Analysis results from the first incident situation were also presented to a multi-disciplinary group of safety researchers (**Huang** 2014b). This presentation prompted lively debate around what was known about the accuracy checking aspects of the incident situation. In this case, the context of discussion was somewhat different from that reported for the **AcciMap** (Rasmussen and Svedung 2000), and Root Cause Analysis based methods (Iedema et al. 2006a, 2006b). However, the Information Safety Method seems to have similarly contributed towards creating a conversation space – around which semi-structured discussion about the strengths and limits of the extant incident knowledge and response could be conducted. From the peer debate which ensued around the Information Safety Method analysis, it became clear that there may be knowledge gaps about the precise physical co-locations of the *tablet box*, *tablets*, and *tablet capsule pack* used. We assumed that the *Boceprevir tablets* were within their *tablet capsule pack* at all times during the incident situation. Further understanding about how the *tablet box labelled as Ribavirin* was physically co-located with the other incident participants, however, could lead to an enriched

[7] Although with obvious caveats relating to its practicality, which incident investigators embedded in an organisation would be better placed to determine in principle.

understanding of the ***drug identity*** information coordinations at the time. Since the participant interactions shown in Figure 4.8 were mostly proximal to the 'critical event' of the incident situation [8], fuller understanding of the precise details of their physical co-locations is an arguably useful area for further reducing investigative uncertainty.

Another notable example emerged through the identification of safety functions from the 1st incident situation, involving safety function **9**. This safety function reified the "*clinical checking of patient prescriptions by a pharmacist*". According to the corresponding incident investigation report, this clinical checking:

> "involves firstly checking the patient's allergy status to confirm the patient is not allergic to the medication prescribed. Next, the *dose*, *frequency*, *route* and *length of treatment* are reviewed"
> (quoted from the original incident investigation report, my emphasis)

Through the analysis, safety function **9** was identified to potentially increase the probability of correct ***drug identity*** information representation (in the form of *Mr P's drug prescription*). The clinical checking process may allow the checking pharmacist to serendipitously detect the wrong drug being used. As reported by the incident investigation however, ***drug identity*** is notably not explicitly included, amongst the (four) aspects to check for in dispensing patient medication. The comparison between the incident analysis and the facts from the report suggest that if the ***drug identity*** is indeed not routinely checked, adding such a check to the existing clinical checking process could increase the chances for timely error detection. Such an addition to the routine checking process would make fuller use of the expertise of pharmacists to help catch, and double check unusual prescription-illness configurations (cf. Al-Khani et al. 2014).

In principle, our Information Safety Method can facilitate uncertainty reduction in incident investigation – by using **Question 1** (where the information trajectory has no safety functions), **Question 2** (only negative safety functions present), and **Question 4** (only positive safety functions present) (Section 3.4). In a formative capacity, the answers to these questions may indicate areas of underdeveloped investigative understanding. The answers to **Question 1** can highlight where few performance

[8] A 'critical event' in the sense of Rasmussen and Svedung (2000).

shaping factors are as yet known or explicitly recognised. The answers to **Question 2** and **Question 4** can highlight where investigative understanding is perhaps as yet biased – towards either the *negative*, or *positive* aspects of incident situations, respectively. Across all of the investigative hypotheses actually developed in the current study, only the *non-human* parts of the natural information systems had no safety functions, in answer to **Question 1**. Very few parts had only positive safety functions, in answer to **Question 4**. This may reflect natural human biases towards focusing only on what went wrong (evidenced by the many answers to **Question 2**). Even so, the use of the Information Safety Method enabled these emergent patterns of inference to be systematically identified, recognised, and potentially addressed for the future.

4.5 Study limitations

A potential weakness of the study reported here is in its use of already interpreted 'incident data', some of which may have been already interpreted so substantively by the original incident investigators so as to be no longer usable as 'raw data'. As contributions such as de Carvalho (2011), Salmon et al. (2012), and Benner (2013) show, the use of second-hand reports of 'incident data' is common in academic incident analyses. We have repeatedly found that the line between 'analysis', and undisputable empirical data in a patient safety incident investigation report can become very blurry in practice. This reflects a growing need for research into standard source data documentation structures, to better support the diverse needs of the many potential users of incident data/reports, or incident investigation reports (cf. Johnson 2003b; Benner 2012, 2013). The reports used for the current study were relatively 'data-rich', however, without too much 'analytical filtering' as to render them unusable for its purposes. An anonymised full example of the source incident data is presented in Appendix A.1, which shows how the level and richness of contextual empirical data used for the current study was an improvement, over that provided by public reports such as Toft (2001), and ISMP Canada (2007). Original investigators involved in the reported investigations were on hand to help us with clarification when needed. This was rarely needed during the study. Nevertheless, live use in an actual incident investigation is a next step needed, to provide a more ecologically valid context of study for the Information Safety Method.

A second potential critique is in the fact that only a single analyst undertook the incident analysis of the current study. Due to its Distributed Cognition based conception of the incident analysis task however, this potential critique is a moot point in the case of the Information Safety Method. Under the Distributed Cognition perspective, there is very little theoretical difference, in kind, between that of the one incident analyst situation, or where multiple incident analysts are involved. The study context reported in this chapter is simply one of a range of anticipated real scenarios for which the Information Safety Method could be deployed. The current study shows that it is possible for a single analyst to distribute their analytical understanding across analysis of multiple incident situations using the Information Safety Method. Further research is necessary, to explore the extent to which similar study outcomes are possible across other incident analysts and incident situations.

4.6 Conclusions

This chapter presented a study exploring the use of the Information Safety Method, and the empirical implications following from its controlled usage.

To determine the extent to which the Information Safety Method can be used to analyse diverse patient safety incident situations (**study aim 1**), the Information Safety Method was applied to analyse previously unseen incident data. It was successfully used across all five of the diverse incident situations independently identified to be relevant for the purposes of the method. While further empirical study is clearly necessary, the diverse incident situations productively analysed suggests that the Information Safety Method can be used to analyse diverse patient safety incident situations.

The **second aim** of the study was to explore the generation of additional knowledge, beyond that obtained from the existing incident investigations. In all cases, additional issues, ideas, and lines of inquiry were generated through applying the Information Safety Method. Although some of these were touched on by the original investigations, the majority of the additional issues and ideas were not substantively reported by the corresponding investigation reports (Collaborating patient safety incident investigation department 2010-2013). In particular, the study showed that the Information Safety Method (Section 4.4):

- can help the analyst better understand where systems of information representation are naturally fragile, and provide Distributed Cognition based insights into the nature of these systemic fragilities;
- can be used to support active learning from incidents, through understanding systemic causes potentially effecting information coordination and representation;
- can lead to various (other) implications of interest.

We found that Information Safety Method analysis can trigger further lines of productive inquiry, suggest ideas for making existing systems of communication more robust, and help create a conversation space for debate about the strengths and limits of the related knowledge about the incident situation analysed. Using the new method, we may therefore discover other knowledge pertinent to an incident situation, to extend and enrich the existing work of incident investigations. These additional knowledge and analytical insights could then be debated and discussed, to help ultimately improve the robustness of the systems of information coordination and representation formed through communicative work acts during incident situations.

The **third and final aim** of the study was to explore potential difficulties unfolding in moving from the abstract theory of the Information Safety Method, into incident analysis practice using the new method. In the current study, a notable logistic issue was unexpectedly encountered. In identifying all of the sub-information-trajectories associated with the multiple ***blood pressure*** and ***Modified Early Warning Score*** information representations (over the course of a single weekend), substantive practical difficulties were encountered in managing the systematic 'live' recording of the Information Safety Method analysis generated. For the current study, a largely manual means was used to record the investigative hypotheses generated. This raised substantive organisational complexity for the author (as incident analyst): to simultaneous manage the development of the multiple 'sub' information trajectories being identified, and explicitly relate them to various individual safety functions being identified. This highlights an area of further methodological development, for the Information Safety Method.

In conclusion, the current study shows that the Information Safety Method can be used to raise new issues of interest. The current study indicates that the Information Safety Method can indeed *do what it is supposed to do* – which is to help illuminate how distributed cognitive systems form during incident situations through attempts at communicative interaction. The current study therefore represents an initial validation of the Information Safety Method (cf. Branford 2007). However, the study also shows that we need to pay more attention to the needs, demands, and constraints, of the practice of doing incident analysis. Empirical understanding of whether systemic incident analysis is practiced (or not) as part of real incident investigation, and exactly how this is done, is as yet underdeveloped. The next three chapters explore the practice of incident analysis in more depth, and explicitly consider the move from research-based theory into practice. This is done through detailed empirical examination of both interview data, and incident analysis tools, drawn from the domain of patient safety incident analysis and investigation.

Chapter 5 – Concepts significantly driving incident analysis and investigation practice

Chapters 3 and 4 explored the development and validation of a new systemic incident analysis method, in an academic research context. However, the review of Chapter 2 also indicated the need to start building bridges, between systemic incident analysis research innovations and practice. To contribute toward this effort (Aim B, Objective 3), this chapter:

- Explores the degree to which systemic incident analysis is in fact practiced as part of patient safety incident investigation
- Reports on two in-depth interviews with practicing patient safety incident investigators, providing an initial answer to a new research question around conceptualisation of their analysis and investigation practice
- Provides an initial understanding of common significant concepts driving incident analysis and investigation at a United Kingdom Foundation Trust
- Further indicates the nascent nature of patient safety incident analysis and investigation practice, as evidenced by a partial rather than full rejection of the monocausal style of incident explanation

5.1 Introduction

The empirical evidence reviewed in Chapter 2 provided an indicative description of issues relating to the gap between systemic incident analysis research and incident analysis practice. This motivated the need to start to bridge the gap between systemic incident analysis methods in theory, and their usage and utilisation in practice. In order to better understand contemporary incident analysis practice, we examine empirical data on safety incident analysis and investigation practice in this chapter. In particular, we focus on practice in the context of patient safety, to better understand the degree to which systemic incident analysis is in fact practiced as part of patient safety incident investigation. This is done through two in-depth interviews, with two of the three practicing patient safety incident investigators directing incident analysis and investigation efforts at a large Foundation Trust in the United Kingdom. Unless specified otherwise in this chapter, 'investigation' refers to the investigation of *Serious Untoward Incidents* – which is the most serious kind of incident situation investigated at the Trust.

5.2 Study aim

Given the substantively conceptual nature of incident analysis work, the following novel research question provided a natural broad focus for the interviews, and the coding process during the qualitative data analysis:

> *What are the significant concepts for patient safety incident investigators in their investigative practice?*

To generate data for answering this research question, the interviews specifically focussed on eliciting both explicit and tacit knowledge: relating to the *process*, *rationale* and *decision-making* aspects of the investigative work practice of the interviewees.

5.3 Methods

5.3.1 Method selection

Given the limited knowledge base on patient safety incident investigation practice, flexibility was needed in terms of the topics explored and examined during the two in-depth interviews. Semi-structured interviews were selected as an appropriate method of qualitative data collection, since they provide the ability to flexibly examine emerging topics of interest in varying degrees of depth, as part of exploratory research design (Robson 2011). To maximise the exploratory aspect of the study, the author-as-interviewer did not assume prior knowledge of what concepts significantly drove the two patient safety incident investigators' practice, for each of the two interviews conducted.

Thematic analysis was chosen to complement the method of interview, for the following reasons. Firstly, thematic analysis is a flexible analysis approach suitable for investigating under-researched areas, regardless of the extent to which data analysis is *inductive* and/or *deductive* (Braun and Clarke 2006). It is therefore appropriate for the current exploratory research study. Secondly, Braun and Clarke (2006) was the same analysis instrument as used by Underwood and Waterson (Underwood 2013, Underwood and Waterson 2013), in their examination of the systemic incident analysis research-practice gap. The analytic narrative (presented later in Section 5.4) was therefore obtained through the use of the same analytical lens. These contributions may thus complement and enrich the nascent knowledge base on the nature and extent of the research-practice gap for systemic incident analysis: as a form of investigator and data triangulation (cf. Rothbauer 2008). In the current study, we specifically examine *practice in conducting patient safety incident investigation.*

5.3.2 Participants and sampling strategy

Two practicing incident investigators participated in the study, from a Foundation Trust in the United Kingdom. They both led safety investigation efforts at the Trust, and formed two-thirds of the team leading patient safety incident investigation at the time of the interviews. A one-to-one interview was conducted with each of the two investigators by the author. Both investigators were originally from a nursing background, coming to their incident investigation role through the 'clinical governance' route. They are referred to as investigator A and B throughout this chapter, using a generic 'his/he' pronoun for reasons of simplicity and anonymity.

A mix of purposive/convenience sampling was used to recruit the two practicing incident investigators for separate interview. Candidate interviewees were first identified through the author's attendance at the 2012 Clinical Human Factors Group conference (Clinical Human Factors Group 2012). The contacts made at this event were further pursued and developed through subsequent email invitations for collaborative research. Snowball sampling occurred when investigator A recommended/recruited investigator B as another interviewee suitable for the current study. Interviewees were eventually chosen based on their detailed knowledge of one or more of the five incident situations analysed in the previous study (Chapter 4), and the corresponding incident investigation of each situation. Shared knowledge of these specific incidents and investigations would then provide a focused context for the conversations between the interviewer (the author) and interviewee, in the context of the current study. The interviewer's knowledge of the incident situations and investigations was developed as part of the incident analysis work reported in Chapter 4.

5.3.3 Interviewer preparation and interview schedule design

The author had some prior experience of conducting semi-structured interviews (e.g., see **Huang** 2011, Appendix 3). However, he was a relative beginner at the practice of research interviewing at the time of the current study. Pilot interviewing with other patient safety incident investigators was not feasible in the run-up to the study. Active measures were taken as part of study planning and research design, however, to offset this *a priori* limitation of the context of research. These measures centred around the preparation of a detailed interview schedule beforehand, a final version of which was used interactively to support the actual interviews. As part of the planning process, supporting cues were also considered, and in the end utilised – with the aim of aiding interviewees in recalling specifics from the past. The developing interview schedule was reviewed by the author's supervisors, to refine and improve the developing study plans. These plans were also explicitly compared with, and refined against ideas from a variety of related interviewing literature by the author: ranging from the more generic (e.g., Klein et al. 1989), to the more specifically relevant (e.g., Rollenhagen et al. 2010). Parts of the interview schedule were also informally piloted beforehand, in non-patient safety contexts.

While considerable care was taken in calibrating the interview schedule, it was not intended to be followed strictly in the actual interview (cf. Blandford 2013). The schedule design and preparation process was the main means by which the 'researcher-as-instrument' could be prepared and refined (cf. Pezalla et al. 2012 for related discussions), within the pragmatic constraints of the study. Given that these interviews took place late on in the training process for a PhD in Safety Science (February 2014), the researcher/interviewer was already considerably sensitised to basic issues in incident analysis and investigation research. The final version of the interview schedule is shown in Appendix B.1. Appendix B.2 shows the related interactive timeline used to support interviewee recall during each interview.

5.3.4 Data collection and transcription

Around three hours of interview data was audio recorded, with the permission and written consent of the two incident investigators. The data consisted of over 35,000 spoken words in total, with a ratio of approximately 60:40 in terms of time spent talking to investigator A and investigator B, respectively. For investigator A, a relatively complete walkthrough of one of his incident investigations formed the main focus for our conversation. A similar walkthrough was attempted with investigator B, but impeded by the fact that both the incident investigations we attempted to walkthrough were considered *not* to be good examples of their investigative practice by investigator B. This was not obvious from the corresponding investigation reports accessed beforehand, and came to light only during the interview. There was consequently less standardisation between the outcomes of the two interviews than we originally hoped for during research planning, to support integrative analysis of the data; references to specifics of incident situations and investigations therefore had to be elicited on a more improvised basis with investigator B.

Nevertheless, both research interviews focused on both the specifics and broader generalities of the investigators' practice. Both conversations were fairly 'natural', and co-constructed, with relatively non-directive interviewing used throughout the bulk of each interview. Specific questions were occasionally used by the interviewer deliberately, however, to probe more deeply into particular details of the incident investigation work practice. In the role of interviewer, the author believes that relatively good rapport was established in both interviews, despite occasional moments of tension and awkwardness during each of the two conversations.

A 'verbatim' representation of the audio stream was constructed following the interviews, in preparation for thematic analysis of the data. Figure 5.1 gives an illustrative example, from the full interview transcription constructed. The fine granularities of talk were mostly unimportant for the purposes of this study (e.g. non-verbals, facial expressions, meaningful pauses etc.). The few potential exceptions were noted explicitly, as part of constructing the textual transcript. Dots of varying lengths (e.g., "..", "...") were loosely used as part of the transcript, to approximate pauses of varying lengths in the conversation. Extra dots have been added to the extracts presented in this chapter to ease reading, without substantively altering the meaning of the quoted passage. A lack of capitalisation is also used in the quotes, to indicate a relatively quick 'run on' from one part onto the next part of the conversation.

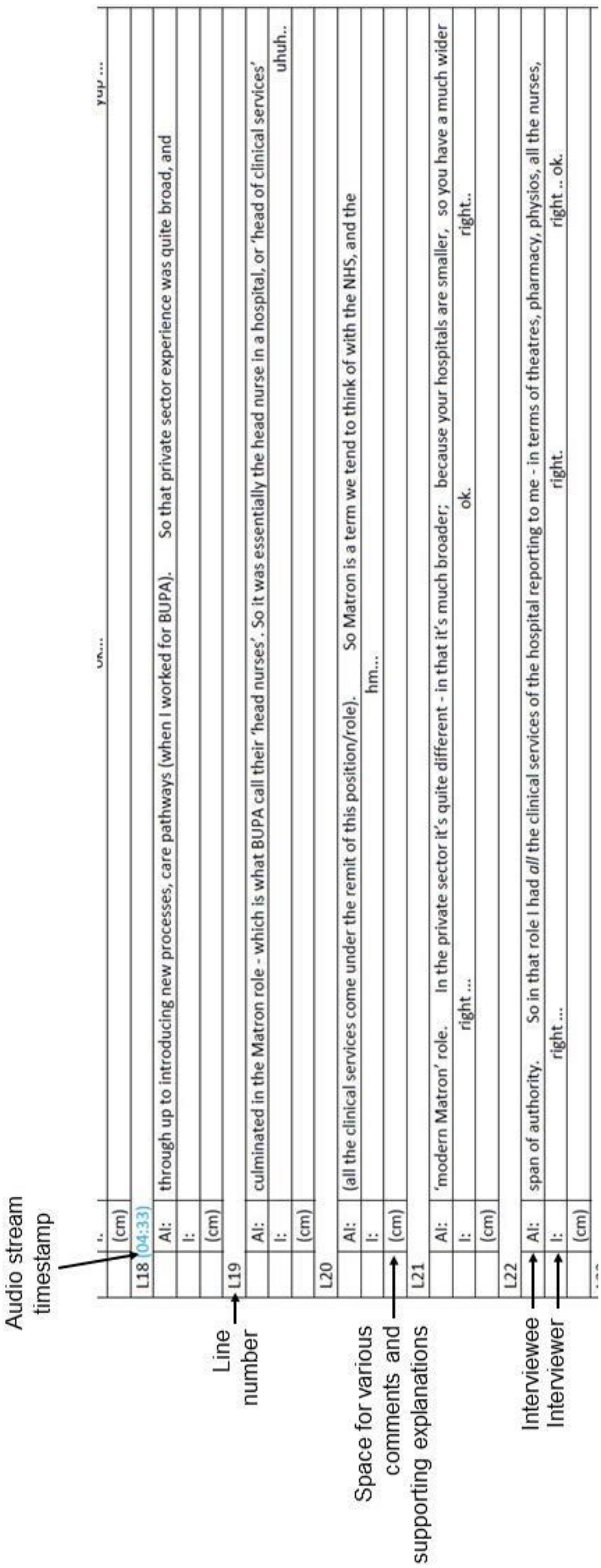

Figure 5.1: A simple 3-line representation of the conversation.

The written transcript served as a convenient intermediate representation for supporting the subsequent data analysis, after being 'accuracy checked' against the original audio stream. The audio stream remained the *de facto* primary data however, for the purposes of the data analysis. Additional 'interview data' also supported the analysis, alongside the audio stream and transcription. This consisted of the final version of the interview schedule interactively used by the author during the interview (using a printed version of Appendix B.1), as well as the interactive timeline sheet used by each of the two interviewees during their interviews (using a printed version of Appendix B.2).

5.3.5 Data analysis

The interview data was analysed from a *critical realist* perspective, which assumes a socially influenced reality (e.g., Danermark et al. 2002; Willig 2013, Chapter 2). An *inductive*, *latent* thematic analysis was conducted (Braun and Clarke 2006). Its *inductive* nature meant that the analysis was primarily data driven, without deliberately coding using existing ideas from the background literature (particularly during earlier stages of analysis). The *latent* aspect meant that the analysis sought to go beyond a surface/descriptive understanding only – and attempted interpretation of some of the underlying ideas, assumptions, conceptualisations, and ideologies underpinning the primary data (not necessarily obvious from a cursory examination of the data). In following the method of thematic analysis set out by Braun and Clarke (2006), review and refinement of the themes was conducted with an eye for achieving both *internal homogeneity* (meaningful cohesion within each theme) and *external heterogeneity* (clear and identifiable distinctions between themes). The iterative/recursive process of qualitative data analysis was continued until nothing substantial was being added or revised through revisiting the emerging themes. A good 'fit' with the underlying data was judged to be achieved, at this point in the study.

Initial coding was started towards the end of the data transcription process (Section 5.3.4), continuing in earnest after 'accuracy checking' the transcript. Just under 400 initial codes were generated in total across the two interviews, as the basis for an initially 'flat' set of themes (i.e., non-hierarchical). These initial themes were then iteratively (re)structured, refined, and compared back with the data: through the process of drafting in the form of five *Microsoft Word* documents. Additional intermediate physical copies of each of these five documents were also annotated, to facilitate effective comparison and refinement between the data and emerging analysis (in-between each of the five drafts of data analysis). The 'headings' functionality of *Microsoft Word 2010* was used throughout, as a hierarchical structuring aid in developing the themes being identified. Figure 5.2 presents a thematic map from early on in the analysis process.

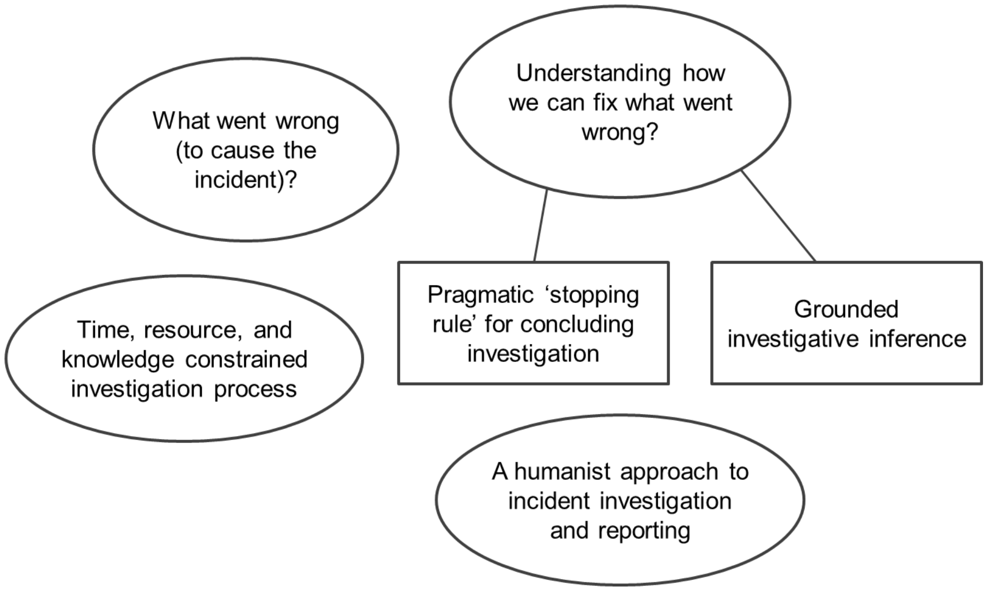

Figure 5.2: A thematic map from early on in the analysis process.

5.4 Findings: An analytic narrative of significant concepts driving patient safety incident investigation practice

5.4.1 Theme A: What went wrong, to cause significant patient harm?

A significant concept for both investigators is to understand the things which went wrong, to have caused significant harm to the patient. For example, investigator B sees "Identifying what went wrong.., to enable you to do something about it" as the principal aim of an incident investigation. This emphasis is congruent with investigator A's repeated emphasis on 'wrong' issues throughout his interview, in explaining and illustrating parts of his investigative process. An example is given below, in the context of investigator A describing the kind of situation clearly requiring a full investigation:

> "..so sometimes you know that quite quickly: we've chopped off the wrong leg, we've given the wrong drug, we missed a fracture, we missed a lung cancer. Sometimes it's absolutely black and white."
> (investigator A)

The other part of this theme is about 'significant patient harm'. Although the interview data shows some inconsistencies relating to this idea, it nevertheless forms a loose, but key focus for driving investigation practice, by virtue of its association with the definition of 'incident' proposed in national-level guidance documents (e.g., *National Patient Safety Agency 2010*, which is part of what the investigators and their Trust are working under).

To support and develop an understanding of what went wrong, a *timeline* is the main supporting tool used. In conversation about its relationship with Root Cause Analysis, investigator A notes that:

> "if I haven't got a timeline, I haven't got a clue what I'm investigating. So I need [the timeline], to give me structure"
> (investigator A)

Investigator B similarly uses the timeline as an interactive aid to support his investigation process:

> "I always start with the timeline, so I always plot the timeline out first. I just find it easier to assimilate *that* knowledge first, so it puts things into... an ordered fashion for me. And as I'm doing it, I always... make little notes in the side (physically gestures to show this point), what the issues are... so, as they come up, to remind you, to make sure that you address those I suppose within the body of the report. Um.. so that's how I would.. do an investigation."
> (investigator B)

Relatedly, a kind of 'pre-investigation' feeds into an internal 'panel decision process'[9] – to collaboratively decide whether to officially declare, conduct, and report a full Serious Untoward Incident investigation. A brief narrative understanding is also important for this 'precursor' stage (regarding the patient harm, and what went wrong to cause it). An example of the initially panel-driven investigation process is given by investigator A:

> "so if we just took a story to panel and said 'well we gave the wrong drug', and the panel will say, 'well what drug? what was the consequences of the drug? what was the impact for the patient?' (hypothetical investigator response:) 'well we don't really know..', they'd say 'well go away and find out, we can't make a decision..' "
> (investigator A, the 'decision' here is whether to officially declare, conduct, and report a full Serious Untoward Incident investigation)

To help determine what went wrong, the events of the incident may be compared with normative practice – in the form of organisational policies or standards for example. This kind of comparison allows an understanding of some of the apparent *omissions*, or *mistakes* made in the care actually given at the time. An example from investigator A describes an important aspect of one particular investigation:

[9] The precise details of how this panel process works was being changed at the time of the interview study.

> "So probably, most of the time, they would *correctly* select the right drug out of the back of the robot. But on this occasion, it didn't happen. So I thought that was important to bring out, because I don't think they'd realised how far they'd deviated away from '*the norm*' – which was 'we rely on the robot to deliver the tablet'."
> (investigator A, here the 'robot' refers to a semi-automated drug dispensing machine in use at a pharmacy)

5.4.2 Theme B: Searching for the root cause of what went wrong?

To avoid, prevent, or reduce the chance of harm to the patient, the 'analysis' part of investigation consists of a loosely defined search for what went wrong. In particular, the focus is on ultimately arriving at a/the 'root cause' (this was always referred to in the singular, and never in the plural form by both interviewees).

Figure 5.3 presents one shared incident causation model the investigators are working under. It was not possible to elicit clearer conceptualisations beyond this level of detail in the interviews.

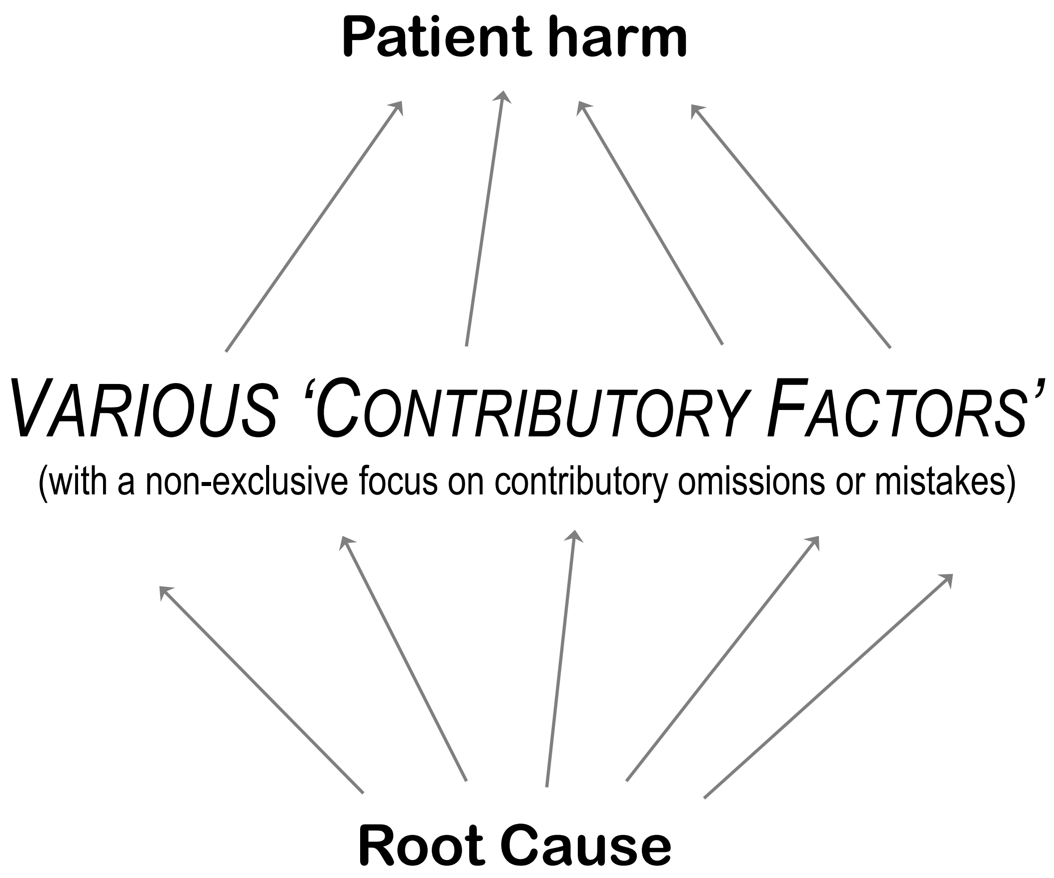

Figure 5.3: A sketch of one incident causation model the investigators are working under. The arrows represent a loose 'causes' relationship.

The search for this root cause is not always straightforward in practice however. For example, investigator B gives an account of when the collaborative 'root cause finding' process may prove to be challenging:

> "And sometimes it just gets you to a point, especially where you're *caught* between two opposing clinical teams, that have got two very different opposing views. You know, you might.. you know.., You could say to me: 'no you did the wrong thing', and I could say: 'no, *you* did the wrong thing'... and you're caught between the middle, because you can't.. – you might not have the knowledge.. the intricate knowledge.."
> (investigator B)

Intuition may also be necessary, to probe beyond the initial accounts of incident participants to get at this root cause:

> "... you've got to have a bit of a *feel* for it – definitely; and maybe that's where that curiosity comes in as well..? Because you *could* accept what people tell you at face value, and not probe any further, but I don't think you'd always get *anywhere near* the root cause then. I think you got to have that ability to sniff it out, like a blood hound."
> (investigator A)

It is worth noting that while the general idea seems to be to search for a root cause leading to the patient harm, there is also a recognition of the multifactorial aspect of incident causation (as shown by the 'contributory factors' in the middle of Figure 5.3). For example, in one part of the conversation about his practice, investigator A draws a parallel with a plane crash incident – touching on some of its potential 'contributory factors':

> "What was it... you'd want to unpick it, wouldn't you, you'd want to say, was the pilot.. was he ok? did he have a heart attack? was he stressed, was he drinking? you'd want to know all those things... What were other people doing, and did they notice anything? you know... if you put it in that sort of context, it's not sufficient to just know the *what*, but it's really important to know the *how* and the *why*."
> (investigator A)

Investigators at the Foundation Trust have only recently been asked to evidence the methods they use for incident investigation. The choice of specific method is however left to the discretion of the individual investigator. This may reduce the level of standardisation between the investigative outputs obtained, in searching for the root cause of what went wrong.

5.4.3 Theme C: A grounded basis for investigative inference

Both investigators believe that investigation must be based on the 'facts' of the incident. In addition to the factual timeline, investigator A notes that the:

> "analysis stage should come at the end, when you've got all the facts, otherwise you might be analysing something that's incomplete."
> (investigator A)

In discussing some of the documentation limitations he faces, investigator B also notes that:

> "So you're trying to make a *rational*.. decision, not based on all the evidence that you could possibly have, so it does make it really difficult... Because you can't.. just make it up, you know.. You've got to *base* it on something.. [...] And I think in *all* our reports, we say that it's factual, you know"
> (investigator B)

For these incident investigators, such 'facts' are inclusive of 'normative items' – such as declared policies, normal practice etc. These are in addition to more obvious primary sources for supporting incident investigation (e.g., patient observation notes, staff interviews).

Sometimes it can be difficult to reconcile this 'factual' basis for incident investigation, and the need to find the *root cause* of what went wrong (Theme B), with the seemingly reasonable clinical judgement(s) made at the time.

> "..it's difficult, because.. These [incident investigation] reports are supposed to be based on what we know to be true – *fact*; but clinical judgement for sure comes into it. And if somebody's given.. if somebody's given documented rationale for a *reason* – for clinical judgement, then.. you know, it.. and their rationale seems to be the correct way of thinking at the time, then they've gone with the best of intentions; *although*.., in hindsight, this was probably an error of judgement. We've done that before – and written that. Because sometimes you don't have a... you can't come up with a.., you know.. somebody has done something with the *very best* of intentions."
> (investigator B, almost certainly referring to not being able to come up with a *root cause* towards the end of this quote)

> "Because what I find quite a lot, is that the consultant group will try and bamboozle you with *academic papers* – they'll say, 'I made that decision, because..' and then they'll pull it up on their laptop, and they'll say: 'see, this is the latest research..!' And I'll say: 'that's fine, but what's our Trust's current policy, and what guidance do *we* follow? ok, did you follow that guidance?' ..."
> (investigator A, in discussing how he probes incident participants about departures from formal organisational policy during the incident)

5.4.4 Theme D: Meeting the challenges imposed by time, resource, and knowledge limitations

Both investigators conduct investigations alongside other 'day jobs'. And one significant shared concern is in managing the substantial time and resource constraints on their work. For example, investigator A comments that "if there were *more* of us doing [incident investigation], we could probably have a better quality product at the end of the day". Figure 5.4 illustrates investigator B's perception of the multitasking/juggling entailed by his work situation, and its routine ebb and flow.

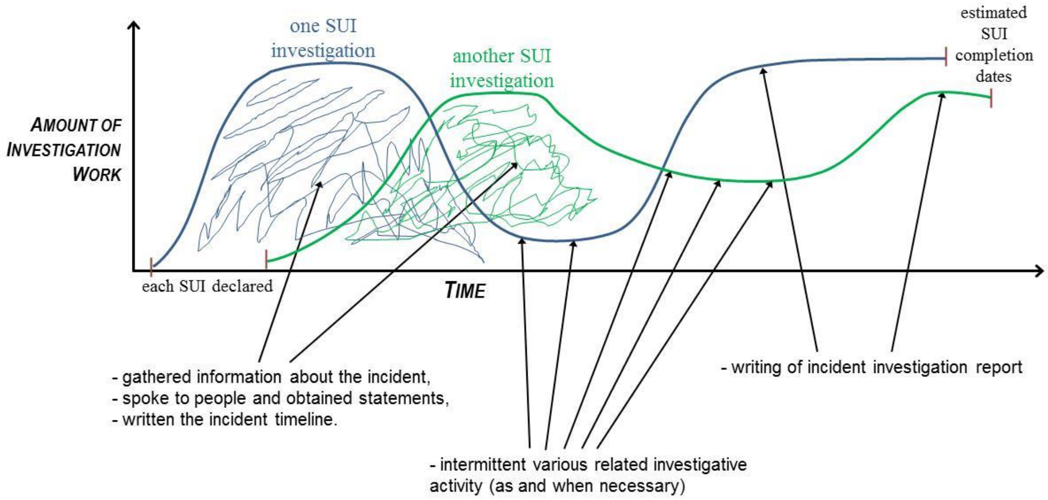

Figure 5.4: An annotated sketch of the interleaved management of multiple patient safety incident investigations (adapted from the original sketch by investigator B, based on corresponding parts of the interview data).

The national '45 working days' limit for completing each investigation is a significant concept in shaping the conduct of investigations. In the interview, investigator B reveals that flexible work patterns for, and between the three 'main' investigators are sometimes necessary, to get the job done in time. For one particular incident situation, the same incident investigation was led by all three of the 'main' investigators working at the Trust at different points in time (investigators A and B were two of these three investigators). Time pressures may also sometimes significantly shape when or how an incident investigation concludes, as the following quote shows:

> "so sometimes, my curiosity – I might hold back; because I might think: ok, I think I've got to the root cause there, or I think I've got/uncovered that, but probably, if I spent another week, I might uncover a lot more."
> (investigator A)

In addition, knowledge limitations are a significant challenge to investigative practice. Reasons for this can range from limitations in the documentation,

> "... in *every* single Serious Untoward Incident investigation, there'll be an element of poor documentation, I would imagine.."
> (investigator B)

to a lack of more specialist knowledge:

> "So what happens there – the basic questions, but the pharmacist *knew* the layout, and the workings; so she had a different view, so she was able to help and support; because it's very *hard* to construct – it's a bit like you

> trying to write the report from scratch, and thinking: 'I don't know the context, I don't know the environment, I don't know which questions to ask..' You *could* argue that's a *good* starting point, but it's a harder starting point – do you know what I mean..?"
> (investigator A, whilst explaining one aspect of the working relationship between him and a collaborating 'specialist investigator from a medical speciality'; such a 'specialist' may sometimes drive the direction of the investigation)

To an extent, such knowledge constraints directly conflict with the need for an investigation to be based on 'facts' (Theme C).

One way to address some of these practical challenges is to devolve some of the investigative responsibilities to 'sub-investigators' from a relevant speciality.

> "... and sometimes it's decided actually at the panel, the *best* person to investigate this will be – person X or person Y, or... yeah, because sometimes it's quite clear who needs to investigate it."
> (investigator A, the 'panel' here refers to the decision panel discussed earlier)

In such a case, the investigator then takes on a much more managerial/supportive role, leaving the bulk of the concrete investigative activities up to the individual 'sub-investigator'. However, such sub-investigations may not always be satisfactorily conducted/completed. A pragmatic attitude is taken towards the specifics of investigation practice. For example, investigator B notes that the proposed responses must be both *achievable* by the organisation, and *measurable*. Both 'actionability', and sufficient incident understanding, are sometimes used as heuristics for concluding a particular incident investigation:

> "and I guess ... it's a judgement call really, as to.., sometimes whether you *feel* you've answered the question. Whether you *feel* you've arrived at what was the cause, what was the *root cause*. Can you keep on digging, you know, have we uncovered enough... And sometimes, if I'm being honest, it's time pressures; if I've got three other investigations that are due in the next 3 weeks, and I've not even started them yet, there's only so much I can spend on this one. If I feel I've got to the *key players*, they've given me a statement, I've unpicked what's happened, I can understand what's

happened, and I can make a series of recommendations, I'll probably stop there. So sometimes I guess it's a bit of pragmatism as to..."
(Investigator A, the 'question' to be answered probably refers to Theme A: relating to what went wrong)

Alongside the substantive practical challenges imposed by time, resource, and knowledge limitations, both investigators explicitly recognise that some of their past investigations can be 'wrong' to an extent – and be potentially improved, or be reasonably done differently. This indicates a reflective, pluralistic attitude to investigative process. It also suggests that outputs from these investigations should not be treated as the 'final word' on understanding and responding to an incident; but instead as a 'best effort' – given the practical circumstances constraining the investigation work.

"... And I don't know that we always get it right.., we may not get it right ..."
(investigator A)

"... and I'm not saying that you get it right every time, I'm sure you don't.., I'm *sure* you don't. And sometimes you know.. we get unstuck with that I'm sure, um.. because we *failed* to see things, and.. *You don't see things the same do you*: so if you and I were to do an investigation, you would probably do a very *different* investigation than I would, and that's your own ..."
(investigator B)

5.4.5 Theme E: A humanistic approach to incident investigation and reporting

Both investigators take an empathetic and sympathetic starting point, in conducting their work. For example, at one point investigator A describes his consideration of how some work demands could potentially be unreasonable, and help explain the incident occurrence (as a hypothetical situation in this case):

> "So again that was.. had we expected too much of her? Had somebody phoned in sick, and they said well you can do 2 hours worth.. you know if the error had happened at the end of that two hours, as an organisation we'd feel pretty bad about that. And in that situation, that's when you say actually, the *individual*, there are.. reasons, why she's *maybe* being tired. Because we've expected too much of her, because it's *beyond* what we said she should do.."
> (investigator A, in talking about reasonable normal expectation for a pharmacy prescription checker)

In terms of the investigation and reporting process itself, the patient forms the substantive focus. Investigator B describes the following idealised incident investigation report:

> "What makes it 'great' is it's got all the key elements in.. [...] well they've identified the right people to speak to – who are involved... They've put the right information in there, and given a really good detailed description of what happened to the patient, in terms of you know.. 'Mrs. X came into hospital on..., she had a chest x-ray, it wasn't acted upon. The reasons it wasn't acted upon were ...... ' you know; And then, obviously identify the errors that occurred during that patient journey, the *root cause*, and then the recommendations ..."
> (investigator B)

And investigator A describes how he always tries to write the report from the perspective of the patient:

> "So you.. I guess it's... maybe I can't really put it into words as to *how* you would synthesise.. the whole [incident] analysis into the conclusions [of the investigation report], but you try and write the report from.. I personally always try and write it from the point of the person receiving the report – the patient, or their family, to say: 'what would I *want* to know, *in words that I can understand?*'
> (investigator A)

Due to resource constraints, it is sometimes necessary for an investigator to play the role of 'family liaison' and 'patient advocate', in addition to their role as 'objective incident investigator'. This can lead to basic conflicts in fulfilling the partially contradictory responsibilities of these multiple roles; and thus confound the investigators' efforts to implement the 'objective investigation' approaches promoted and portrayed by healthcare policy stakeholders, in the form of policy documents for guiding patient safety incident investigation (cf. Dechy et al. 2012).

5.5 Study limitations

Only two patient safety incident investigators from one Foundation Trust were interviewed, and a single qualitative analyst conducted the data analysis. Similar studies with investigators from other healthcare settings would therefore give further insight, into the extent to which the five significant concepts identified in Section 5.4 *transfer* to other research contexts (cf. Graneheim and Lundman 2004). Like in Iedema et al.'s (2006b) analysis of a 1-hour Root Cause Analysis meeting, the limited contact time for the two research interviews here is an important qualification to bear in mind, in interpreting and using the themes reported.

Despite these limitations however, the current study adds to the nascent, piecemeal, and growing evidence base on *how* patient safety incident investigation is actually practiced (e.g., Braithwaite et al. 2006, Tamuz et al. 2011, Wu et al. 2008, Nicolini et al. 2011). In focusing specifically on the *conceptual aspects* driving this work process, an initial answer is provided to the novel research question posed at the outset of the study, of:

> *What are the significant concepts for patient safety incident investigators in their investigative practice?*

Given that the two investigators interviewed formed two-thirds of the frontline investigation team at the Foundation Trust, the analytic narrative reported in Section 5.4 may have broader implications for the Trust's incident investigation practice. Given the currently limited empirical evidence base on patient incident investigation practice, however, further research is needed before conclusive arguments on the benefits and drawbacks of their current incident analysis and investigation practices can be made.

5.6 Conclusions

This chapter presented an inductive study of significant concepts driving patient safety incident investigation practice. An explicit study of the concepts driving patient safety incident investigation practice has not been attempted prior to the study reported here.

This chapter therefore contributes a new research question. In successfully answering this question, we have also shown that Braun and Clarke's (2006) version of thematic analysis can be used to productively analyse the conceptual motivations driving incident investigation practice.

From the interview data, the five themes identified show that for the two investigators interviewed:

- Incident investigation work is very much a "pragmatically rational" process, often conducted under conditions of high uncertainty, and a largely unknown degree of completeness in relevant knowledge of the particular situation (cf. Lundberg et al. 2010).

- A grounded, 'fact-based' search is crucial to these investigators and their incident investigations, to determine the *root cause* of what went wrong to cause significant patient harm (**Themes A, B, C**). This analysis rationale is however tempered by both the substantive time, resource, and knowledge limitations of an investigative situation (**Theme D**), as well as the investigators' naturally humanistic approach to incident investigation and reporting (**Theme E**, explainable by both investigators' nursing backgrounds).

- For the two investigators interviewed at least, their main focus is *not* on analysing how *systems* of information representation and coordination form during incidents, or on any of the three major alternative conceptions of *system* proposed in the general systemic incident analysis literature (compare **Themes A, B,** and **C**, with Section 2.3). There is no obvious focus on issues of how *communication* or *cognition* during incident situations lead to the emergence of *natural information systems*, in the analysis and investigation practice identified. This suggests a niche for the Information Safety Method, in practice, as a means of opening up new avenues of productive analysis and inquiry during patient safety incident investigation.

As a whole, the experiences and data from the current study suggest that mixed rationales are in operation in patient safety incident investigation practice. In conducting their incident analysis work, the two incident investigators interviewed draw on both the belief that there *is* a *single*, *ultimate cause* to be uncovered (e.g., **Theme B**, Figure 5.3), alongside the conflicting belief that such a *single cause* is impossible to determine practically (e.g., **Theme D**). The monocausal assumption of a single main cause seems to be only partly rejected as a basis for incident analysis for these two incident investigators, despite the full rejection of the monocausal ‘root cause’ assumption by the safety scientific research community at least since 1995 (cf. Section 2.2.1; Stoop 1995 for example). This conceptual conflict seems to be only one part of the complex mix of ideational and practical concerns and pressures surrounding the systemic incident analysis research-practice gap (Section 2.6). In this particular study, five concepts have been identified to significantly drive incident analysis and investigation, in the nascent area of patient safety practice.

Detailed empirical understanding of the interrelation between investigation process, and the broader organisational context in which this work occurs, is currently in its infancy. Examples such as Nicolini et al. (2011), Lundberg et al. (2012), and Drupsteen and Hasle (2014) are starting to open up our nascent understanding of this growth area of empirical research, both in patient safety and beyond. Through its design and findings, the study reported in this chapter contributes towards furthering our developing understanding of this issue; focusing on the qualitative-conceptual aspects of doing incident analysis in the case of this chapter.

Chapter 6 – A new method for relating incident analysis research theory to its practice

The small interview study of Chapter 5 further confirmed the need to build bridges between systemic incident analysis research and practice. To better understand the conceptual and other challenges which may arise in the move from systemic incident analysis theory into practice (Aim B, Objective 4), this chapter:

- Develops a new research method, to support empirical analysis of the point at which systemic incident analysis research theory becomes practice
- Gives detailed insight into how systemic incident analysis methods are enacted in practice
- Provides a general way of characterising how particular methods *constrain* or *afford* elements of real investigation practice

6.1 Introduction

The literature review in Section 2.6 showed a substantive and complex gap existing between systemic incident analysis research theory with its practice. Little knowledge yet exists, on exactly *how* systemic incident analysis research theory is enacted by practitioners, and the extent to which it is in fact enacted at all as part of real incident investigation. This was reinforced by the interview study reported in Chapter 5. Part of those study findings suggest that the investigators' practice are not really strongly influenced by contemporary incident analysis research theory (e.g., **Theme B:** *Searching for the root cause of what went wrong?*). There was little evidence of either the concepts or methods from mainstream systemic incident analysis research having any substantive influence on the practice of the patient safety incident investigators interviewed.

To better understand the move from theory into practice, in this chapter we develop a method for detailed characterisation of the relationship: between the theoretical and practical elements of systemic incident analysis. This new method explicitly relates the abstract theory of the chosen method to its concrete practice during incident investigation. It is called the **Systematic Reanalysis Method**.

The next section discusses the notion of *constraint* and *affordance* of theories of systemic incident analysis when used in practice. This forms the theoretical basis of the Systematic Reanalysis Method.

6.2 Understanding systemic incident analysis methods in terms of their *methodological constraints* and *methodological affordances*

Many kinds of contextual factors, such as psychological, group-based, and organisational ones, could potentially shape the behaviour of participants of the systems under investigation (e.g., see Reason 1990, Johnson 2003a). Many of these factors may also shape incident analysis process, since incident investigators are also participants of the systems they investigate (cf. Drupsteen and Hasle 2014). Like the participants of the systems investigated, investigators are also fallible. In attempting understanding of a new incident situation for example, it is possible that an investigator may not *representatively* recall the most relevant past incidents and factors worth reconsidering for the current situation (cf. Kahneman 2003).

Given the intimate interrelation between investigative process and the object of incident investigation, it is natural to inquire about the extent to which particular aspects of incident investigation are attributable to a particular systemic incident analysis method. To start clarify the relationship between a particular method and its notional effects and outputs, we need a general way of explicitly discussing *how* the theoretical abstractions of the method (e.g., as embodied through Canadian Patient Safety Institute et al. (2012)) relates to its actual practice as part of real incident investigation. In this and the next chapter, we will use the term '*manual*' to refer to the tangible guidance for the systemic incident analysis method. The Canadian Patient Safety Institute et al. (2012), and Hollnagel (2012), are both concrete examples of such guidance.

The notion of ***constraint*** has been previously utilised by Nancy Leveson, in the form of *safety-**constraints*** imposed by systems of socio-technical control (cf. Section 2.3.3, Leveson 2011). The **Systematic Reanalysis Method** we develop in this chapter provides a way to consider the specific ***constraints*** methods impose on investigation process, and how they consequently limit investigative behaviour (to reduce the degree of behavioural freedom that may otherwise have been possible). These limiting aspects are referred to as the **methodological constraints** of a particular method.

The converse of such ***constraints*** on investigation methodology, are the behaviours actively encouraged by a systemic incident analysis method. These are referred to as its **methodological affordances**. The notion of ***affordance*** refers to a set of perceived or actual action possibilities predicated on a particular environment, situation, or artefact (cf. McGrenere and Ho 2000). Here, we consider the ***affordance*** of systemic incident analysis methods and their manuals. In particular, a Systematic Reanalysis Method analysis considers which investigative ***actions*** and ***findings*** are explicitly or implicitly encouraged by a systemic incident analysis method.

Figure 6.1 presents the workflow in using the Systematic Reanalysis Method. As is common in qualitative data analysis, these steps in practice are unlikely to be quite as linear as suggested by the figure.

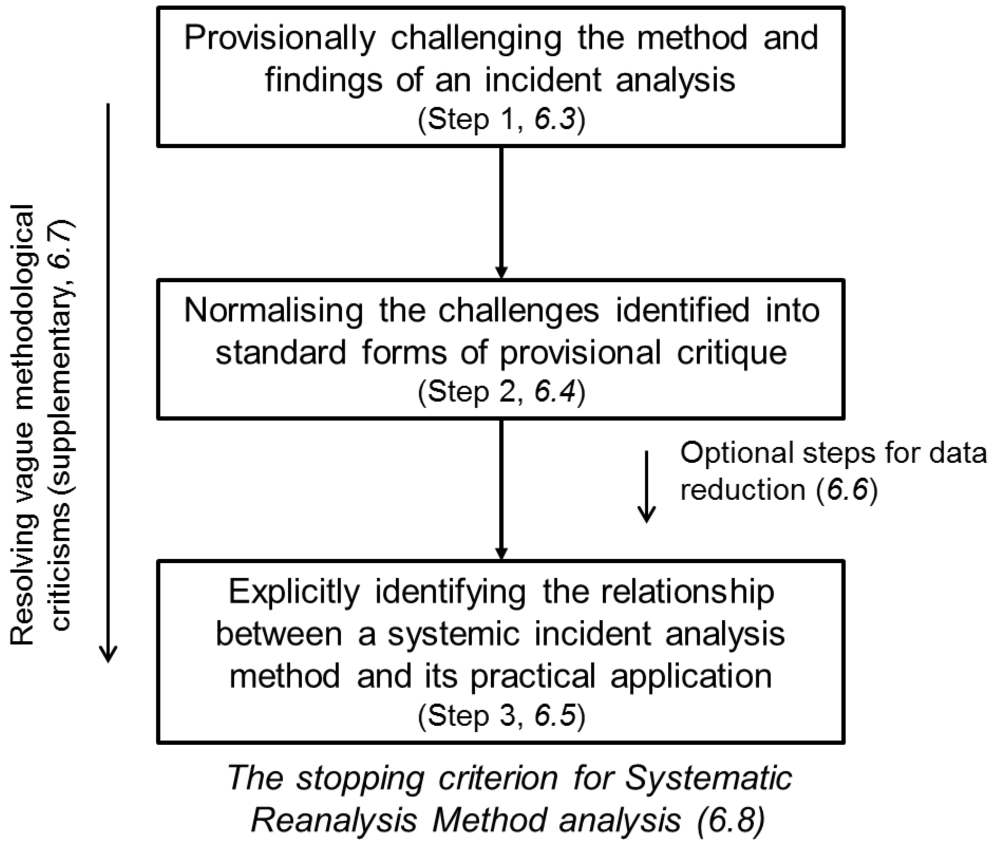

Figure 6.1: The workflow in moving between different parts of doing a Systematic Reanalysis Method analysis.

6.3 Step 1: Provisionally challenging the method and findings of an incident analysis

The Systematic Reanalysis Method analyst starts by critically inspecting and comparing the *actions* and *findings* from an actual incident investigation against the guidance for the chosen method. While inspecting the record of the investigation enacted, the analyst challenges the validity of the enacted investigative actions and findings, provisionally. Potential **methodological criticisms** are raised, based on closely reading of the account of the incident investigation. Such criticisms are contingent on later confirmation, refutation, and/or elaboration, as part of the ongoing systematic reanalysis. These critiques may relate to the validity of both:

1) the investigative *procedure* followed, and/or
2) the validity of particular investigative *findings* obtained.

The analyst's preferred means of recording and notation should be used at this initial stage. The critical challenges raised by a Systematic Reanalysis Method analyst may be about 'omissions' during investigation (i.e., actions that were *not* done, and/or things that were *not* found). These challenges may also be about various 'commissions' (i.e., things that *were* done/found). A challenge to the *method* of investigative analysis is 'action-based' – regarding the particular part(s) of a manual used to support the incident investigation for example. An example of a 'finding-based' challenge may be about the *type* of investigative findings actually obtained through utilising the chosen method of investigative analysis.

6.4 Step 2: Normalising the challenges identified into standard forms of provisional critique

After identifying an initial set of methodological criticisms, the Systematic Reanalysis Method analyst reviews and rephrases each of them, to fit with one of the three standard phrase templates presented below:

1. "*The investigative choice(s)* **<?>** *was/were invalid* ", or
2. "*The investigative finding(s) obtained* **<?>** *was/were invalid* ", or
3. "*The investigative choice(s)/finding(s)-obtained* **<?>** *was/were invalid*".

The third template is for when a particular part seems to relate to both the method of investigation and the investigative finding(s). **<?>** denotes where a rephrased methodological criticism should be inserted, to fit within each of these templates. These three phrase templates are intended to normalise the critiques generated initially, in preparation for subsequent comparative analysis (described in the next section). A concrete illustration for the second phrase template could be: "*The investigative findings obtained* **<of five findings per 'cause category'>** *was invalid*". If such a provisional challenge holds, based on closer inspection of the account of the incident investigation and its chosen manual, then 'more valid' courses of investigation could have been taken with respect to the chosen method.

The three phrase templates above are intended as a focusing device for the Systematic Reanalysis Method analyst – to clarify the specific nature and scope of each criticism raised. In these templates we refer to investigative *actions* only *indirectly*, through the particular *choices* made in incident investigation (for example regarding the kind of incident data to collect). This was a deliberate design choice for the Systematic Reanalysis Method, because the appropriate level of granularity for examining investigative *actions* is not obvious. These 'choice points' are where the incident investigation could potentially have taken a substantively different course. These choices are also arguably more important to examine than the consequent investigative actions, for the purposes of enriching our understanding of *how* methods are applied during incident investigation.

6.5 Step 3: Explicitly identifying the relationship between a systemic incident analysis method and its practical application

The Systematic Reanalysis Method analyst has by this point decided on a specific set of methodological criticisms, to be assessed explicitly against the chosen manual. The analyst has also determined the order in which these criticisms will be compared against the manual in turn (e.g., through the optional steps presented in the next section). The account of the investigation is now compared explicitly, against the chosen manual; in order to systematically understand the validity of the investigation done *with respect to the chosen method*. Analytical understanding of the chosen method is thus gained, and expressed in terms of the *methodological affordances* and *methodological constraints* of the manual.

Concretely, the actual investigative *choices* and *findings* encapsulated within each of the critiques raised may be resolved into one of three mutually-exclusive possibilities:

as **constrained**, **strongly afforded**, or **weakly afforded** by the manual. This is done using the three definitions below:

- The **constrained** *choices* or *findings* are those where the investigation is unambiguously contradicted by the manual. This is where the manual does not offer methodological support *for*, but only explicitly *against* the investigation as done.
- The **strongly afforded** *choices* or *findings* correspond to the converse situation, where the chosen manual only offers support explicitly *for* the investigation as done. When a **strongly afforded** analytical assignment is made, the particular *criticism* initially raised is judged to be an *invalid* critique, based on detailed examination of the manual used.
- Finally, the **weakly afforded** *choices* or *findings* correspond to the situation where the manual used apparently offers *contradictory*, *underspecified*, or *otherwise ambiguous* guidance. These highlight parts of the manual where users are less likely to be able to faithfully follow the methodology prescribed.

Due to potential ambiguity in understanding what ought to be done according to the chosen method, the **weakly afforded** areas of a manual are less likely to be dominant, in shaping the development of an incident investigation. These **weakly afforded** areas also partly contradict the normalising and standardising role of systemic incident analysis methods, in a sense. In the face of unintended methodological ambiguity, more *ad hoc* investigative solutions may *necessarily* dynamically develop for the investigators, as they fall back to operating at a more knowledge-based level (Rasmussen 1983). They may intuitively resort only to more familiar strategies and operations (cf. Rasmussen and Jensen 1974), with little tendency to pause, backtrack, or develop alternative or parallel paths of reasoning. Such unpredictable investigative solutions could sometimes conflict, with the more idealised aims of the chosen method (cf. Lundberg et al. 2010, Tamuz et al. 2011). These points of **weak affordance** may only minimally influence the actual course of the investigation, and also indirectly enable a stronger impact from the many other contextual factors shaping its course.

We need to note a caveat about these points of **weak affordance** however. Since systemic incident analysis methods are designed for use as part of contingent practice situations (e.g., incident investigation), *intentional underspecification* in describing and presenting the method is often necessary and helpful. This underspecification serves to maintain a usable degree of flexibility of method. Like any ‘rules’ for people to follow, the normative guidance of manuals may sometimes be followed in practice only partially for good reasons (cf. Rasmussen 1997, Leveson 2011, Hale and Borys 2013); due to limitations of time, resource, and knowledge for example. Forms of ambiguity of methodology relating to *contradiction* seem less desirable, however.

Figure 6.2 complements the current text: to visually depict how notions of *constraint* and *affordance* are extended to analysis of investigative methodology, as part of the Systematic Reanalysis Method. It illustrates the extent to which parts of *actual*, and *potential* investigations are classified as supported by a particular method. Light-grey arrows indicate hypothetical courses of investigation which may in principle have been taken using the chosen method, but were not taken in the case of the actual investigation.

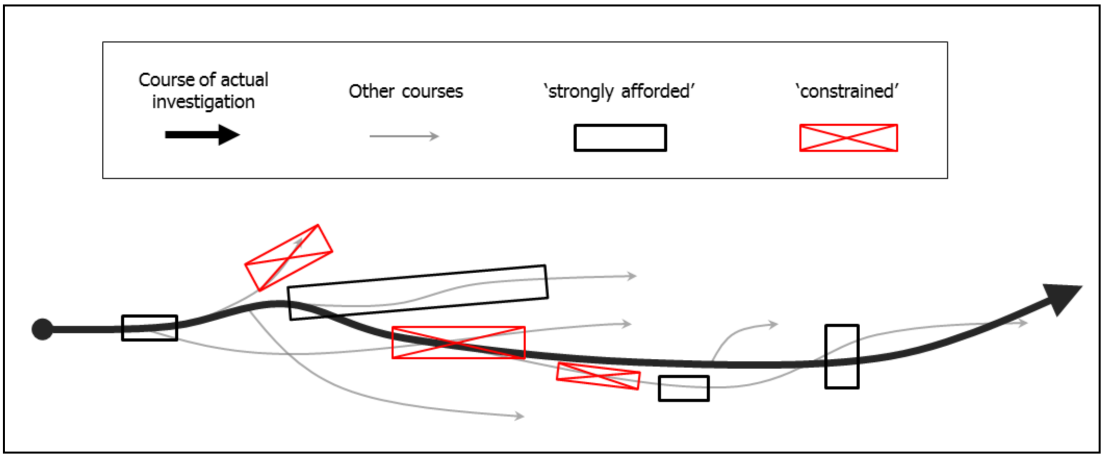

Figure 6.2: A visual depiction of how *actual* and *potential* courses of investigation may be **strongly afforded**, or **constrained** by a particular method. The **weakly afforded** parts are the various other potential courses of investigation unmarked by any box.

In conducting this part of the systematic reanalysis, the analyst should fully search the chosen manual for guidance relevant to the particular criticism under consideration. This should be done regardless of the portions of the manual originally used for enacting the investigation. In doing this, the systematic reanalyst minimises the likelihood of missing relevant guidance distributed throughout the manual, in multiple, and possibly non-contiguous places for example. Detailed reasons and discussions should be recorded to support the specific assignments of **constraint** or **affordance** made at this point. These reasons and discussions should explicitly refer to both the chosen manual, as well as parts from the account of incident investigation using the manual.

6.6 Optional steps for data reduction

Data reduction is an integral part of qualitative data analysis (Miles and Huberman 1994). This refers to the process of selecting, focusing, simplifying, abstracting, and transformation of the original data (in the form of field notes, transcriptions etc.). Data reduction is not a process separate from that of qualitative data analysis, but a transformative process which continues through and after the fieldwork, until a final report is completed. Two optional strategies are presented in this section for doing data reduction using the Systematic Reanalysis Method. These options are to be considered in case of limited time and resources for doing the systematic reanalysis.

6.6.1 Annotations to support (further) qualitative data reduction

When resources for supporting the reanalysis are limited, two independent sets of annotations may help the analyst further decompose the set of critiques and challenges initially identified, to inform which ones to prioritise for further analysis. These annotations reduce the set of methodological criticisms into more manageable subsets, to enable systematic prioritisation based on the analyst's particular interests and concerns.

The first set of annotations correspond to the three phrase templates prescribed in Section 6.4. The analyst annotates each criticism according to whether it is specifically about:

1. the *investigative procedure*,
2. *investigative findings*,
3. or potentially relating to both *investigative procedure and findings*.

The second set of annotations sort the criticisms identified according to whether they seem *general* or *specific*. *General* criticisms could undermine the validity of a significant portion of the investigation, if found to be evidenced and sustained by the chosen manual. *Specific* criticisms are ones judged to have only a localised potential effect on the validity of the investigation, if found to be evidenced by the manual. The precise point at which a particular criticism becomes *general* rather than *specific* is left to the discretion of the analyst. A *general* criticism may be about the data collection strategy used throughout an entire incident investigation, for example.

These two sets of annotations can be utilised independently of each other. The *general* and *investigative procedure* related critiques might be explored first, for example, as they arguably most significantly affect how valid the investigation is with respect to the manual. Note that there is no single 'correct' way of annotating the various methodological criticisms identified. These annotations are intended purely as a means for facilitating the comparative reanalysis described in Section 6.5. They are not an end in themselves. To be of most practical benefit in saving time, these annotations should be done largely prior to doing the comparative reanalysis.

6.6.2 Simple random sampling of methodological criticisms

If it is not feasible to exhaustively evaluate every criticism identified, simple pseudo-random processes may be used to control for potential selection bias on the part of the data analyst, whilst reducing the scope of the data analysis. Such pseudo-random sampling may be used either in conjunction with the annotations described in Section 6.6.1, or independently of them.

6.7 Supplemental step: Resolving vague methodological criticisms

In utilising the Systematic Reanalysis Method, ambiguities may arise in how to deal with methodological criticisms that are too general. For example, a broad and rather ambiguous criticism of *"The investigative choices made at all steps were invalid"*, is a coarse-grained and multi-faceted criticism. This kind of critique could be potentially confusing to reanalyse directly. The analyst should instead deconstruct and further unpack such coarse-grained statements, until the resulting 'sub-criticisms' are at a level of detail comparable with only a *specific* part rather than most of the chosen manual. To avoid unnecessary confusion, such clarification of criticisms should be done prior to proceeding with the main, comparative analysis step detailed earlier in Section 6.5.

6.8 The stopping criterion for the analysis

A Systematic Reanalysis Method analysis is finished, once *all* of the criticisms chosen for comparative analysis (Section 6.5) have been assessed in turn. The primary data for this consists of both the manual chosen, together with the account of investigation enacted using the manual.

6.9 Summary

This chapter has motivated and presented the second of the two new methods of analysis developed: the **Systematic Reanalysis Method**. It is a semi-structured qualitative research method, developed specifically for analysing the detailed relationship between a method in the abstract, and its actual practice as part of real investigation. In particular, the comparative analysis of Step 3 (Section 6.5) leads to an evidenced, demonstrable assessment, of the extent to which particular parts of an investigative enactment can be directly related to the chosen method.

Sometimes, aspects of an investigation may be due to *a priori* limitations of the context of investigation. These are situations where investigative choices were inherently lacking – regardless of the particular method chosen. Such 'contextually limited' aspects should *not* be analysed as part of the Systematic Reanalysis Method analysis, since the resulting analysis would tell us little about how the chosen method effected the course of investigation.

As systemic incident analysis methods are used more in future, the Systematic Reanalysis Method may be useful, as part of broader efforts for bridging the gap between systemic incident analysis research theory, and its practice. A crucial point in the journey between theory and practice is empirically examined, through analysing how a chosen method ***constrains*** or ***affords*** particular aspects of investigative practice. The Systematic Reanalysis Method analyst actively challenges the validity of the particular ***investigative actions taken***, and the particular ***investigative findings*** obtained, as a way to critically examine how the chosen theory of systemic incident analysis in fact relates to its attempted practice.

The 'Reanalysis' part of the name emphasises that in principle, the Systematic Reanalysis Method can be used to reanalyse existing accounts of how analysis methods were used as part of a *completed* incident investigation, as a form of secondary research. This usage of the Systematic Reanalysis Method is explored in the next chapter, as part of the analysis of the move from theory to practice within a small scale incident analysis and investigation. The primary account of incident investigation is interrogated using the Systematic Reanalysis Method, to start exploring the actual implications of the new research method for both the theory and practice of systemic incident analysis.

Chapter 7 – Exploring the implications of the Systematic Reanalysis Method

To investigate the empirical implications of the new research method developed in Chapter 6 (Aim B, Objective 5), this chapter:

- Reports on an initial study of the use of the research method, to analyse how systemic incident analysis theory becomes practice in the context of a small scale incident investigation
- Reports on how two researchers conducted independent empirical analyses using the new method
- Explores, illustrates, and discusses the actual implications of the method, for generating new knowledge on issues relating to both systemic incident analysis theory and practice
- Generates detailed research results using the new research method, which could be used to support both the work of method designers, and stakeholders interested in quality assuring the conduct of incident analyses

7.1 Introduction

The last chapter developed the **Systematic Reanalysis Method**, for relating incident analysis research theory to its practice. To start exploring the practical consequences of this method, it was used to analyse the relationship between:

- a systemic incident analysis method from research, and
- its investigative enactment as part of real incident investigation.

The method chosen was a ‘systemic Root Cause Analysis’ method, similar to those reviewed in Chapter 2. Its tangible representation (i.e., the ‘manual’) was the *ISMP Canada (2006)* document. This manual, and the primary account of a real incident investigation done using it, together formed the ***primary data*** interrogated using the Systematic Reanalysis Method.

A study was conducted, where the author serendipitously needed to investigate a small incident situation formally, using a specific, codified incident analysis method. This provided experience of a live, real incident investigation, and the incident situation. Here, the safety researcher (i.e., the author) ‘wore the shoes’ of an incident participant (cf. Saleh et al. 2010, Saleh and Pendley 2012); the author was also the incident investigator here. This experience allowed broader insight into the practical aspects of doing real incident investigation. It also supported a high fidelity primary account of the incident situation (from one of its participants).

The current study focuses on exploring the empirical implications of the Systematic Reanalysis Method. The focus is therefore *not* on the underlying incident situation, nor even the incident investigation *per se*. As such, details of both will only be selectively referenced in the chapter as needed. It is also worth re-emphasising that a Systematic Reanalysis Method analysis does not ***compare between*** two or more ***different*** methods (as in the contributions of Underwood and Waterson (2014) for example). Instead, the relationship being empirically examined here is between the abstract theory of a ***single*** method, and its enactment as part of incident investigation. Here, we explore in detail how *ISMP Canada (2006)* is related, to the incident investigation practice detailed in full in Appendix C.1.

We first briefly overview the incident investigation as done (Section 7.2.1, full details in Appendix C.1). Then, we summarise the two independent Systematic Reanalysis Method analyses of the incident investigation situation, and the subsequent wrap up session based on these analyses (Section 7.2.2). We go on to discuss three different knowledge generating roles emerging for the Systematic Reanalysis Method, and also present feedback from the independent researcher-analyst who used the Systematic Reanalysis Method (Section 7.3). Finally, the main study limitations and conclusions are presented (sections 7.4, 7.5).

7.2 Methods

7.2.1 Overview of the incident investigation done

The incident situation investigated occurred on 10^{th} September 2012. I parked my car and paid for the parking space, but did not display the proof of purchase for the space. As a result I was charged with a *Parking Contravention Charge Notice*. This notice was eventually revoked, after further correspondence with the car park management company.

To understand and explain this incident through systemic analysis, we investigated the situation using the ISMP Canada method (ISMP Canada 2006). This involved gathering incident data leading to both an initial and final incident understanding. Both these incident understandings were then used to analyse the root causes of the situation. This data was derived by personal reflection after the incident, supported by a return visit to the site of the incident situation where photographic evidence was also collected. The related correspondence with the car park management company formed the final part of the evidential basis for the incident investigation. The proximal cause, for commencing the analysis of root causes, was the fact that:

> *'the user (A1) of the car park forgot to display the proof of purchase for parking after paying for the space'*

The investigation took just over 45 man-hours, and was completed by the end of the 27th day after the occurrence of the incident situation. Figure 7.1 shows the final investigative hypotheses developed using the ISMP Canada method, about the causative factors contributing towards the incident situation.

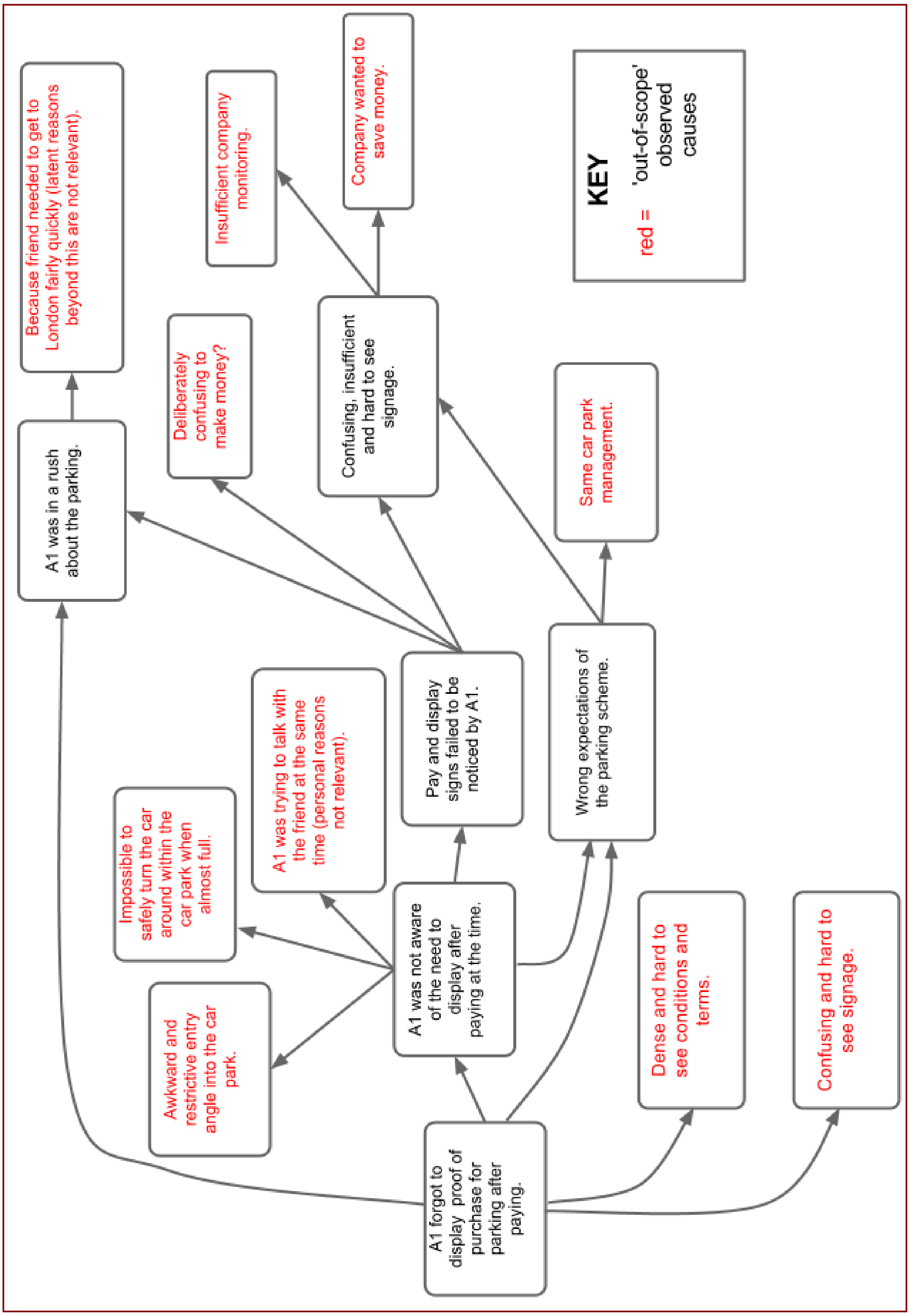

Figure 7.1: Final set of investigative hypotheses about factors contributing to the proximal cause (Appendix C.1, Figure 12). Each arrow should be read as 'caused by' (e.g., *A1 did not notice the pay and display signs*, 'caused by' *A1's rush about the parking*).

On completing Figure 7.1, the investigator judged the analysis of the incident situation to be both sufficiently accurate and complete. The *time* spent investigating, and *speed* of investigative response, were both comparable with contemporary expectations for RCA-based patient safety incident investigations (cf. *NHS Commissioning Board (2013)*, for instance). Unlike the *Serious Untoward Incident* investigations discussed earlier in Chapter 5, no *a priori* deadline was imposed on the incident analysis and investigation done here.

A variety of contributing factors were identified through the investigation. The tree of root causes developed in Figure 7.1 was delimited by the potential scope of future intervention by the incident investigator, as suggested by the ISMP Canada method. In particular, contributing factors relating to the management of the car park was deemed outside the likely capability of the investigator to intervene on. These kinds of factors were explored no further as part of the incident analysis.

The chronological record of the investigation enacted (Appendix C.1) is comparable with the corresponding parts of an independent investigation using the same ISMP Canada method in a patient safety context (ISMP Canada 2007). As Hanks et al. (2002) points out, such concrete investigations are basically two 'instances' of the same theoretical guidance. Since the car parking incident situation was not within a patient safety context, only the *domain-independent* aspects of the ISMP Canada method were used to support the current incident investigation.

7.2.2 A summary of the Systematic Reanalysis Method analyses and subsequent wrap-up study session

Systematic Reanalysis Method analyses were independently conducted by two analysts, of the same incident analysis and investigation situation. I was analyst A, and lead developer of the Systematic Reanalysis Method. Analyst B was another researcher in the same department not involved in developing the Systematic Reanalysis Method. The same basic Systematic Reanalysis Method procedure (as detailed in Chapter 6) was followed in each case. A final joint wrap-up session was then conducted, for the two analysts to jointly talk through and agree on their final determinations of the **constraints** and **affordances** of the ISMP Canada method. This concluding wrap-up session was done after each analyst had familiarised themselves with the other's independent analysis. This final part of the study explored the role of the Systematic Reanalysis Method in facilitating (possibly adversarial) agreement or disagreement between analysts. We briefly summarise these aspects of the study below.

First Systematic Reanalysis Method analysis

Analyst A took around 33 man-hours to analyse the *constraints* and *affordances* of the ISMP Canada method (using the Systematic Reanalysis Method), with respect to the car parking incident investigation. This excluded the time devoted to understanding the manual chosen (ISMP Canada 2006), which was done prior to conducting the investigation. As developer of the Systematic Reanalysis Method, analyst A encountered no problems in applying it. This systematic reanalysis was started around one month after the completion of the incident investigation overviewed in Section 7.2.1.

Analyst A meaningfully analysed 42 methodological criticisms using the Systematic Reanalysis Method. 2 were found to be *constrained*, 8 *strongly afforded*, and 32 *weakly afforded* by the manual used. A small proportion of other criticisms were initially identified by analyst A as not suitable for full comparative analysis (as described by Section 6.5). This was because they were:

- 'contextually limited', representing an *a priori* lack of methodological freedom before the investigation even began (cf. Section 6.9), or
- too vague and broad for useful/practical comparative analysis (see Section 6.7), or
- either subsumed by another critique raised, or duplicating it.

Second Systematic Reanalysis Method analysis

As independent analyst, analyst B took around 24½ man-hours to perform his systematic reanalysis. This included the time taken for him to understand the ISMP Canada (2006) manual, as well as the investigation enacted using it. Both were new to analyst B (who was not involved in the investigation or incident situation). This all took place substantively after analyst A's analysis was completed, forming an independent replication of the use of the Systematic Reanalysis Method.

10 methodological criticisms were initially identified by analyst B. All were then meaningfully analysed. Analyst B found 8 to be *constrained*, 1 to be *strongly afforded*, and 1 to be *weakly afforded* by the manual used. None of these critiques were identical to the ones generated by analyst A, though many were closely related. Analyst B chose not to do the random sampling step (Section 6.6.2), deeming it unnecessary given the relatively small number of criticisms he identified. All other steps of Systematic

Reanalysis Method were followed. Some issues related to the usability of the Systematic Reanalysis Method were encountered by analyst B (summarised later in Section 7.3.4). Analyst B limited his challenges and critiques to the non-healthcare-specific aspects of the ISMP Canada method.

<u>The wrap-up session</u>

A wrap-up session was conducted after the two independent systematic reanalyses. This session lasted just under 1 hour. It was used to discuss and agree on the final joint assignments regarding the *constraints* and *affordances* of the ISMP Canada method. The main outcomes of the session are described as part of Appendix C.2. The discussions focused on talking through all of the stronger claims of each independent data analysis. These claims were the *investigative choices* and *investigative findings* independently coded as either *strongly afforded*, or *constrained*. The two analysts talked through their independent findings in turn, clarifying where necessary; and jointly discussed whether any of their original claims ought to be changed.

Due to the very *explicit* nature of the Systematic Reanalysis Method, both analysts agreed that it was unnecessary to go through their *weakly afforded* assignments. If one analyst had already identified such an ambiguously relationship between the chosen manual and the incident investigation, this was considered to be enough. These originally *weakly afforded* assessments were already based on close reading of the manual. They were therefore unlikely to be transformed into a more definitive assessment: of either *strongly afforded* or *constrained* by the manual.

The certainty of some of the initial assessment of *affordance* and *constraint* were reduced at this point in the overall process: from the stronger assignments of *constrained* or *strongly afforded*, to a more ambiguous categorisation of *weakly afforded* by the manual embodying the method. One critique was also reassigned from *constrained*, to the converse category of *strongly afforded* by the manual; this particular critique is discussed later as part of Section 7.3.3.

7.3 Findings and discussions

Three different roles emerged for the Systematic Reanalysis Method from the study; as a means to generate knowledge to:

1. help understand where an investigation may be improved with respect to the chosen method (Section 7.3.1);
2. help locate areas of potential ambiguity in the manual used (Section 7.3.2);
3. increase our confidence in attributing particular investigative enactments (including findings) to the chosen method (Section 7.3.3).

We discuss and illustrate each of these roles in turn, using concrete examples drawn from the Systematic Reanalysis Method analyses and wrap-up session. We refer to the individual challenges (to investigative method or findings) using the same references as given in **Huang** and Hough et al. (2013c) and Appendix C.2. In the following, notation such as **{AC1}** and **{BC1}** is used to refer to specific critiques. Critiques prefixed with '**AC**' are ones originally raised by analyst A; similarly, ones prefixed with '**BC**' are ones raised originally by analyst B.

The walkthroughs of the following sections serve to illustrate the concrete application of the Systematic Reanalysis Method by independent analysts. They also demonstrate some of the concrete outcomes and implications following from using the method. In the following, ***M***, ***F***, ***G*** and ***S*** denote the investigative **M**ethod/procedure, investigative **F**indings, and the **G**eneral and **S**pecific annotations (cf. Section 6.6.1). 'Subcriticisms' refined from initially vague critiques (cf. Section 6.7) are indicated by using a decimal point, as in **{AC1.1}** for example. In Section 7.3.1, we start by explicitly referring back to particular parts of the Systematic Reanalysis Method presentation (Chapter 6) as we go. We then proceed similarly for sections 7.3.2 and 7.3.3, but omit similar such explicit referencing back to Chapter 6 for succinctness.

7.3.1 Understanding where investigation may be improved

The use of the Systematic Reanalysis Method helped to uncover areas of possible contention in the validity of the investigation done, with respect to the chosen method. In particular, the analysis highlighted areas where the chosen method may be inadequately followed (i.e., an investigative *choice* or *finding* found to be *constrained*). The argument here is that if *one* person strongly doubts the validity of part of the investigation – based on careful and close scrutiny of the chosen method – other investigation stakeholders could reasonably have similar doubts.

In contrast, the *strongly afforded* and *weakly afforded* assignments (of the Systematic Reanalysis Method) effectively refer to where the practice is found to be of adequate validity – with respect to the particular manual used.

In an on-going investigation, it may be sensible to improve the credibility of the investigative process, by addressing the issues raised by these *constrained* aspects where possible. In the final wrap-up session, we explicitly discussed each of the *constrained* part of the investigation with potential improvements in mind. Our discussions identified how the investigation could be further improved, with respect to the manual used and within the practicalities of the particular investigative situation.

Without the detailed and evidenced approach of the Systematic Reanalysis Method, contentions about the validity of investigation practice may have been reduced to less demonstrable differences in opinion in the wrap-up session. Unsubstantiated differences in opinion can be difficult to resolve, especially given the diverse perceptions of the nature, role, and purposes of incident investigation (cf. Stoop and Roed-Larsen 2009, Roed-Larsen and Stoop 2012, and also the various practical challenges identified as part of Section 5.4). The Systematic Reanalysis Method is not intended to be a tool for deriving 'objective knowledge'. In comparison with a simple eyeball assessment however, it offers an evidence-based alternative for assessing and improving the validity of an investigation according to its chosen method(s).

A concrete example relates to the part of the investigation described in {AC46}. This criticism was initially identified by analyst A, from reading a part of the account of the investigation which stated:

> "*Information from Figures 8 and 9 were not included in the consolidated 'causal-tree'* " [Appendix C.1, a-38]

These two figures show two sub-branches of the developing root cause tree, which were 'accidentally discovered' as part of the investigation. These sub-branches explored why the signage used in the car park was perceived to be confusing and hard to see (Appendix C.1, Figure 8), and why the 'conditions and terms' for using the car park was dense and hard to see for the user (Appendix C.1, Figure 9). These are reproduced in figures 7.2 and 7.3:

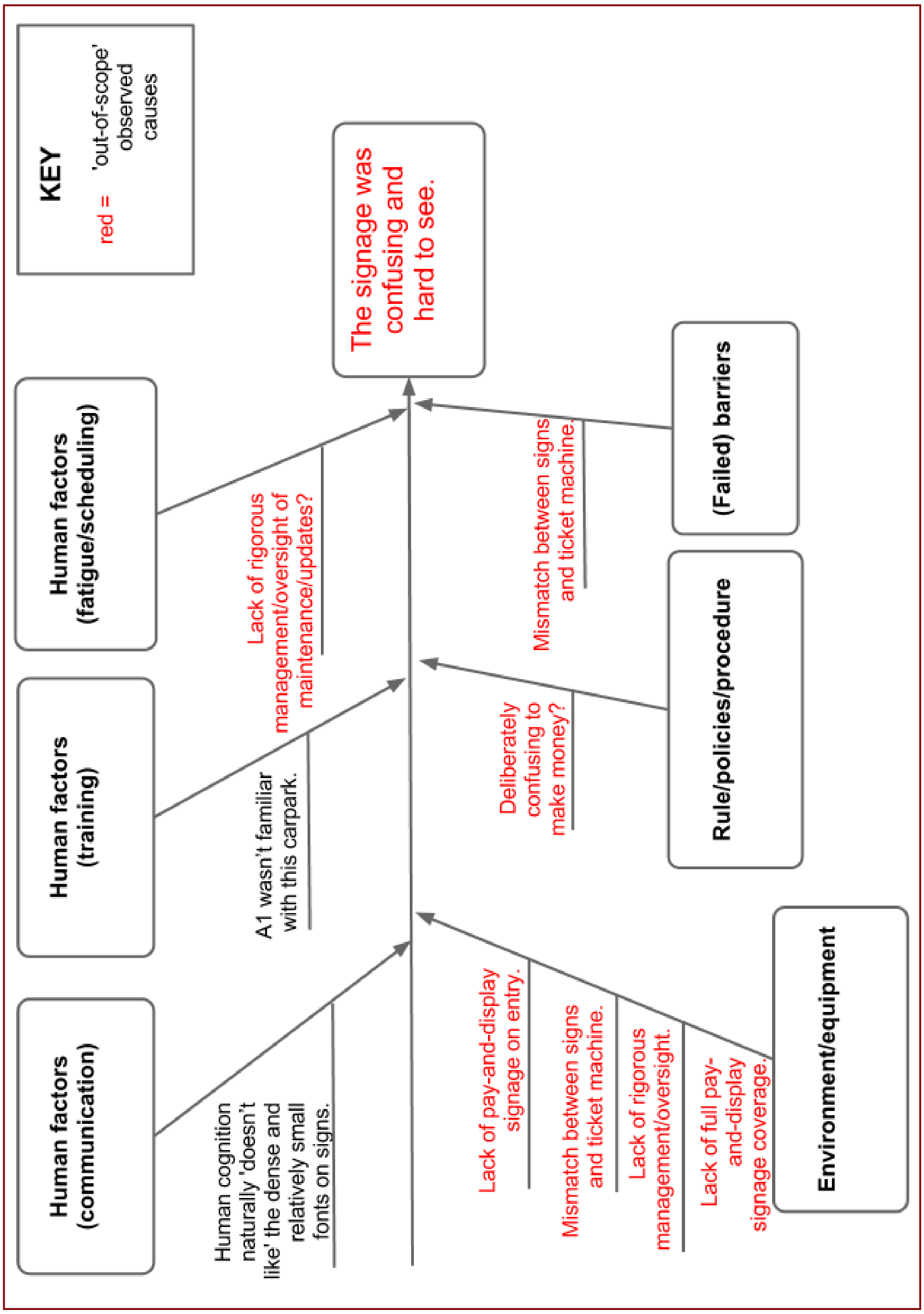

Figure 7.2: Reasons for confusing and hard to see signage.

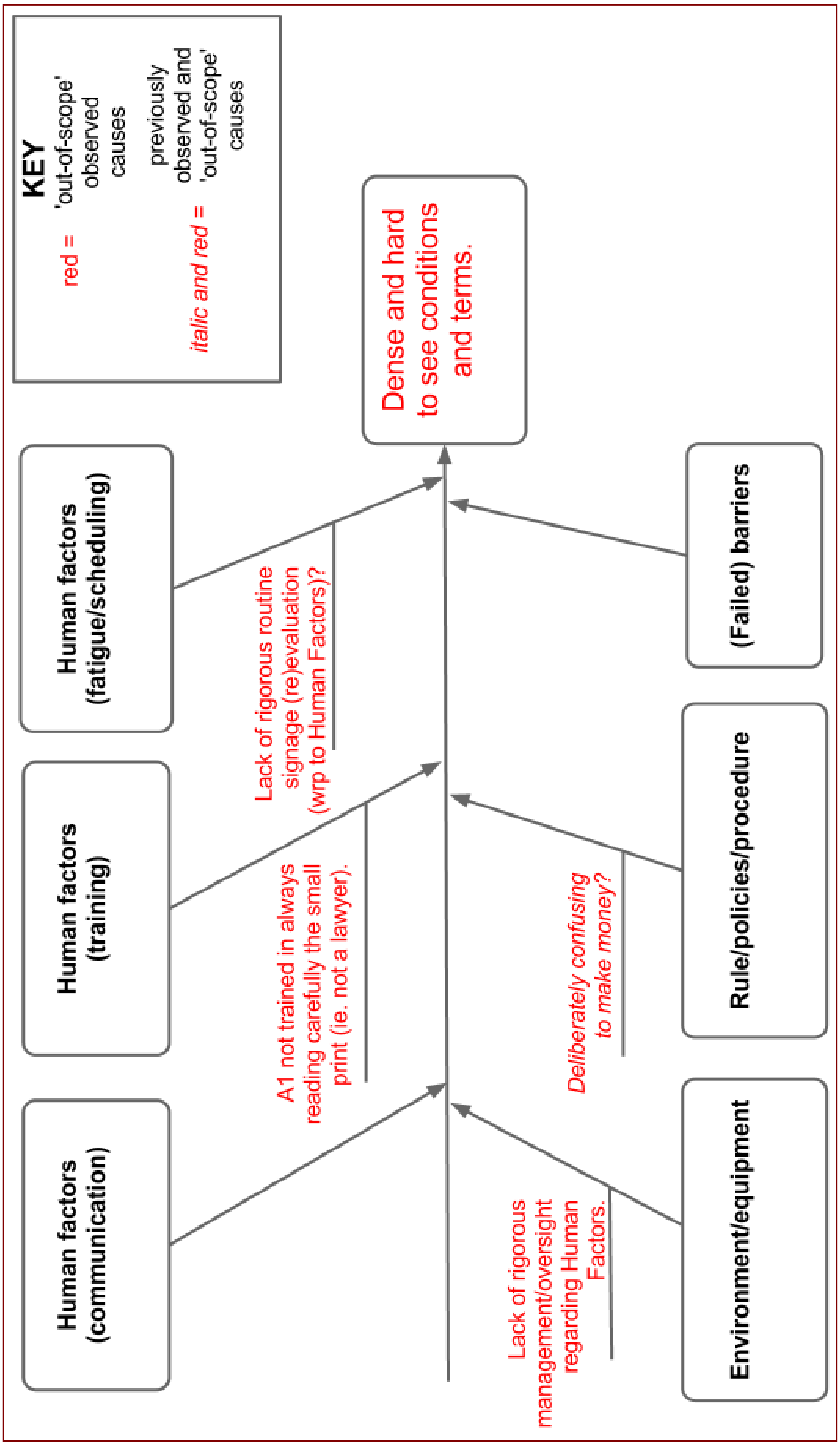

Figure 7.3: Reasons for dense and hard to see conditions and terms.

In particular, analyst A wanted to know whether such 'additional sub-branches' ought to have been included in the overall root cause tree or not. This overall root cause tree (Figure 7.1) was a kind of compilation tree – which brought together multiple 'sub-branches' of a similar form to those shown in Figures 7.2 and 7.3. The initial freely constructed critique (Section 6.3) was therefore the following:

> "*Should incidental findings be included in the consolidated 'final' tree?*"

This led to the following 'normalised' critique (using the templates from Section 6.4):

> ***The investigative choice*** of not including the 'accidental' investigative findings as either 'incidental findings', or as part of the consolidated overall causal understanding of the incident ***was invalid***.
> (***bold*** highlights denote the generic phrase templates)

Analyst A found this critique to be about investigative procedure, potentially affecting the validity of a relatively small part of the incident investigation. It was therefore annotated with ***M*** and ***S*** (Method/procedure, Specific), to denote these analyst judgements (Section 6.6.1).

After comparing against the entirety of the chosen manual (Section 6.5), analyst A was unable to find clear guidance on how to distinguish between 'direct causes' or 'incidental' ones. A single place in the manual suggested that any issues of relevance ought to be documented for facilitating later response. Analyst A took a broadly inclusive interpretation of this guidance, finding that the investigative choice – of not intending to include the 'accidental investigative findings' shown in Figures 7.2 and 7.3 – was ***constrained*** by the manual used. According to the Systematic Reanalysis Method definitions, such ***constrained*** choices/findings are those where the investigation enacted is unambiguously contradicted by the manual (Section 6.5). This implied that the 'accidental' findings shown in figures 7.2 and 7.3 ought to be included, as part of the final tree of causes identified during the investigation (Figure 7.1). Through the joint wrap-up session, both Systematic Reanalysis Method analysts agreed that it would be sensible to include all investigative findings as a minimum – at least as part of the 'incidental findings' part of the formal reporting of an investigation using the ISMP Canada method.

Another example from analyst B was {BC1}. This critique was initially identified by noting that the investigation did not apparently use, or attempt to adapt, the initial decision tree presented in the manual (Figure 7.4). The initial freely constructed criticism (Section 6.3) was about why such a decision tree was not used to check the broad applicability of the ISMP Canada method, to the incident situation investigated in this study.

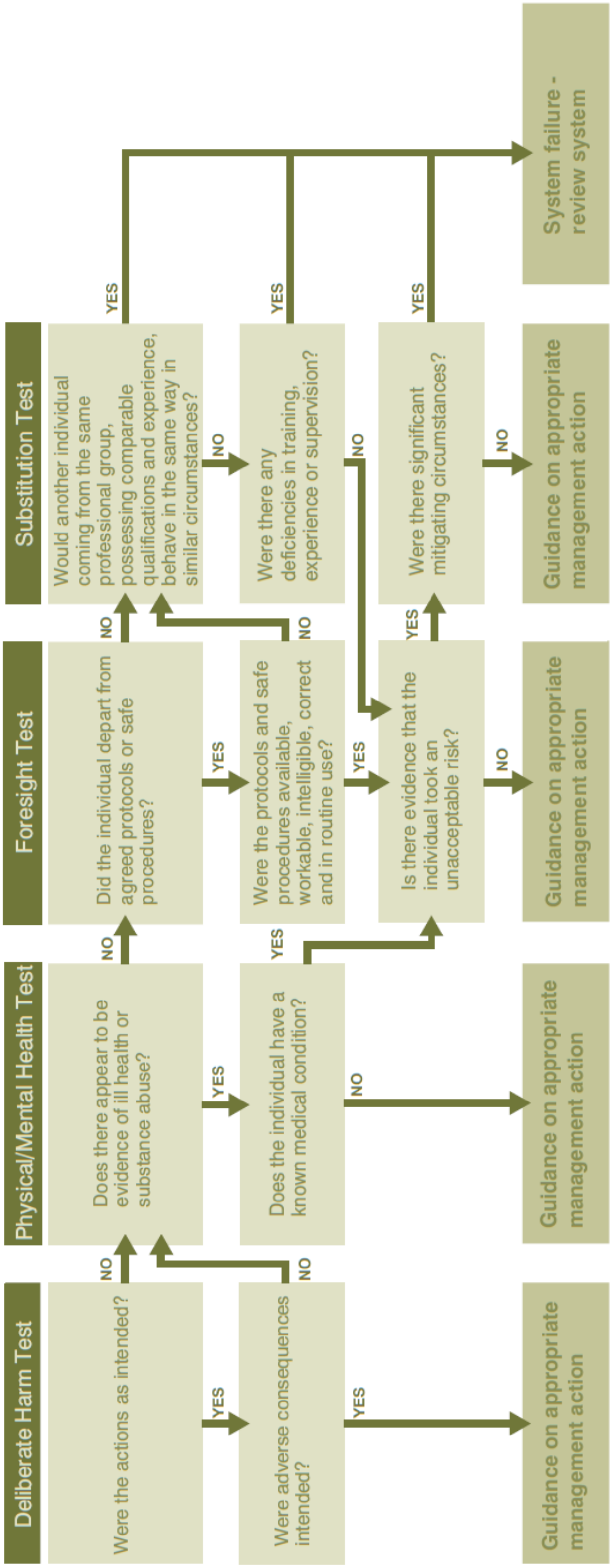

Figure 7.4: Incident decision tree. Reproduced from ISMP Canada (2006, Figure 2) with permission.

This led to the following 'normalised' critique, using the Systematic Reanalysis Method phrase templates (Section 6.4):

> ***The investigative choice*** of not including a proper justification for the use of RCA, for example through the decision tree method, ***was invalid***.
> (here RCA refers to the ISMP Canada method)

Analyst B found this critique to be about investigative procedure. The decision tree in Figure 7.4 ought to have been used early on, if at all, in the course of doing the incident investigation. This decision tree helps the ISMP Canada method user to decide whether 'systemic Root Cause Analysis' should be conducted at all (i.e., the '*System failure – review system*' box/decision-path shown on the right hand side of Figure 7.4). The investigative choice to not to have used it therefore potentially affects the fundamental validity of the entire incident investigation. This criticism was therefore annotated with ***M*** and ***G*** (Method/procedure, General; as detailed in Section 6.6.1).

After comparison against the entirety of the manual used (Section 6.5), analyst B found that at the very least, an equivalent decision tree could be *adapted* for the current incident investigation, with relatively few problems. He therefore concluded that the particular choice made in this particular investigation – to not properly justify using the ISMP Canada method for the incident investigation – was ***constrained*** by the ISMP Canada method (i.e., 'restricted' by the manual). Through the joint wrap-up session, both analysts agreed that it would be sensible to revisit the decision tree shown in Figure 7.4 (which is part of the ISMP Canada method). This would provide a retrospective sanity check of whether the chosen method *was* indeed sufficiently applicable for use in the current incident investigation (with obvious caveats relating to the minor medical-specific aspects of the decision tree).

By the end of the wrap-up session, few parts of the incident investigation remained as *constrained* by the ISMP Canada method. Other examples included the fact that *no 'incidental findings' were found* {AC43}, *the emphasis on attributing blame predominantly to the equipment involved in the parking system* {BC5}, and the fact that *not all participants were interviewed* {BC6}. In the role of incident investigator, analyst A had endeavoured to faithfully enact the domain-independent parts of the ISMP Canada method; for example through doing an equivalent 'car-parking' literature search to inform the incident analysis and investigation (Appendix C.1, Section 2.4). Such efforts may in part explain the relatively small number of *constrained* parts of the investigation remaining (2 identified by analyst A; 3 identified by analyst B), as well as the relatively few critiques independently identified by analyst B in total (n=10).

Each part of the investigation found to be *constrained* by the ISMP Canada method could be improved upon in principle. In helping to demonstrate how each of these parts were *constrained* by the chosen method, the Systematic Reanalysis Method has helped to identify specific areas in which the adequacy of investigation may be further strengthened.

7.3.2 Locating potential ambiguity in investigative method

The Systematic Reanalysis Method analyses also highlighted places where the ISMP Canada manual potentially offers ambiguous guidance for supporting incident investigation. Each *weakly afforded* investigative *choice* or *finding* exemplifies such a situation. This is in contrast to where particular *choices* or *findings* were found to be *constrained* or *strongly afforded* by the manual, indicating where the investigative guidance was interpretable with more certainty.

The Systematic Reanalysis Method assumes that if an individual analyst finds the guidance of a method somewhat unclear (based on careful systematic examination and consideration of its manual), then others attempting to practise the same method could encounter similar interpretative difficulties. In the nascent area of patient safety (Jorm and White 2009, Wachter 2010), the kind of interpretative ambiguities we go on to discuss below may be plausibly encountered by practicing investigators; some of whom may be novices in operationalising RCA based ideas. Given that patient safety investigators may sometimes operate largely alone (Clinical Human Factors Group 2012), they may not have ready access to 'method experts' to clarify ambiguities in the method presentation and description. Each area of interpretative ambiguity identified through systematic reanalysis may be jointly discussed in principle – between the designers of the ISMP Canada method, and its potential users (e.g., patient safety incident investigators, incident analysis researchers, incident investigation researchers etc.). This may aid in improving the communicational functionality of the method's manual (e.g., ISMP Canada 2006). Such discussions may also help to determine the extent to which the kinds of interpretative ambiguities we go on to discuss do in fact need to be addressed (or not), and if so how this may best be done.

<u>Interpretative ambiguities around the literature reviewing part of incident investigation</u>

Through Systematic Reanalysis Method analysis, we identified potential ambiguities around the suggested *nature*, *scoping*, and *usage* of the 'RCA literature review'. This review is of literature relating to the incident being investigated, and has some broad similarities to the underlying rationale for narrative literature reviews like the one presented in Chapter 2. Like the narrative literature review, the nature and extent of this 'incident literature review' – done as part of an incident investigation – may significantly contribute towards what investigation findings are obtained. Depending on the actual nature of the review conducted, investigators may be sensitised in different ways, and possibly identify different contributory factors as part of their subsequent analysis. It is therefore important that there is clarity around the guidance for this part of the ISMP Canada method.

An example from the Systematic Reanalysis Method analyses relates to appropriate time-frames for conducting such literature reviews {AC26}. This criticism was initially identified by noting the half-day or so spent on this part of the incident investigation.

The initial freely constructed criticism led to the following 'normalised' critique:

> ***The investigative choice*** of spending only half a day or so on the literature search part of the investigation ***was invalid***.

This critique was found by the Systematic Reanalysis Method analyst to be about the investigative procedure, and of only minor potential effect on the validity of the investigation as done. This choice was therefore annotated with ***M*** and ***S*** (Method/procedure, Specific).

After comparing against the entirety of the manual used, the analyst found that there was no guidance about expected timeframes. A uniform time-frame for this kind of context-specific review is perhaps unreasonable to expect as part of method design. However, the lack of *any* guidance about possible time-frames could leave an investigator trying to follow the manual very unsure about the adequacy of this part of their investigation. The analyst therefore judged this investigative choice to be ***weakly afforded*** by the manual used, due to *underspecification* by the ISMP Canada method. Additional related examples around reviewing the literature during 'systemic RCA' may be found in Appendix C.2 (see {AC22, AC23, AC25, AC26, AC27, AC30, BC7}).

Interpretative ambiguities around *growing* the tree of causes

In principle, the generation and exploration of the 'root causes tree' (e.g., Figure 7.1, 7.2) is a core part of RCA based incident investigation. However, our reanalysis identified considerable potential ambiguities, around both how this tree ought to be *grown*, and how it ought to be *bounded* (using the ISMP Canada method). We discuss an example of ambiguity in guiding the *growth* of this tree here; and then discuss an example of ambiguity in the *bounding* of such trees next.

The first example relates to understanding the validity of having sub-branches of a root-cause tree with only '1 member' {AC47}. The nature of these sub-branches may have a significant impact on the particular findings of an investigation, and the subsequent responses. Figures 7.2 and 7.3 provide examples of this '1 member' situation. For Figure 7.2, the "A1 wasn't familiar with this carpark" cause is the only member of the *Human factors (training)* sub-branch. By contrast, the *Environment/equipment* sub-branch in Figure 7.2 has 4 members. For the ISMP Canada method, six major 'triggering categories' are proposed for supporting the causal analysis. These are the six shown in both Figure 7.2 and Figure 7.3. This led to the following normalised critique being proposed:

> ***The investigative findings*** obtained of having no more than one contributing factor in each triggering category (for some steps of the RCA) ***were invalid***.

The analyst found this critique to be of only minor effect on the potential validity of the investigation enacted, and annotated it with ***F*** and ***S*** (Findings, Specific).

After comparing against the entirety of the manual used, the analyst found no guidance about the number of such sub-branches to expect, in developing the contributory causes. Relatedly, the manual also gave no indication of whether finding *no contributory factors* in a triggering category is valid. The *underspecification* of the chosen method observed here, again, may leave its user unsure about the adequacy of the causal inference part of their investigation. Based on Systematic Reanalysis Method analysis, the analyst judged the '1 member' type of investigative findings to be

weakly afforded by the manual. Additional related examples around the growing of a root cause tree may be found in Appendix C.2 ({AC32, AC33.1, AC34, AC37, AC39, AC40, AC47, AC48}).

Interpretative ambiguities around *bounding* the tree of causes

Ambiguity was also found in the means of *bounding* the development of the 'root causes tree'. This relates to the general, and practical issue of 'stopping-rules' in designing methods for investigative analysis.

{AC42} provides an example, about whether an investigator ought to stop further exploration of contributory factors when a stopping rule was perceived to be fulfilled. The initial criticism led to the following 'normalised' critique:

> ***The investigative choice*** to assume that the 'correct' RCA-based procedure was to curtail investigation of 'more-latent' causes as soon as a stopping rule is satisfied ***was invalid***.

The analyst found this criticism to be about investigative procedure, and of potentially significant effect on the validity of the investigation. It was therefore annotated with ***M*** and ***G*** (Method/procedure, General).

3 parts of the ISMP Canada method were found to be interpretable as operational 'stopping rules' – to guide the growth and bounding of a tree of causes:

1. The first rule is based on a simple heuristic estimate of the likely recurrence of similar incidents after intervening on a candidate 'root cause' factor (Figure 7.5).

2. The second rule consists of a set of three criteria (ISMP Canada 2006, p27), about:
    a. whether the investigator(s) have any more questions, or
    b. whether there is no more incident knowledge, or
    c. whether the issues raised are perceived to be beyond the scope of the incident investigation.

3. The third rule is a simple heuristic based on substantive team consensus and agreement (ISMP Canada 2006, p28).

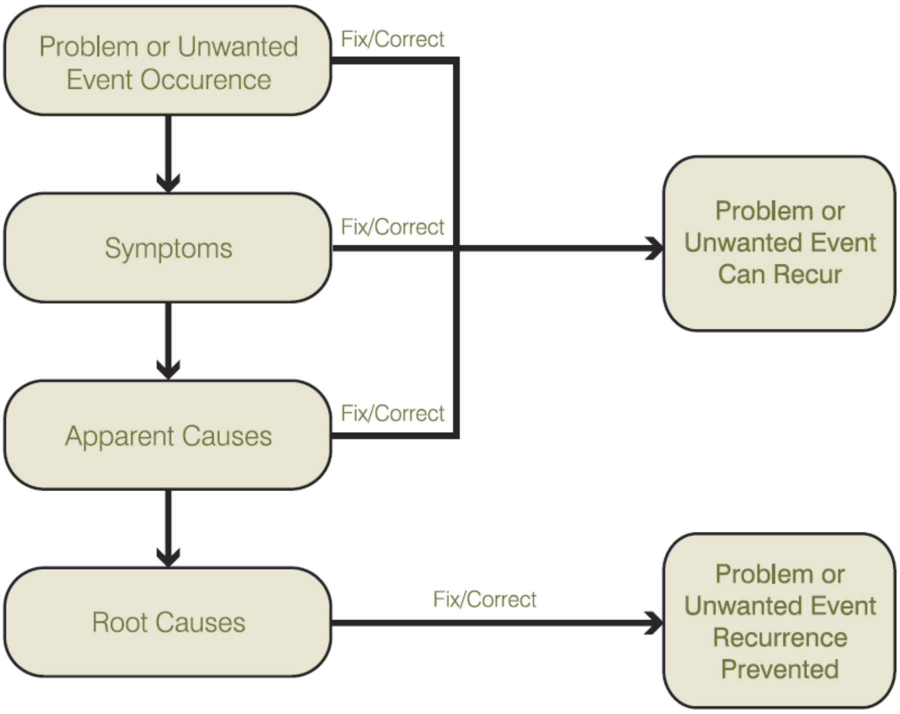

Figure 7.5: A simple heuristic estimate of the likely recurrence of similar incidents. Graphic reproduced from ISMP Canada (2006, Figure 7) with permission.

Such rules seem reasonable. They are however subject to a wide range of reasonable interpretations. This embedded source of subjectivity, in method design, may partially explain why such 'causal chain' aspects are perceived by some safety researchers as too arbitrary and subjective (e.g., Leveson 2011). The reanalysis found no clear guidance for prioritising between these stopping rules, and whether these rules are globally applicable throughout the whole process of growing of the tree of causes. Both were quite practical concerns during the incident investigation done, having a concrete impact on the extent, and nature of the investigative analysis. The third stopping rule – of substantive team consensus – may also be difficult to simultaneously satisfy alongside the others; for example if potential disagreements arise about the extent to which the first or second stopping rules are satisfied. The *investigative choice* to curtail investigation into 'more-latent' causes, as soon as a stopping rule is satisfied, was found to be ***weakly afforded*** by the chosen manual.

Here, the Systematic Reanalysis Method helped to elucidate aspects of the charge of 'subjectivity' claimed by researchers such as Leveson (2004). Through semi-structured analysis, the new method has facilitated deeper insight into the where's and how's of such potential subjectivity. Like Johnson et al. (2012), we do not regard this subjectivity as either inherently 'good' or 'bad', since analysis methods must be used by 'subjects' to have any value at all (e.g., incident analysts from diverse academic or practitioner backgrounds). The suggestion here is that the *nature* and *extent* of the interpretative subjectivity inherent to incident analysis methods and process should be ideally at the level, and specific places intended by the method designers. Additional related examples around the bounding of a tree of causes may be found in Appendix C.2 ({AC33.2, AC33.3, AC36, AC42}).

7.3.3 Warranting the link between the chosen method and actual investigation

A third role for the Systematic Reanalysis Method relates to the scientific assessment of incident analysis methods. Their assessment and evaluation is often done through comparative discussion, drawing on the outputs obtained using them (e.g., Herrera and Woltjer 2010, Salmon et al. 2012). However, an issue not yet explicitly tackled is that of *attribution*. This concerns understanding and *demonstrating* the extent to which actual investigative *actions* or *findings* are in fact attributable to the method.

The Systematic Reanalysis Method was originally developed as a means to generate explicit *warrants* – to evidence the connection between the theory of the method (such as ISMP Canada (2006)) and its attempted practice (e.g., Appendix C.1). The Systematic Reanalysis Method does not provide a *conclusive* solution; but it *can* increase or decrease our confidence in the nature, and degree of attribution warranted – between the theory of the method and its practice. The rest of this section aims to show that it is possible to *demonstrate* the attribution of particular parts of incident investigation to the chosen method – using the Systematic Reanalysis Method. Ideally this will be done in an incrementally more objective way, as we go on to explain.

Through repeated examination, assessment, and critical discussion using the Systematic Reanalysis Method, we can come to an increasingly more objective understanding of which parts of the investigation are *strongly afforded* by the method being scrutinised. This generates detailed understanding of where a method can provide strong encouragement for particular investigative *actions* or *findings*. Each of the *strongly afforded* judgements represent an evidenced empirical attribution: from the theoretical abstractions of a method, to its practical enactment. Repeated such grounded judgements increase our confidence in the intersubjective validity of findings from the qualitative data analysis. This is similar to the rationale underlying the valid analysis of qualitative data from Anderson et al. (2013), or Kitson et al. (2013), for example.

Like other qualitative data analysis methods (e.g., Braun and Clarke (2006)), the Systematic Reanalysis Method provides a focused instrument for priming the intersubjective reasoning and sense-making process of the data analysts. In the case of the current study, the systematic reanalyses helped to structure the initial challenges made of an incident investigation as done (Section 6.4). It also encouraged detailed comparative analysis: between the primary evidence of the manual and its attempted practice. When independent systematic reanalysts keep giving the same *strongly afforded* assignments, the corresponding part of the investigation being scrutinised is shown to be strongly attributed to the chosen method. Each 'repeated' analysis will extend and refine the existing body of reasoned insight into the same primary data set. For the Systematic Reanalysis Method, the body of analytical knowledge generated is in the form of all of the prior reanalyses done, together with outcomes from any critical discussion between the independent reanalysts (as shown in Appendix C.2 for example).

In our study, the two independent reanalyses (by analyst A and B) start to build up this body of analytical knowledge. To increase or decrease our confidence in the nature, and degree of attribution warranted between:

- the particular *theory of method* embodied by ISMP Canada (2006),
- and its *enactment* as part of actual investigation practice (e.g., Appendix C.1).

An example that illustrates how the Systematic Reanalysis Method can be constructively used in this kind of intersubjective role is from analyst B {BC9}. The original critique noted the lack of an entry in the 'failed barriers' triggering category, as part of the investigative hypotheses developed initially (see Figure 7.6). Here, the incident investigator did not come up with any safety barriers that failed, when perhaps the chosen method required this. Analyst B challenged this situation, with the following normalised critique (simplified here):

> ***The investigative choice*** of not positing any possible failures of safety barriers in the cause diagram ***was invalid***.

Analyst B found this critique to be about the investigative procedure, and potentially affecting the validity of a relatively small part of the incident investigation. It was therefore annotated with ***M*** and ***S*** (Method/procedure, Specific).

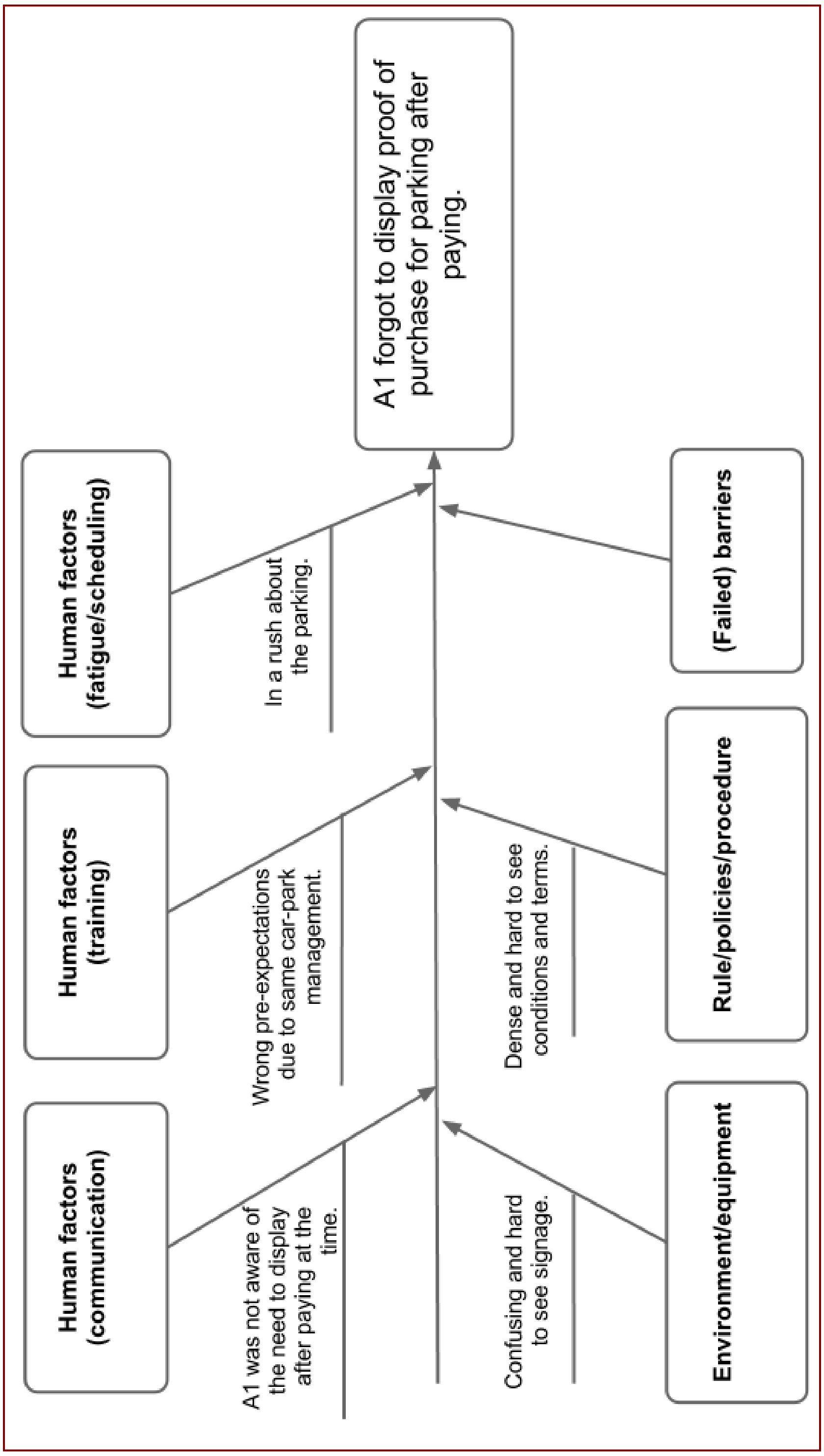

Figure 7.6: An Ishikawa diagram overview of the initial 'major causes' identified from the investigative analysis (Appendix C.1, Figure 3). The *safety barriers* analyst B is referring to is the '*(Failed) barriers*' heading in the figure.

After careful scrutiny, analyst B found an explanatory example from the manual demonstrating the concrete use of this 'failed barriers' category, in the form of ISMP Canada (2006, Figure 8). Based on this supporting evidence, the analyst identified the *investigative choice* – of not initially positing any possible failures of safety barriers –

to be ***constrained*** by the manual used. This suggested that this part of the causal analysis should be improved upon.

As part of the discussions during the joint wrap-up session, analyst A pointed out that this 'failed barrier' category had in fact been used in developing *some* of the investigative hypotheses developed here. Upon further discussion and consideration, alongside explicit references back to the manual used, both the analysts found the idea of such 'safety barriers' to be only vaguely defined by the manual used. This led to a revised assessment of the part of the incident investigation being scrutinised. Both analysts agreed that the assessment regarding this part of the investigation should be revised: as ***strongly afforded*** by ISMP Canada (2006) instead.

In the example above, analyst B's initial judgement was subsequently revised, as part of the formation of inter-analyst judgement and consensus. In such a fashion, the various final assessments by the end of the wrap-up session are arguably more objective, than either of the independent analytical judgements made initially by each analyst. In this particular case, the two analysts came to a joint conclusion. The joint conclusion was that the lack of safety barriers in one part of the causal analysis (Figure 7.6) was perhaps more reflective of the nature of the 'system' under investigation; and did not reflect a clear flaw in enacting the chosen method. Here, the Systematic Reanalysis Method supported a process of intersubjective reasoning, sense-making, and reflection; to enable a more considered, complete, and revised state of analytical understanding upon the completion of the wrap-up discussions.

Many other parts of the incident investigation were also found to be *strongly afforded* by the ISMP Canada method, by both Systematic Reanalysis Method analysts. These investigative *choices* and *findings* include:

- *basing the core steps of the investigation primarily on a limited section of the manual* {AC3};
- *using a flow-diagram and a supporting narrative for forming and consolidating the initial understanding of the incident* {AC13};
- *using 'call-out' boxes in the 'final understanding' flow-diagram identified during the investigation* {AC28.1};
- *using the Ishikawa diagram to represent the causal relations in the analysis (e.g., Figure 7.6), rather than an alternative tree-format suggested as part of the ISMP Canada method* {AC31};

- *interpreting the second of the three stopping rules discussed earlier in Section 7.3.2 as an inclusive-OR* {AC35};
- *using only photographic and documentary evidence to support the investigation* {AC49}; and
- *finding one of the principal causes of the incident as being beyond the scope of the analysis/investigation enacted (i.e., not further analysing the "confusing and hard to see signage" sub-branch shown in Figure 7.6)* {BC10}.

Analyses using the Systematic Reanalysis Method identified all of these parts of the investigation to be strongly attributable to the chosen ISMP Canada method (i.e., **strongly afforded** by it). Together with the other two assessments of **constrained** and **weak afforded** by the chosen method (Section 6.5), we have shown how the Systematic Reanalysis Method can provide a way to explicitly warrant the link between the chosen method and its practice in actual investigation.

7.3.4 Initial feedback on the usability of the Systematic Reanalysis Method

Analyst B was a new user of the Systematic Reanalysis Method, but was not involved in its creation. He was therefore able to provide informal feedback on its usability, from an independent perspective.

He found its pipelined and systematic approach relatively easy to follow, and helpful for supporting a gradually deeper and thorough understanding of the chosen manual. He also found this research method helpful, in showing how the investigation may have diverged 'outside' the space of methodological constraints described by the manual. In particular, both the distinction between the *procedure* and *outputs* of investigation (e.g., Section 6.3), and the suggested demarcation between the *general* and *specific* methodological criticisms (Section 6.6.1) were found to be easy and clear to use.

Some difficulties were caused by the 'double-negative' aspect of the initial Systematic Reanalysis Method presentation however, since it applies the notions of **constraint** and **affordance** to *the part of the investigation being critiqued*, not to the *methodological criticism* itself (encapsulating the investigative *choices* or *findings* being critiqued). This issue has since being acted upon, as part of the minor update of the Systematic Reanalysis Method presented in Chapter 6.

Analyst B also suggested the inclusion of illustrative examples, to help improve the clarity of presentation of the Systematic Reanalysis Method. Examples were also suggested as potentially helpful, to further highlight the fact that criticisms about both 'investigative commissions' (things that *were* done/found), and 'investigative omissions' (things *not* done/found) are equally valid aspects to challenge for a Systematic Reanalysis Method analyst. This suggested clarification has since been incorporated, to further clarify the presentation of the Systematic Reanalysis Method in Chapter 6 (see Section 6.3). The current study generated many concrete examples for illustrative and explanatory purposes, whose full details can be found in **Huang** and Hough et al. (2013c).

7.4 Study limitations

The first limitation of the study relates to the scoping of the incident investigation conducted (analysed using the Systematic Reanalysis Method). The incident investigation process related mainly (but not exclusively) to incident *data collection and analysis*; the latter parts of *designing and selecting remedial responses* was not really possible in the current research study (cf. Lundberg et al. 2010). This was due to situational limitations relating to the particular incident situation, and the constrained resources available for the small scale incident investigation. It was unlikely that the national car management company involved in this incident situation would have readily participated in collaborative redesign of the car park or associated procedures, to better support its users to remember to display their proof of purchase after parking. Further research could therefore focus on the use of Systematic Reanalysis Method to analyse the relationship between:

1) the methodological and theoretical aspects of a manual for guiding *design and selection of remedial responses*, and
2) the actual enactment of this *design and selection* as part of a real incident investigation.

The second limitation relates to the fact that the ISMP Canada method (enacted in the study) was originally designed for the patient safety domain. The implicit argument of this chapter is that the generic parts of the ISMP Canada method are sufficiently generic to be readily transferable – to the given *non* patient safety incident situation. The ISMP Canada method itself transfers basic RCA principles from outside of patient safety. We focused on only the *domain-**independent*** aspects of the ISMP Canada method for the current study. Systematic Reanalysis Method analysis of an account of patient safety incident investigation would generate insight, into how the *domain-**dependent*** aspects of the ISMP Canada method *constrain* or *affords* aspects of investigative practice. Detailed chronological descriptions of the conduct of patient safety incident investigations – at a level of detail comparable to that given in Appendix C.1 – are to the best of the author's knowledge not yet publically available. Given the increasing emphasis on more transparent management of patient care and safety however (cf. UK Department of Health 2013), such data limitations impeding safety research in the area will hopefully be reduced in the near future.

A third limitation of the current study is in the fact that only two researchers have so far applied the Systematic Reanalysis Method in practice. Such users are within its intended scope. But future research could explore the extent to which the Systematic Reanalysis Method does in fact open up the potential for demonstrable validity judgements to other safety stakeholders not included in the current study, through investigating the benefits and drawbacks of Systematic Reanalysis Method use with patient safety managers, professional incident investigators etc. This is not to say that all safety stakeholders would necessarily want to scrutinise the enactments of methods in detail in the manner of the current study, however.

7.5 Conclusions

This chapter has presented an exploratory study of the Systematic Reanalysis Method. Two independent data analyses were conducted using it, to characterise the investigative enactment of a systemic incident analysis method. The Systematic Reanalysis Method characterises parts of an investigation as **constrained**, **strongly afforded**, or **weakly afforded** by the chosen method. By using it, we have gained insight into how the abstract, tangible *representation* of the ISMP Canada method (ISMP Canada 2006) relates to its *enactment* as part of incident investigation practice.

Through exploring its use in practice, the study shows that the Systematic Reanalysis Method can:

- help an analyst understand where incident investigation may be improved with respect to the chosen method (Section 7.3.1),

- help an analyst locate areas of potential ambiguity in investigative method (Section 7.3.2), and
- facilitate explicitly evidenced and warranted links to be made between the chosen method and its actual enactment (Section 7.3.3)

Through such knowledge generating roles, the Systematic Reanalysis Method helps to extend an evidenced, explicit bridge: from the abstractions proposed by theoretical research into the systemic analysis of incidents, to incident analysis in practice. The resulting analysis outputs may be used to support the work of **method designers**: by systematically informing our understanding of the extent to which systemic incident analysis methods are in fact being used as intended in practice, and help identify where methodological difficulties can and do arise. For stakeholders more interested in **quality assuring** incident analyses (e.g., as part of incident investigation, cf. Benner and Rimson 2012), the Systematic Reanalysis Method offers a way to systematically demonstrate the extent to which an incident investigation is adequate – with respect to the chosen analysis method(s). These concerns are addressed through researching the ***constraints*** and ***affordances*** of a systemic incident analysis method. Both aspects are important for researchers, practitioners, or researcher-practitioners to consider, as part of further research and development of methods of doing systemic incident analysis.

Chapter 8 – Conclusions and Future work

This chapter:

- Briefly summarises the work of the thesis, conducted to meet the project aims and objectives set out in Chapter 1
- States the main conclusions from the theoretical and empirical work of the thesis
- Explains how the developments of the thesis advances existing related research reviewed in Chapter 2
- Provides indicative discussion and recommendations for future research following on from the current work

8.1 Summary

Based on the literature review conducted in Chapter 2, two main project aims were set out. The first aim was to develop and demonstrate a new method, to offset the misleading dominant illusion of 'objective information transmission' during incident situations. This conceptual illusion was shown to be present in the field of systemic incident analysis, through a critical review of the relevant methodological literature (Section 2.3). In meeting this first aim, a new method of systemic incident analysis was developed based on Distributed Cognition precepts. It is called the **Information Safety Method**, and the first of two new methods of analysis developed in this PhD project.

A controlled empirical study was conducted to validate the Information Safety Method. Using Branford's (2007) validation criterion, we sought to find out whether this new method does what it is designed to do. The basic finding from the study was that the Information Safety Method can indeed do what it is designed to do. The method is designed to support analysis of *how* natural information systems emerge – through identifying the natural systems of information representation and information representation coordination shared during an incident situation. This follows through on the promise of Distributed Cognition based safety explanations recognised earlier (e.g., by Busby and Hughes 2003, and Sweeney 2009), for explaining problems of communication during incident situations. Through doing so, we provide a new method for conducting systemic incident analysis.

The second main aim of the project was to start to bridge the gap between systemic incident analysis methods in theory, and their use in practice. Such efforts need to be attempted, for the various systemic incident analysis research innovations to be taken up in safety practice. We first conducted in-depth interviews with practicing incident investigators working in patient safety. This helped us better understand the significant concepts driving their analysis and investigation practice. Concepts of how natural information systems form, along with the concepts of the mainstream systemic incident analysis methods, were both absent from the interview data. This suggests a possible niche for these systemic methods, to enrich the analytical insights gained from the incident investigators' practice. To better understand how the theory of systemic methods relates to their actual practice, we developed a new method of empirical analysis, for critically examining the move:

1) from systemic incident analysis methods in theory,
2) into their practical utilisation as part of the complex process of real incident investigation.

This second new method of analysis is called the **Systematic Reanalysis Method**. It was used as part of an exploratory empirical study, conducted to understand how the theory *moved into practice*, for an established method of systemic incident analysis (ISMP Canada 2006). The study showed that the Systematic Reanalysis Method can be applied in practice productively. The study also identified a number of substantive methodological challenges, in using in the established method of systemic incident analysis in practice.

8.2 Original contributions

Through meeting the two main project aims, we have made several contributions to the theory and practice of systemic incident analysis. They are presented below.

8.2.1 Development of a new method of systemic incident analysis (to meet Aim A: Objectives 1 and 2)

Through the literature review of Chapter 2, we showed that a misleading view of 'objective information transmission' is currently present, and dominant in the field of systemic incident analysis. This view seems to be sustained by all three of the major methods of systemic incident analysis reviewed (AcciMap, CAST, and FRAM). These existing methods adopt the 'information as object' view, which is a misconception in explaining how people naturally communicate during incident situations (cf. Lakoff and Johnson 2003). This motivated Aim A of the PhD project: to develop an alternative means of explaining how information flows through representations and their propagation during incident situations.

To offset the misleading illusion of 'objective information transmission' during incident situations, we turned to the theory of Distributed Cognition. Based on the Distributed Cognition worldview, we developed a new method of systemic incident analysis in Chapter 3. This new method is called the **Information Safety Method**. It builds on the Distributed Cognition focus on *propagation of representation states,* to provide a method of systemic incident analysis. It allows us to analyse how information 'flow' during incident situations is *constitutive*, of the systemic formation of distributed cognitive systems. The systemic analysis is conducted through identifying the *interactive*, *emergent*, and *naturally fallible* acts of communicative representation during incident situations. This development represents a step forward for research into understanding information 'flow' as part of systemic incident analysis. The new method also represents an *advance in theory*, through codifying Distributed Cognition ideas for the purposes of systemic incident analysis.

For the Information Safety Method, communication during incident situations is understood as a direct function of the communication *context*, irrespective of the degree of success or failure in attempting communication. The method embodies a strong interpretation of Distributed Cognition concepts (cf. Pea 1993). The method design incorporates a disbelief of the possibility of cognition residing solely in people, as well as a disbelief of the flow of objective information between people in communicating (Lakoff and Johnson 2003). Instead, the incident analyst is prompted to assess for *correct representation*, and *consistent coordination of representation states* during incident situations. The new method also seeks to improve the likelihood of actual *learning from incidents*, through treating incident analysis as a distributed cognitive process of ongoing *incident analyst and data triangulation* (cf. Rothbauer 2008). This triangulation is done mainly through associating and scoping of the safety functions, *across* the information trajectories identified from different incident situations.

Through initial validation of the Information Safety Method, in Chapter 4, we found that the new method of systemic incident analysis *can do what it is designed to do*. In providing a distributed cognitive mode of incident analysis, the new method enabled:

- learning about the nature of fragilities in the natural information representation co-ordination systems developing during incident situations;
- active learning through understanding systemic causes potentially effecting information coordination and representation, to support the active sharing of knowledge from analysis of individual incident situations. Such sharing was conducted via a distributed learning process, of ongoing *incident analyst and data triangulation*;

The method was applied to five real, diverse incident situations here. This showed that the Information Safety Method can be used in practice, at least in a research context. Original safety implications were also identified through this work, going beyond the insights from the prior incident analysis (as reported). This indicates the potential for new insights to be gained on incident situations, through systemic analysis using the Information Safety Method.

8.2.2 Understanding the practice of patient safety incident analysis during incident investigation (to meet Aim B: Objective 3)

As part of our contribution towards broader efforts at bridging the gap between systemic incident analysis research and practice (Aim B), further empirical data and insight was sought regarding professional incident analysis and investigation practice. A novel research question was raised in Chapter 5: of *"What are the significant concepts for patient safety incident investigators in their investigative practice?"* An initial answer to this question was obtained through conducting in-depth interviews, with two out of the three incident investigators responsible for directing patient safety incident investigation at a large United Kingdom Foundation Trust.

The research question provided a novel focus on the *significant concepts* driving their incident investigation practice. The review in Chapter 2 indicated the nascent nature of patient safety incident analysis and investigation practice; which was further confirmed by the answers from the interview data obtained here. The interview study also confirmed that Braun and Clarke's (2006) version of thematic analysis can be used to productively interrogate interview data: in order to understand the conceptual motivations driving patient safety incident investigation practice. The five themes of the qualitative analysis are contributed to the field, to embody the significant concepts driving these investigators' practice. A grounded, 'fact-based' search is crucial to their incident investigations, to determine the *root cause* of what went wrong to cause significant patient harm (**Themes A, B, C**). This analysis rationale is however tempered by the substantive time, resource, and knowledge limitations of an investigative situation (**Theme D**), as well as the investigators' naturally humanistic approach to incident investigation and reporting (**Theme E**). Additional answers from other patient safety incident investigators and organisations would give an idea of the extent to which these initial insights *transfer*.

The evidence from patient safety research suggests that systemic analysis of incident situations seems to be as yet only partially embraced, in practice (Chapter 2). Our new interview data and study supports this view, indicating that the idea that incidents occur due to *many causes* seems to be accepted only in part, in practice. The focus in practice seems to be on an *ultimate root cause* for the incident, in this case. This style of monocausal explanation has been rejected as viable by contemporary safety scientists as far back as 1995 (Stoop 1995). This further confirms the existence of a research/practice gap (Underwood 2013), in the specific case of patient safety incident investigation. Through providing a deeper descriptive understanding of the dominant incident analysis rationale at a large United Kingdom Foundation Trust, we have contributed towards greater understanding of the *analysis approach of practitioners*, in the particular context of patient safety incident investigation. This additional evidence further reinforces the need stated previously, to find ways to start bridging the gap between systemic incident analysis research and practice.

8.2.3 Development of the Systematic Reanalysis Method (to meet Aim B: Objectives 4 and 5)

Another contribution towards broader efforts at bridging the gap between systemic incident analysis research and practice (Aim B) was presented in chapters 6 and 7. Here, we sought to more clearly understand what is happening as systemic incident analysis theory *becomes* practice. We sought to enable focused and detailed empirical analysis of this part of the process of incident investigation. A new research method was developed for this purpose, called the **Systematic Reanalysis Method**. This second new method of analysis provides a way to understand and explicitly research *how* systemic incident analysis methods are utilised in practice, in detail (Chapter 6).

Through examining the detailed relationship between the theory and practice of the method, we can identify its *constraints* and *affordances*, when it is utilised as part of real incident investigation in practice. Such analysis may improve our understanding of how particular systemic incident analysis methods supported particular incident investigations. This would support systematic and detailed understanding of the strengths and limitations of these methods.

Through two independent analysis using the new research method, three distinct knowledge generating roles emerged for it in Chapter 7. In particular, we found that the Systematic Reanalysis Method can be used to:

a) help the analyst understand where the conducted incident investigation may be improved, with respect to the guidance of the chosen method,
b) help the analyst locate areas of potential ambiguity in the presentation of the method, and
c) help increase our confidence in linking particular parts of the investigation conducted, to the chosen method, through empirical confirmation or refutation of each potential link. These three potential links are in terms of the **strong** or **weak affordance** of the theory of method on its practice, or how the theory of method **constrains** its practice.

In particular, the findings from the Systematic Reanalysis Method analyses indicate that many challenges arise in the move: from the theory embodied by a simple systemic incident analysis method (ISMP Canada 2006), into its practice as part of incident investigation (see Appendix C.2 for a full list of the specific challenges discovered). Such results could potentially be used to improve the method, or its tangible guidance to support the conduct of incident analysis and/or investigation. In conducting the work of Chapter 7, both the study experiences and findings provided further support to the *information only as a consequence of interaction* assumption underpinning the Information Safety Method (Section 3.3.3), as well as the empirical literature reviewed in Chapter 2. The practice of systemic incident analysis seems to be a highly interpretative qualitative enterprise, rather than an 'objective' one.

8.3 Recommendations for future work

Based on the experience gained of method design, analysis practice, and related research into methods of systemic incident analysis, we now go on to detail some recommendations for further work.

8.3.1 Progression from the Information Safety Method related work

- A new method of systemic incident analysis has been now developed, to counterbalance against the pervasive and dominant influence of the illusion of 'objective information transmission' during incident situations. However, further work is needed to understand how the Information Safety Method can be adapted for use in a professional practice setting. Following on from the validation study of Chapter 4, a natural next step would be to attempt analysis of other incident situations, as part of small scale patient safety incident investigations for example. This would enable better understanding, of some of the practical challenges arising from using the Information Safety Method in practice.

- It would also be useful to compare the Information Safety Method with other methods of incident analysis (using the same incident situation). Due to the nature of systemic incident analysis, any comparison of such methods may lead to insights which are new relative to the outputs from another; alternatively, the analytical outputs from a method could also lend mutual support to that of another. Both kinds of empirical findings would be of interest to investigators considering the actual scope and nature of individual systemic incident analysis methods. Like the comparative research of Salmon et al. (2012), and Underwood and Waterson (2014) for example, a related further work could be to compare the extent to which the Information Safety Method generates new insights and recommendations, when directly compared with the existing major methods of systemic analysis reviewed in Chapter 2.

8.3.2 Progression from the interview study on how patient safety incident investigators analyse and investigate incident situations

- A key limitation of the interview study, imposed by resource constraints, was the limited data on analysis practice during patient safety incident investigation. An opportunity therefore exists to conduct further interviews with incident investigators from other healthcare organisations, to gain more complete understanding of the significant concepts of incident analysis practice. The basic research design of Chapter 5 could be adapted or extended for this purpose.

8.3.3 Progression from the Systematic Reanalysis Method related work

- Now that the Systematic Reanalysis Method has been independently trialed by two researchers, it would be useful to further explore the use of this research method with others interested in detailed empirical examination of the move from theory into practice. For example, further work could use the Systematic Reanalysis Method to research the details, of *how remedial responses to incident situations were designed and selected* using a systemic incident analysis method.

- Another direction of further work could adapt the basic research process of Chapter 7, to study the move from theory into practice for the Information Safety Method (developed in Chapter 3). This would generate further empirical knowledge, to support further methodological development of the new method of systemic incident analysis. If conducted in an appropriate study setting, such work could give further insight into the strengths and weakness of the Information Safety Method beyond the academic research context.

- Given the highly detailed empirical examination of practice encouraged through the Systematic Reanalysis Method, feedback is also needed from professional practitioners of incident analysis and investigation. This would enable better understanding of the extent to which such close empirical scrutiny of their professional practice and findings would be acceptable and workable, in the face of the complexities and other considerations of larger-scale incident investigation situations for example.

In conclusion, we have contributed towards two areas of systemic incident analysis related research. The first set of contributions make inroads, into counterbalancing against the view of ‘objective information transmission’ present in the field. Through providing a less misleading method of analysing how human communication naturally occurs during incident situations, we open up a new strand of systemic incident analysis research. The initial steps in this direction were taken in chapters 3 and 4. Further work in this direction may result in a more productive way of thinking about and responding to situations of human misunderstanding and miscommunication during incident situations.

The second set of contributions make inroads into developing bridges between the systemic incident analysis research and practitioner communities. Many complex challenges remain to be addressed here, in order to reduce the extent of the current gap between the two communities. From the perspective of practice, we contributed a small study and insights to enrich our understanding of professional patient safety incident analysis and investigation (Chapter 5). To more clearly understand what is happening during the transitional process of *practicing systemic incident analysis*, we contributed both research method and insights to the empirical scrutiny of this part of the incident investigation situation (chapters 6, 7). Further work on reducing the extent of the current research-practice gap is urgently needed, to enable increased impact of research in the field to positive effect actual safety practice. This would increase our chances of keeping future generations safe and sound, through critical and reflective analysis of the various systemic factors helping to structure past and future incident situations.

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Appendix A.1: One of the investigation reports used as a source of incident data

Report for the 3rd incident involving a late diagnosis of Acute Kidney Injury. Numbers such as "**3.3**" are the custom annotations used to facilitate precise (cross)referencing in developing Information Safety Method investigative hypotheses during the study.

1. Introduction

On 28th July 2013 Mr K developed acute kidney injury (AKI) following surgery for a fractured humerus, and required admission to critical care for treatment with haemofiltration. This report investigates the care and treatment that Mr K received from the medical and nursing teams to learn any lessons that might help to prevent any further incidents of this nature and to help improve the reporting and investigation of similar serious events in the future.

2. Acknowledgements to the patient

2.1

Acknowledgments

Hospital A is committed to being open, honest, transparent, and candid. Being open involves apologising in a prompt and meaningful way, and fully explaining what happened when an incident has caused harm to a patient. This investigation report aims to demonstrate this commitment.

2.2

Involvement of MK.

The designated family liaison lead was Dr NP, Consultant Orthopaedic Surgeon. An explanation and apology was given and provided in writing on 30th August 2013.

It is the sincere hope of the independent investigation team that this investigation process has addressed all of the issues that Mr K may have sought to have examined and explained.

3. Terms of reference

3.1

The terms of reference for this investigation were set by the Patient Safety Manager in conjunction with the supporting clinical lead.

1. To examine:

- the reasonability and suitability of the care and treatment provided to Mr K at the time of the incident, in view of his history and assessed health care needs;
- the extent to which care and treatment complied with statutory obligations, relevant best practice guidance, and local operational policies;

- the adequacy of risk assessments and care pathways that were undertaken to support Mr K's care planning;
- whether the right information was available to the right people at the right time, and whether this was used effectively to meet the Mr K's needs; and

3.2

2. To identify:

- the facts as can be reasonably determined, i.e. what happened, to whom, when, where, how and why;
- recommendations / learning points for improving individual practice, or local and organisational systems and services; and
- any action taken by services since the incident occurred to address any shortfalls.

3.3

3. To make:

- realistic recommendations for action to address the learning points to improve systems and services and use this information to significantly reduce the likelihood of future harm to other service users.

3.4

4. To report findings and recommendations to:

- Mr K by sharing the completed report;
- the Trust Board
- the clinical team/s involved in the incident, so that learning and action can be undertaken to prevent similar incidents happening again; and
- the Commissioners of the service/s in which the incident took place.

4. The investigation team

REDACTED

5. Information and evidence gathered

5.1

As part of this investigation, a range of evidence and information has been reviewed. These include: patient records; interviews with staff; electronic results system; and two witness statements.

The following people were interviewed as part of this investigation. They have been identified only by their designation and an identifying letter / number as appropriate.

5.2

Date	Identifying letter/ number and designation and workplace of individuals interviewed
3rd December 2013	SN SG
27th November 2013	Dr AJ, telephone interview

5.3

Best practice

The following policies and guidelines were used to benchmark practice:

- Minimum Standard of Observations Policy; and
- Trust Guidelines on Fluid Balance monitoring

6. Investigation methodology

This investigation used a tabular timeline to review events in Mr K's journey up to the point he was admitted to critical care. Also used was the "5 whys" as a root cause analysis tool.
The incident decision tree was also applied to promote a fair investigation process and inform the recommendations. This is a framework to decide whether systems failures, or individual acts or omissions were the cause of contributing factors in the incident.

7. Background and chronology of events

7.1

Mr MK was admitted to Hospital A on 18th July 2013 at 13.04pm, following a fall at home. , He fell approximately 8-10 feet from ladders, whilst cleaning his caravan roof, onto his left shoulder and elbow.

7.2

On arrival at Hospital A, Mr K was reviewed by the Emergency Department's (ED) medical team. His past medical history was taken, and a clinical examination was undertaken and documented. Mr K was known to have type 2 diabetes, treated hypertension (high blood pressure), ischaemic heart disease, and he also had a permanent pacemaker in situ (model number: Medtronic Sensia NWR7339475 RT Vent lead 4074 Medtronic 4074).

7.3

The initial clinical examination recorded that MK had not had any loss of consciousness following his fall, and had no amnesia or neurological symptoms. His left arm, onto which he fell, was noted to be pink and well perfused. Mr K was referred to the orthopaedic team on call and x-rays of his left arm were requested.

7.4

Whist in the ED it was noted that Mr K's blood pressure (BP) was low at 84/66, given that he had treated hypertension. An intravenous (IV) cannula was inserted and 500mls of normal saline was prescribed and given which increased his BP transiently. Mr K was also prescribed and given analgesia (medication given for pain) which reduced his pain with good effect. At the same time blood samples were obtained and sent to the laboratory for urea and electrolytes, clotting and full blood count. The investigation has noted that Mr K's blood results were normal on admission to Hospital A and showed no signs of renal impairment.

7.5

Mr K went to the radiology department for the x-ray of his left humerus and left shoulder at 14:53 and returned back to the ED. Mr K's BP was noted to have decreased again therefore more IV fluids were prescribed and administered and the next dose of his morphine was delayed in case this was contributing to his hypotension (low BP).

7.6

Mr K was seen by the orthopaedic team at 17:00 and he was diagnosed with a complex fracture of the elbow and shoulder. A back-slab plaster was applied in the ED and the decision was made to admit Mr K for surgical repair of his fractures when BP had responded to IV fluid.

7.7

Mr K's BP increased to 107/60 and the decision was made to admit Mr K to ward A2, the plastic surgery ward, as there were no orthopaedic beds available at time of his admission. A2 is a plastic surgery ward which has orthopaedic patients on a regular basis. Mr K was to be kept nil by mouth (NBM) from 02:00 am as it was planned for surgery to be undertaken the following day.

7.8

On Friday 19th July 2013 Mr K was reviewed on Mr R's ward round (Mr R is a consultant orthopaedic surgeon). The plan was made to check Mr K's pacemaker, to arrange a CT scan of the left shoulder, to transfer Mr K to the orthopaedic ward when a bed was available, and possibly for theatre on 20th July. Mr K was also reviewed by Dr A (consultant orthopaedic geriatrician) who was asked to review Mr K in regards to his hypotension since admission. Following this review, the plan was made to undertake additional blood tests, reduce Mr K's anti hypertensive medication (medication for high blood pressure) and to commence lying and standing BP measurements. The investigation has not been able to identify if lying and standing BP was undertaken as the observation charts and fluid balance charts for the pre operative period are not within the medical records and have not been located.

7.9

On 19th July 2013 Mr K was advised that he would not be having surgery that day, so he could now eat. The sliding scale insulin regimen that he had been on was discontinued and his MEWS was 1. (Modified Early Warning Score: a score used to assess if a patient is starting to show early signs of deterioration). Mr K was experiencing a significant amount of pain and described this as being 8/10 in severity (10 being the worst pain he had ever had). Mr K was reviewed by the medical team and his analgesia medication was increased. Mr K's nursing records at the time note that Mr K was passing urine, although he was not on a fluid balance chart at the time.

7.10

On Saturday 20th July 2013 Mr K was reviewed by the orthopaedic SHO, who advised that his injuries would need be reviewed by an upper limb specialist surgeon and that the surgical procedure to repair the fracture would not take place over the weekend.

7.11

Mr K was reviewed again on the 21st and 22nd July 2013 by the orthopaedic team. As Mr K's injuries to the elbow and shoulder were so significant he required the input of a specialist elbow and shoulder surgeon, Mr P. The plan was made that Mr K would be put onto Mr P' theatre list. The trauma coordinator advised Mr K that his surgery was planned for Thursday 25th July 2013.

7.12

On Monday 22nd July 2013, Mr K had a CT scan of his shoulder: at this point Mr K's renal function was still within normal limits according to his blood results.

7.13

On Tuesday 23rd July 2013, Mr K was transferred to ward A3, the orthopaedic ward for continuing care. On the Wednesday 24th July 2013, Mr K mentioned that he had not had his bowels opened for 2 days. Laxatives were prescribed and given.

7.14

Mr K was transferred to the acute theatre at approximately 08:00am for surgery under the care of Mr P, consultant orthopaedic surgeon. From review of the anaesthetic charts, the surgery commenced at 08:55am and lasted until 12:55pm. During this time it was documented by Dr C, consultant anaesthetist, that Mr K received 2 litres of IV fluid, which included 500mls of Gelofusine. Mr K's BP was recorded throughout and noted to be around 90 / 60 mm/Hg.

7.15

Mr K arrived in the recovery area following surgery at 13:40 where it was recorded that he was hypotensive with a BP of 80/48. 500mls of Gelofusine was administered and Mr K's BP increased. Mr K was transferred back to ward A3. There is no documentation to record if Mr K passed any urine whilst in the theatre or recovery unit, nor is there a time recorded when Mr K left the department.

7.16

Mr K was received back onto ward A3, where it is recorded in the nursing notes that his MEWS was 0 (this is a normal MEWs). A patient controlled analgesia (PCA) pump containing morphine was attached to a cannula in Mr K's arm and was working well. Mr K had a unit of blood going through another cannula and was to receive a further unit of blood that evening. Mr K had his fluid balance recorded from his return from theatre: this should record all fluid on a fluid chart for a 24 hour period. From 16:00 to 00:00 there was only 55 mls of urine documented that Mr K had passed. Mr K did not have a urinary catheter in situ.

7.17

The following morning (Friday 26th July 2013) there is a documented entry in the nursing notes at 06:00 which records that Mr K has had acute pain in his arm and that the on call SHO has reviewed him. There is no entry in the medical notes from the doctor to reflect this review nor is there any mention in the nursing notes of who the doctor was. The nursing notes also state that Mr K had "urine output only 350mls up to now, push oral fluids, doctor happy, just keep on top of pain". There is no documented action taken on the low urine output.

7.18

Mr K was reviewed on the ward round later that morning by Mr P, the operating surgeon. The medical plan documented in the notes at the ward round was to request a review by the acute pain team, x-ray of left shoulder, blood tests and for Mr K to return to theatre the following day for the next part of the planned surgery which would involve an open reduction, internal fixation of left proximal humerus.

7.19

The acute pain team anaesthetist reviewed MK at 10.30 am: the anaesthetist who reviewed Mr K altered some of Mr K's existing pain medication and prescribed some additional pain relieving medications called Gabapentin and Tramadol. Both these new medications can accumulate in the blood in renal impairment and/ or failure. There was no documentation to identify if Mr K's poor urine output or fluid balance was noted at this review.

7.20

The nursing notes written at 14:00 record that Mr K was passing urine "not great amount", only 250mls passed from 7am to 14:00pm. There is no documentation which could be found during this investigation that these concerns were escalated to the medical team. SN R who was caring for Mr K during that shift has been interviewed as part of this retrospective review, she recalled that she did not think that Mr K was in acute renal failure but thought it was acute urinary retention.

7.21

SN G took over care of Mr K on the late shift and accessed his blood results at 17:10 that day on the electronic results system. Those blood results identified that Mr K's renal function had deteriorated with an increase in both his urea and creatanine (urea and creatanine are chemicals in the blood which rise in the presence of acute kidney injury). There was also a decrease in his eGRF rate (eGFR is Glomerular Filtration Rate, which is a derived value and it provides an estimate of kidney function and reduces in the presence of AKI). There is no evidence that the deterioration in these results were acted upon or handed over to nursing or medical staff. Mr K passed urine once on that shift, but this was an unknown amount as he used the toilet.

7.22

During the nightshift 26th-27Th July it is recorded in the nursing records that Mr K had large vomit at 1:00am (not recorded on fluid chart). There is no urine output recorded for the entire night shift, and urine output not mentioned in the nursing documentation of the nightshift.

7.23

Mr K was escorted to theatre at 10:45am the morning of 27th July 2013. There is no evidence that could be found during this review that the anaesthetist was aware of Mr K's poor urine output or deteriorating blood results. The anaesthetic record from the operation states that Mr K's oxygen saturations and BP were persistently low during the procedure.

7.24

From review of the anaesthetic chart it appears that Mr K's BP was rarely above 100 systolic throughout the procedure. During the surgery Mr K required 2 units of saline (no volume recorded), 750 mls of Gelofusine and 2 units of blood. In addition, metaraminol (a vasoconstrictor medication which increases blood pressure transiently) was given at frequent periods throughout the surgery. The fact that Mr K was hypotensive may have indicated that he was also hypovolaemic (depleted fluid volume), although this is difficult to say with certainty.

7.25

Initially following the surgery Mr K was transferred to theatre recovery (an area that patients go to after their operation to be closely observed before going back to the ward). Mr K was reviewed by an anaesthetist, Dr H, at 17.20 as he was experiencing a lot of pain (8/10 on the pain scale). The anaesthetist had a discussion with Mr K and planned for him to have an interscalene block (this involves injecting local anaesthetic to the nerve supply to the shoulder area to provide instant pain relief). The block was administered successfully and provided rapid pain relief as evidenced by Mr K's pain score which went down to 0/10. Dr H also advised to administer regular analgesia on the ward even if Mr K was not experiencing pain; the medications were Tramadol, Gabapentin and Paracetamol.

7.26

Mr K's BP on leaving the recovery area was 92 systolic, which is lower than his normal BP. Mr K arrived back on the ward at 18:00 where no urine documented to have been passed for 24 hours by midnight that night.

7.27

The nursing documentation at 20:30 reflects that Mr K has not passed urine (since 18:00 the previous night) and also not had his bowels open for 6 days. There is no documented evidence of this information being escalated to medical team nor handed over to the nursing staff taking over Mr K's care for the nightshift.

7.28

On Sunday 28th July 2013 at 04:10, the nursing notes record that Mr K's observations had been recorded 2 hourly, and that his MEWS was 0. A statement from the nurse caring for Mr K that night records that he was offered a bottle numerous times overnight as he had not yet passed urine post operatively. The statement also records that the on call SHO (AJ) visited ward in early hours of the morning. Dr AJ was informed that Mr K had no urine output, but it is recorded that she had no concerns as Mr K did not have a palpable bladder and was comfortable: she advised to continue to monitor Mr K's fluid balance.

7.29

At 08.30am on 28th July 2013, Mr K was seen on the ward round by Mr P and his junior Dr S. The entry in Mr K's medical notes states that Mr K is "day 1 post-op, left shoulder plating", that he is comfortable and "nil new": there is no evidence that blood results, fluid charts or observation charts were viewed as part of this ward round.

7.30

The nursing notes at 11:30am record that Mr K's surgical drain was removed and that his observations were stable. It was also recorded that he had not passed urine. At 12:00 a bladder scan was undertaken by SN: there was no urine in Mr K's bladder visible on this scan. A further bladder scan was undertaken at 18:00, and again there was no urine seen in Mr K's bladder. There is no documented escalation of this finding by the SN.

7.31

SN VG came onto the night shift and handover from day team included that Mr K had not passed urine. This was escalated to the on call SHO AJ who had attended the ward the night before. An entry in the medical notes at 23:17 record that "MK has struggled to pass urine all day and that his blood results are deranged". The plan was made to repeat blood tests urgently, insert a catheter (with Gentomycin cover), monitor urine output hourly and give IV fluids.

7.32

On Monday 29th July 2013, Mr K's blood results were checked by Dr AJ and they showed a worsening degree of renal function. This was escalated to the senior doctor, Dr M who then escalated his concerns to intensive care, who arranged for Mr K's admission to HDU (high dependency unit) for renal replacement therapy as Mr K's kidneys had stopped functioning. Mr K received 3 days of renal replacement therapy and was discharged from critical care on 1st August 2013.

7.33

Mr K was discharged from Hospital A on 16th August: he no longer requires renal replacement therapy but is monitored as an outpatient by the renal team.

8. Tabular timeline

Date	Key clinical/ other contacts and events	Source
18/07/13 13.04pm	Mr MK was admitted to Hospital A as an emergency following a fall from a caravan roof whilst attempting to clean it. Suspected fracture of the left humerus. Mr K was in pain and given 10mg morphine. Note that Mr K has low BP 84/62mmhg (usually 130/70 on ramipril 2.5mg+ diltiazem 180mg). Given IV fluid. Also note that Mr MK has a past medical history of hypertension and type 2 diabetes. **Note: Both type 2 diabetes and hypertension can increase the risk of developing renal impairment.**	ED Notes
19/07/13 09.00	Ward round Mr R, plan made to: order a pacemaker check and order a CT of Mr K's left shoulder. Mr K may possibly go to theatre tomorrow. Aim for nil by mouth from 02.00.	Medical notes
19/07/2013 12.10	Note ongoing low BP, no observation charts available to review for this part of Mr K's admission. Vacant episode on return from bathroom, Reduction in ramapril /diltiazem (drug used to treat high blood pressure). **Note: Mr K is reported to be having periods of hypotension, where he is normally hypertensive.**	Medical notes
20/07/2013 08.58	On call SHO review of Mr K, who advises Mr K's operation to be discussed with an upper limb surgeon and this will happen during the week not weekend.	Medical notes
22/07/2013	Mr MK has a CT scan	Medical notes
23/07/13 19.15	Mr K transferred to A3 from A2, MEWS 0, bowels not opened Day 2, documented in the nursing records that Mr K is passing urine with no problems.	Medical notes
25/07/13 03:00	No diet from 03.00 and no water till 06.00 in preparation for theatre.	Medical notes

25/07/2013 08:35	Mr K goes to theatre for open reduction of distal humerus. 1500mls of crystalloid and 500mls of colloid given during surgery. **Note Mr K hypotensive post operatively in recovery and required another 500mls colloid. No documentation that Mr K passed any urine during the time he was in surgery**.	Anaesthetic chart
25/07/2013 15:30 approximately	Mr K returns back to ward A3. On fluid balance chart, no observation chart able to be located. Fluid chart started at 16:00. 55mls of urine passed from 16:00 up to 00:00. **Although Mr KK is not catheterised at this point, this should have triggered a response as urine output did equate to 0.5mls / kg/hour, as would be expected in an adult. This should have been escalated.** **Fluid balance did not include all fluids given in theatre therefore not accurate. If all fluids given in fluid included then balance at end of 25th July would have been 3445 mls positive.**	Medical notes and Fluid balance charts

26/07/2013	Urine output and fluid input monitored overnight. Entry in the nursing notes at 06:00 reflect that "urine output only 350mls up to now, push oral fluids, doctor happy, just keep on top of pain". There is no documentation from the medical staff to reflect this. The ward round conducted by Mr P, plan included check x-ray and bloods. Plan for proximal humerus repair on 27th July 2013. Reviewed by anaesthetist at 10.30 from acute pain team as Mr K in pain from surgery and injury. Neither Mr K's fluid balance nor poor urine output noted at this review. Gabapentin added for pain relief. Nursing notes written at 2pm record that passing urine "not great amount", only 250mls passed from 7am to 14:00pm. No documentation of escalation of concerns to the medical team. SN R reported at interview that she didn't think Mr K was in acute renal failure, thought it was post op retention. The staff nurse that provided care for Mr K on the late shift accessed his blood results at 17:10: there is no evidence that the deterioration in these were acted upon or handed over. Mr K passed urine once on that shift, and this was an unknown amount as he used the toilet. Nursing notes at 19:00 records "passing urine". There is no documentation that Mr K passed anymore urine that night. **There is no mention in the records that Mr K's fluid balance was reviewed at this ward round.** **Bloods only viewed on this day by Staff Nurse, no documentation of escalation of these to the medical staff.** **The blood results demonstrated a sharp rise in Mr K's urea and creatanine and his GFR (glomerular filtration rate) has decreased to 28 from 60 on admission. This GFR result and deterioration in renal function was not identified.** **Gabapentin that was prescribed for pain relief is known to be nephrotoxic and should be reduced in patients who have renal impairment.**	Medical notes, nursing notes and electronic results system, staff interviews

27/07/2013	Note in nursing records at 1:00 that Mr K has had large vomit (not recorded on fluid chart). No urine output recorded for the entire night shift, and urine output not mentioned. Mr K is escorted to theatre at 10:45. Anaesthetic record states that Mr K saturations and BP persistently low during procedure. BP rarely above 100 systolic throughout. 2 units of saline given (no volume recorded), 750 mls of Gelofusine given, 2 units of blood given. In addition metaraminol (a vasoconstrictor medication which increases blood pressure) was given at frequent periods throughout the surgery. Mr K's BP on leaving the recovery area was 92 systolic, he arrived back on the ward at 18:00. No urine documented to have been passed for 24 hours at midnight. Nursing notes reflect that Mr K not passed urine and not had bowels open for 6 days. No documented evidence of escalation to medical team. **Fluid balance for the day states no urine output and fluid given in theatre is not included.** **No escalation to medical staff**	Medial notes, nursing notes and fluid balance.
28/07/2013 Night shift	Nursing cardex notes that Mr K's observations recorded 2 hourly, his MEWs was 0. Nursing statement records that Mr K was offered a bottle numerous times overnight as he had not yet passed urine post operatively, also records that SHO visited ward in early hours of the morning. Doctor was informed of no urine output, no concerns from SHO as Mr K did not have a palpable bladder, advised to continue to monitor. **Medics happened to visit ward, where issues re urine discussed, NPU (not passed urine) had not been escalated as a call by NS.** **No documented review by medics.** **Failure to recognise AKI by both Medic and SN.**	Medical notes, Staff statement

28/07/2013 day	Mr K seen on Mr P ward round at 08:30am. Noted that "day 1 post op, comfortable, nil new". No evidence that blood results, fluid chart or observations were reviewed by medics. Nursing notes at 11:30 record that drain out, observations stable, Not passed urine. At 12:00 bladder scan undertaken by SN. No urine in bladder. No documented recognition that this may be AKI, or escalation to medics. Although in interview SN recalls trying to contact the medical team (SHO and Registrar) who were busy in the ED with trauma calls. Bladder scan repeated at 18:00, no urine in bladder. No documented escalation. **No documentation that this was been escalated to medical team.** **No escalation to Consultant given that other medics were busy.**	Medical notes, Staff statement
28/07/2013	SN VG came onto the night shift and handover from day team included that MK had not passed urine. This was escalated to the on call SHO who had attended the ward the night before. Entry in the medical notes at 23:17 record that Mr K has struggled to pass urine all day and that his blood results are deranged. Plan was made to repeat blood tests, insert a catheter (with Gentomycin cover), monitor urine output hourly and give IV fluids. **Note gentamycin is contraindicated in renal failure.**	Medical notes, Staff statement
29/7/2013	Mr K's blood results show further deterioration in renal function: urea is 36.6, creatinine is 635 and potassium is 7.4. MK has only passed 40mls since catheter inserted. Mr K's case was referred to medics on call, who advised critical care. MK was admitted to critical care where he had to undergo renal replacement therapy. Mr K was discharged from Hospital A on 16/8/2013	Medical notes, Staff statement

9. Lessons learned

9a. Good practice findings

Once acute renal injury is recognised the management plan is detailed and timely.

9b. Findings requiring improvement

9b.1

Cause of renal impairment in MK
As part of this investigation it has not been possible to identify when exactly Mr K developed acute kidney injury (AKI) or what caused this. It is likely that with an earlier diagnosis Mr K's AKI may have been treated with IV fluids and discontinuation of antihypertensive and nephrotoxic drugs. However the following may have been contributory to the incident:

9b.2

- **Mr K had predisposing risk factors**
  On admission to Hospital A, Mr K had normal eGFR and kidney function on blood tests. Mr K was known to have both type 2 diabetes and hypertension when he was admitted to Hospital A. Both conditions can predispose patients to renal (kidney) impairment and therefore a greater awareness and closer monitoring of his renal functions should have been employed during his admission.

  Mr K also had a permanent pacemaker device in situ and which meant that he would not have an increased heart rate (tachycardia) in periods of dehydration as his heart rate was controlled by the pacemaker.

9b.3

- **Mr K had several periods of hypotension**
  Mr K was noted to have treated hypertension and was on medication for this on admission to Hospital A (Ramipril and Diltiazem). Mr K was noted to normally have a blood pressure that was 130-140 /80. However from the point at which Mr K was admitted to Hospital A, and at several periods in the pre- and peri-operative phase, he had periods of hypotension It is difficult to say retrospectively whether the hypotension was due to hypovolaemia or something else. It is also difficult to say how long these periods lasted for with absolute accuracy as the observations charts up to and including the 29th July have not been able to be found.

  From the documentation reviewed as part of this investigation, it is apparent that Mr K's antihypertensive drugs were reduced but still continued despite the periods of low blood pressure. It is also evident that during his operations Mr K required additional fluid and drugs to raise his BP (Metaraminol).

  In a patient who is normally hypertensive and who has periods of hypotension, it is important that this is recognised and acted upon. This is because the kidneys in a patient who is normally hypertensive are used to functioning with a higher than normal blood pressure, therefore a drop in blood pressure can reduce the blood flow to the kidneys making the patient more susceptible to acute kidney injury.

  This investigation has concluded that these periods of hypotension during Mr K's pre-and peri- operative periods could have been contributory to Mr K's development of acute kidney injury although it is impossible to say with certainty.

9b.4

- **Incorrect fluid balance**
  As part of the review into Mr K's care, the fluid balance charts have been reviewed and scrutinised for accuracy and completeness. Although there are some examples of good practice when reviewing Mr K's charts from the 25th 29th July, this is not consistant for each day that is was recorded.

  The fluid balance charts that were completed on the days that Mr K went to theatre do not record any of the additional fluid that Mr K was given during surgery. The lack of this documentation could be significant, as had this information been included it would have identified that on both operation days that Mr K was in a positive fluid balance, even counting an insensible loss of 500mls. An insensible loss means how much fluid a person may lose through normal body functions this is on average 500mls. Had the fluid charts been recorded accurately they would have identified that at the end of the first operation day (25th July) Mr K was positive 3445 mls, and the 2nd operation day (27th) he was 2120 mls positive, but with little urine output. The fact that Mr K had this much additional fluid and yet still was borderline oliguric for 2 days (oliguria is defined as an adult who patient passes less than 400mls of urine in 24 hours), and anuric on the 27th July (no urine passed in 24 hours) which should have alerted medical and nursing staff to take appropriate action.

9b.5

- **Use of nephrotoxic agents**
  Based on review of the medical notes, drug kardex's and blood results; Mr K was receiving medications that could have exacerbated his acute kidney injury (nephrotoxic). Mr K was prescribed Gabapentin for treatment of his acute pain, and this drug should be used in caution and with a reduced dose in patients that have kidney impairment.

  Gentomycin (an antibiotic) was given as a stat dose to cover the insertion of his urinary catheter once it was known that Mr K was in acute kidney failure. Whilst this single dose of Gentomycin was unlikely to have had a significant effect upon Mr K's kidneys, an alternative should have been considered.

<u>Recognition of Mr K's Acute Kidney Injury</u>

9b.6

Failure to act on oliguria / anuria by nursing and medical staff
In the early hours of 28th July 2013, Mr K had had no urine output documented since 18:00 on 26th July (36 hours). The nursing staff were concerned by this but did not bleep the medical team to review, they offered Mr K a urinary bottle numerous times through the night but Mr K was unable to pass urine. They did discuss this with the SHO on call, Dr AJ who happened to be visiting the ward in the early hours of the morning.

9b.7

There is no documentation in medical notes to evidence that a clinical examination took place when Dr AJ visited the ward, but the nurse caring for Mr K that night recalls in her statement and in the nursing notes that the doctor was not concerned as Mr K was comfortable and had "no palpable bladder" (the bladder is able to be felt on clinical examination if it has large volume of urine contained within it). The doctor advised to continue to monitor Mr K. There is no evidence that there was any other escalation to medical staff that night shift despite Mr K passing no urine. The SHO's instructions were handed over to the day nursing team, who thought that Mr K was in urinary retention post surgery. At this point given that there was a possibility that Mr K was in retention there should have been a consideration to insert a urinary catheter to alleviate the retention and also to monitor the urine output.

9b.8

Mr K was reviewed by the Consultant Orthopaedic surgeon the following morning, where it was noted that he was comfortable and there was "nil new". There is no evidence in the medical notes that this review noted that Mr K had been anuric for many hours at the time of this review.

9b.9

During the day of 28th July 2013 Mr K was cared for by SN G the nurse who had accessed Mr K's abnormal blood results on the 26th July, it was documented regularly on the fluid balance chart "NPU" (not passed urine). At 12 midday a bladder scan was undertaken by SN G. A bladder scan is an ultrasound scan which allows the scanner to estimate how much urine is within the bladder. The bladder scan identified that Mr K had no urine in his bladder, this was repeated at 18:00 where there was still no urine seen within the bladder.

9b.10

The nursing staff were under the impression that as Mr K had no pain and no urine in the bladder, that he was still in urinary retention post surgery. However from review of the notes and fluid balance charts it is likely that this assumption was incorrect, as urinary retention is usually accompanied by pain, discomfort and over distension of the bladder as urine builds up within it; Mr K had none of these symptoms. The fact that Mr K had no pain, no palpable bladder, no urine in the bladder and abnormal blood results should have alerted the staff to the fact that Mr K was not producing urine as he was in acute kidney failure not post surgery retention.

9b.11

During the day of the 28th July SN G attempted to contact the orthopaedic SHO and registrar on call who were providing cover for the wards to inform them that Mr K had yet to pass urine. The content of the calls were not able to be recalled in detail by SN G at interview but she relayed information to alert the doctors that Mr K was in retention but was comfortable with no urine in the bladder on scanning. During staff interviews the SN was unable to recall how many times she contacted the SHO and registrar about Mr K, but stated that they were busy all day with trauma calls and in theatre and were unable to come to the ward. There was no escalation of concerns by the nursing staff or medical on call staff to the consultant during the day on 28th July.

9b.12

There is guidance on actions to follow if a patient has much lower urine volumes than expected and these are found on the back of the fluid balance chart and in the MEWs escalation policy. Although there were some attempts made to escalate concerns, these were not escalated above registrar level. The content of what information was handed over to medical staff is also key in this case, as the message from the nursing staff was that Mr K was in retention, but comfortable, however if the information that Mr K had not passed urine for over 36 hours in addition to his deterioration of blood results been highlighted it may have prompted different action.

9b.13

- **Failure to act on abnormal blood results**

  Mr K had blood taken on the 26th July which was the day following his first operation and the day prior to his second operation. The blood tests taken on this day were available on the electronic reporting system, from 15:10. The blood tests were abnormal and identified that Mr K's kidney function was deteriorating (Mr K's kidney function was normal on admission to Hospital A).

  From the audit trail on the electronic results system only 1 person viewed Mr K's blood results on 26th July at 17:00, this was SN G. There is no documentation that these results were communicated to the medical team or handed over to other members of the nursing team. No other member of staff reviewed those blood results until 28th July at 22:32, when Dr AJ was reviewing Mr K prior to his admission to critical care.

  This represents both an omission in the communication of deteriorating / abnormal results and lack of review of results by different members of the medical team including the anaesthetic staff, both of which may have contributed to the delay in diagnosis of Mr K's acute kidney injury. It has not been possible to interview the anaesthetic consultant who anaesthetised Mr K during his operation on 27th July 2013 as he is no longer employed by the Trust.

9b.14

- **Quality of documentation**

  As part of this investigation the medical and nursing notes have been reviewed. From the review of the medical and nursing notes there are some examples of excellent documentation, with clear, detailed, legible entries and signatures. However this is not consistant throughout Mr K's notes.

  Most notably the investigation has been unable to locate Mr K's observations charts from admission to Hospital A until his admission to the critical care unit. This has led to difficulties in the retrospective investigation as not all of Mr K's relevant documentation has been reviewed.

9b.15

- **Ward rounds**

  Mr K was reviewed by the operating consultant on both post operative days 26th July and 28th July. Following the first operation there is an entry that records that Mr K is comfortable and that his arm was neuro vascularly intact (this means that Mr K has no loss in sensation, feeling or circulation following his operation), that Mr K's observations are stable, and that bloods were to be checked. There is no record that the doctor requesting these bloods came back to review the results of these blood tests. This was a missed opportunity as the results of these blood test identified that Mr K's kidneys were failing.

  On the 28th July 2013 the operating consultant conducted another ward round with another doctor (whose designation is not recorded in the notes). This review of Mr K stated that Mr K was "post operation, day 1, left shoulder plating, comfortable, nil new". There is no evidence that Mr K was examined or his observation or fluids charts were reviewed. This represents a missed opportunity to identify Mr K's acute kidney injury, as at this point Mr K's had not passed urine for 36 hours.

During the weekend the orthopaedic consultant is expected to conduct a meeting from 8am, where all trauma patients are discussed. Following this meeting the consultants review the ward based patients who are pre operative and post operative. The consultant is then required to be present in the theatre for the pre operative safety checks prior to their list commencing from 9am. This leaves little time for the consultant to have a physical presence on the ward. Therefore the SHO on call should return to the ward to follow up on instructions and plans made during the ward round. It is clear that on 28th July 2013 this did not occur as the SHO had to attend ED. It has not been possible to investigate this further as part of this review as the SHO was a locum doctor who no longer works at Hospital A.

Management of Mr K's Acute Kidney Injury

9b.16

Once Mr K's acute kidney injury was identified on the night of the 28th July 2013 the initial management and referral to critical care was on the whole to be commended. Mr K was admitted to the critical unit where he underwent renal replacement therapy for several days. Mr K renal function recovered with the assistance of the treatment provided.

9c. Missed opportunities

There were missed opportunities:

9c.1

To recognise that Mr K was at risk of renal impairment with his pre existing conditions of type 2 diabetes and hypertension.

9c.2

To identify that Mr K had several periods of hypotension which may have contributed to the development of AKI; these may not have been treated as robustly as they could have. The periods of hypotension could have been related to hypovolaemia or may cardiac in origin.

9c.3

To review Mr K's blood results that identified that his kidneys were failing.

9c.4

To not escalate Mr K's abnormal blood results when electronic results accessed by nursing staff on 26th July.

9c.5

By assuming that Mr K was suffering with acute urinary retention despite having no pain, no distended bladder and no urine in the bladder on scan. Had Mr K been suffering with acute urinary retention medical staff should have considered insertion of a urinary catheter.

9c.6

To complete accurate recording of fluid balance which may have delayed the diagnosis of acute kidney injury.

9c.7
On Sunday 28th July when nurses raised concerns to the SHO and Registrar about Mr K's urine output, both doctors were unable to come to the wad as they were in theatre and the ED. Concerns were not escalated to the consultant on call.

9c.8
To identify the signs and symptoms of acute kidney injury.

9c.9
By no follow of blood results that were requested on the ward round and limited mention of Mr K's observations and fluid balance.

9c.10
By Mr K receiving nephrotoxic drugs despite deteriorating blood results.

10. Conclusion

10a. Actions or omissions which contributed to the incident

Based on the facts gathered as part of the investigation and the / missed opportunities outlined above, it is the conclusion of the investigation team that the following actions or omissions contributed to the incident:

The incorrect attribution of Mr K's lack of urine output was due to acute urinary retention by both medical and nursing staff.

Incorrect and incomplete fluid balance charts which may have delayed the diagnosis of AKI

Failure to recognise that Mr K had several episodes of hypotension during the pre and peri operative period, this may have been due to hypovolaemia.

10b. Actions or omissions which caused the incident – avoidable harm

Based on the facts gathered as part of the investigation and the lessons learned/ findings requiring improvement/ missed opportunities outlined above, it is the conclusion of the investigation team that the following actions or omissions caused the incident and resulted in avoidable harm:

There was a failure of the medical and nursing staff caring for Mr K to identify the signs of acute kidney injury which led to a delayed diagnosis.

Administration of nephrotoxic drugs to Mr K when he already had signs of AKI

11. Recommendations and actions to be taken

The recommendations that the investigating team has concluded as a result of this investigation, to address the findings of the incident identified above, are:

- This report and its findings will be shared with Mr K and his family

- This report and the learning from this will be shared with the medical and nursing staff involved in the incident, but also to the wider orthopaedic team to ensure learning.

- The escalation of clinical concern by the nursing staff should be escalated higher if there is inadequate response by the reviewing doctor. This should include contacting critical care outreach for advice within the scope of their hours.

- The process for patient review and initiation of recommended treatments during the ward round to be reviewed

- The Trust should implement the recommendations contained within NICE guidance CG 169, AKI: prevention, detection and management of AKI as a priority. http://publications.nice.org.uk/acute-kidney-injury-cg169
- Review of medical staffing on the weekend for orthopaedics to ensure that every patient has a review.
- Matron and Governance lead to meet with staff involved with this incident to ensure that any deficiencies in knowledge are addressed.
- Development of a guideline to ensure that high risk patients are reviewed daily by the ortho geriatric team.

END OF THIS APPENDIX

Appendix A.2: Textual parts of the recording scheme used to record the investigative hypotheses developed using the Information Safety Method

This appendix illustrates the textual recording scheme used for the main study reported in Chapter 4. This scheme was mostly developed through both a pilot Information Safety Method analysis before the main study, in addition to additional experience gained from two other preliminary analyses conducted using the Information Safety Method (**Huang** et al. 2014a). Tables A.2.1, A.2.2 and A.2.3 illustrate how the developing Information Safety Method investigative hypotheses were recorded using the textual recording scheme, with example entries from analysis of the 1st incident (involving a wrong drug), 4th incident (involving a late detection of lung cancer), and 5th incident situations (involving a late detection of patient physiological deterioration) respectively (cf. Table 4.1 in the thesis body). A custom cross-referencing scheme was used for the entries under the '**Specific data sources**' column in the three tables of this appendix. These entries referred to both particular parts from the corresponding incident investigation reports, as well as other background material consulted as part of the incident analysis process.

Schemes used to record each link of the 'information trajectories' identified through Information Safety Method analysis

Table A.2.1: Scheme for recording the information trajectories identified using the Information Safety Method.

Link identified (including selected counterfactual ones, marked with ***CF***)		**Brief summary/description**	**Specific data sources**	**Additional comments**
From this participant:	**To this participant:**			
Dispensing technician (Mr E)	Pharmacy computer system	Mr E correctly enters drug identity information into the pharmacy computer system.	[2: 13. 14. TT_{13-3}]	Technically there are 'multiple' drug identity information flows here.
Chest x-ray image report (an electronic document filed on the 25th July 2012)	Paper copy of chest x-ray image report (for faxing)	A paper copy of the electronic version of Mr G's chest x-ray image report is made; in preparation for faxing to Mr H, ENT consultant.	[20: 46. 59.]	Here we assume that a traditional paper-based fax machine was used to fax a copy of Mr G's chest x-ray image report.
The on-duty Max Fac SHO	A member of the outreach team	The on-duty Max Fac SHO 'escalates' Mrs R's BP-reading/MEWS to the outreach team.	*Sun-BP1*, *Sat-MEWS1*, *Sat-MEWS2*, *Sat-MEWS3*, *Sun-MEWS2* *****.	There did not seem to have been escalation of patient care information to the outreach team in this incident (e.g. see [26: 1.5 1.6 2.5.5]). ***CF***

***** In analysing the 5th incident situation, multiple 'sub' information trajectories were identified, to be associated with the same *information representation* (e.g., for the **Blood Pressure**, or **Modified Early Warning Score** *information representations*). To cope with the further logistical overhead introduced by this unforeseen study complication, the additional recording scheme below (Table A.2.2) was devised during the main study reported in Chapter 4. This addition helped with management and recording of the association between the Information Safety Method investigative hypotheses, and the incident data and other background material. Entries for the 2nd blood pressure reading on Sunday (*Sun-BP2*), and the 2nd Modified Early Warning Score on Sunday (*Sun-MEWS2*) are presented as illustrative examples in Table A.2.2.

Table A.2.2: An addition extension to the recording scheme shown in Table A.2.1.

Sub information trajectory identifier	BP/MEWS reading	Time at which the BP/MEWS reading was taken (24hr format)	Specific data sources	Corresponding PowerPoint slide visualisation	Additional comments
Sun-BP2	BP: 80 systolic	Between 06.30 and 14.00	[1.6 TT_{25-1} TT_{26-1} TT_{27-1} TT_{26-3} TT_{26-6}]	Slide 2	Cross-referenced 1.6 with all the entries in the [26: TT_{26}] row, to determine that a Max Fac registrar took/recorded Mrs R's BP here.
Sun-MEWS2	MEWS: 3	06.30	[1.6 2.5.4 TT_{25-3} TT_{26-3} TT_{26-6}]	Slide 9	We assume that the Max Fac registrar (working on the Sunday morning) *did not* re-take Mrs R's MEWS, and simply read-off the last MEWS reading taken at 6.30.

Scheme used to record each of the 'safety function' investigative hypotheses

Two examples are given here to illustrate how the safety functions were recorded during the main study (Chapter 4). The first entry is safety function 26, giving an example of a 'newly identified' safety function, identified through Information Safety Method analysis of the second incident situation. The second entry is safety function 30, giving an example of where an 'old' safety function's scope was successfully extended to a new Information Safety Method incident analysis – based on new incident data. This second entry is from analysis of the 5th incident situation, showing the way in which the scope of safety function 30 (originally identified through Information Safety Method analysis of the 2nd incident situation) was then extended: as a factor deemed to be relevant to the analysis of the 5th incident situation.

Table A.2.3: Scheme for recording the safety functions identified.

Safety function identified (briefly)	**More elaborate description and explanation**	**Specific safety function assignment and scoping** (i.e., 'instantiating' the abstract safety function descriptions, see Section 4.3.4)	**Specific data sources**	**Additional comments**
26: Provide a fluid challenge to each sucker.	This is another one of four standard checks that are expected to be undertaken – to ensure that the direction of a particular sucker is both correct and safe. This check did not seem to have been done by trainee perfusionist NS in this incident.	This is a *correctness-enhancing* safety function, which can increase the probability of correct *direction-of-blue-pump-tubing* information representation in *all* the pump tubing related non-human participants (e.g., the *Pump-side part of the blue tubing*; *Blue tubing for 3rd sucker (cannulated within the heart)*; and *Blue tubing for 3rd sucker (in the saline receptacle)* participants.	[7: 2.2.1 TT_{7-6} TT_{27-3}]	We assume that this check was basically an 'offline wet test' – intended to be done at time of setting-up the perfusion equipment, and substantively before the 'live wet test' at the operating table (i.e., safety function 27).

30: (Perceived) surgeon/doctor 'dominance', over 'lower' parts of the medical hierarchy (e.g., nurses, junior doctors, perfusionists etc.).	This safety function is relevant to the current analyses.	Like in [10], this acts as a *consistency-reducing* safety function here, which can reduce the probability of consistent information flow between two interacting *human* participants – where the 'receiving participant' is 'higher' in terms of their perceived 'clinical seniority'.	[26: 2.5.6 4.2.4 5.4 TT_{35-6}; 10]	To avoid visual clutter, here we do not exhaustively visualise all counterfactual consistency-links, like was done for [8: Slides 4/5].

Appendix A.3: The 8 'seed safety functions' used as a starting point for the Information Safety Method analysis reported in Chapter 4

(Adapted from **Huang** et al. 2014a, supplementary paper)

Building up conceptual models of two patient safety incidents using the Information Safety Method

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1. Introduction

This appendix reconstructs the 'final' line of reasoning taken by the first author, in constructing conceptual models of incidents using a prototypical version of the Information Safety Method. The Information Safety Method was used to help understand and reframe incident data, drawn from the investigation reports for two independent incidents. This document is based on notes taken as part of the Information Safety Method analyses done between late May and early July 2012. These earlier notes include other less certain lines of reasoning not presented here.

The first of the two incidents analysed involved an overdose of Fluorouracil [1], and the other involved an injection of Vincristine via the wrong route of administration [2]. Inline citations to the two reports are used throughout this document, to explicitly link the reasoning described to incident data from the reports. The specific references presented are indicative rather than exhaustive.

2. Information Safety Method analysis of the Fluorouracil incident situation

2.1 The information representation selected

We selected the *rate of infusion* (for the Fluorouracil drug) information representation for Information Safety Method analysis. This was the information representation eventually (wrongly) given to the patient. The reasoning by which the Information Safety Method analysis of the incident was derived is detailed below. Section 2.2 describes the reasoning leading to the information flows identified, and Section 2.3 describes the reasoning leading to the safety functions identified.

2.2 The information flows identified

Starting with the patient, the initial 'upstream' participant subsequently identified was the infusion pump [1, p13], and nurse RN #1 programmed and initiated the infusion [1, p13]. The rate of infusion information used by nurse RN #1 was informed both by her reading of the pharmacy label [1, p13], as well as by the confirmation from nurse RN #2 [1, p13]. Both nurses signed off on the handwritten medication administration record (MAR) [1, p13]. RN #1 also electronically signed for the total dose of drug to give on the computer [1, p13]. We do not know whether either of the nurses did, or did not in fact use the handwritten MAR to inform them specifically of the rate of infusion information. We do not know whether this rate information was available as part of the electronic signing off done by nurse RN #1. We do not know whether nurse RN #2 was primarily responsible for the infusion given to the patient. Nurse RN #2 did a passing check only at the request of RN #1 [1, p13]. Nurse RN #2 clearly had to have obtained information about the rate of infusion from somewhere in order to be able to do this checking. Here we assumed that the handwritten MAR was used to inform nurse RN #2's knowledge of the correct rate (prior to her signing off on it). It was unclear to us where the information in the handwritten MAR came from. This therefore formed one stopping point for analysing the flow of information, due to a perceived lack of further clear incident knowledge. Since RN #1 seemed to have used the pharmacy label to inform her knowledge of the rate of infusion, it was unnecessary for us to make a similar assumption of RN #1 also using the handwritten MAR to gain knowledge of the rate information.

We found insufficient incident data to fully and clearly trace back the flow of rate of infusion information – from the pharmacy label to its source and 'creator'. It was also unclear who prescribed the chemotherapy order used in the first place. The chemotherapy order was entered into the pharmacy information system by a pharmacy technician [1, p12-13]. We assumed that the rate of infusion information was included as part of this order. Pharmacists were also involved in this part of the information flow, but it was unclear whether multiple pharmacists were involved, and how their involvement related to the rate of infusion information specifically [1, p12-13]. The pharmacy technician clearly transcribed the rate information from somewhere else into the pharmacy information system. In this case a computerized prescriber order entry (CPOE) system seemed to exist separately from the pharmacy information system. The CPOE system was used to inform the pharmacy staff as to what must be entered into the pharmacy information system [1, p33]. We conjectured that the pharmacy label was generated by the pharmacy information system. Figure 1 shows the Information Safety Method based information flows identified.

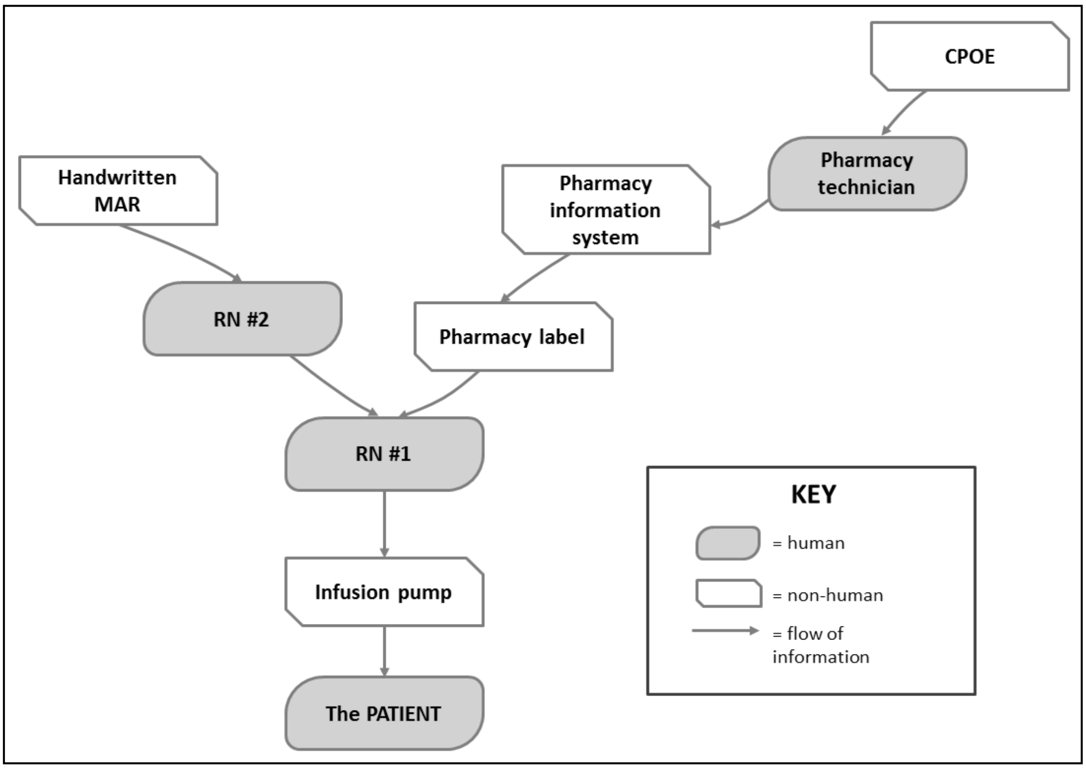


Figure 1: An Information Safety Method analysis of the flows of *rate of infusion* information.

2.3 The safety functions identified

Three safety functions were identified and reified with a degree of confidence from analysing the incident data in the report. These are detailed below. Figure 2 shows how these safety functions were perceived to relate to the flow of *rate of infusion* information.

Safety function 1: Low index of suspicion for unusual rate of infusion for new nurse

We know that nurse RN #1 was new to the day care unit where the patient was being cared for. This was the first time RN #1 administered a 4-day Fluorouracil infusion [1, p18]. The rate of infusion calculated was apparently not so unusual for other similar infusions in the clinic [1, p18]. The report holistically summarised these contributory factors, as resulting in a 'low index of suspicion' regarding the high infusion rate calculated. A reported consequence of RN #1's relative unfamiliarity with the work-setting and particular administration protocol used, was that no subsequent mental approximation of the calculated rate was done [1, p18].

We interpreted RN #1's low index of suspicion, as an aspect of the interaction context which reduced the probability of a correct rate of infusion information representation being in both RN #1's head, as well as in the infusion pump itself. This contextual aspect was perceived to reduce RN #1's chances of timely self-detection and correction, upon calculating an incorrect rate of infusion. This contextual aspect was also perceived to reduce the chances that RN #1 would detect any wrong rate values whilst programming the infusion pump (and therefore reducing the chances of a correct rate existing in the pump). RN #2 was apparently a 'trouble shooter' [1, p16]. This suggested that this 'low index of suspicion' safety function was unlikely to be applicable to RN #2 also, due to her relative familiarity and experience with the work-setting and administration protocol used at the time of the incident. This safety function may potentially apply to all such 'new' nurses, in a position similar to RN #1 at the time of this incident.

Safety function 2: Complex workload and multitasking for nurses

Nurses in the day care unit where the patient was being cared for were expected to deal with complex workloads, and often multitask between different parts of this workload simultaneously [1, p20]. In this situation, information (such as the rate of infusion) may potentially be communicated both to and from such nurses inconsistently (through misreading/mishearing for example). The additional cognitive load that may be induced through routinely needing to simultaneously manage the individual subtasks of these complex workloads, also reduces the chances for information representations to remain correct within the nurses' heads (through an increased chance of forgetting for example).

This contextual aspect of the system was interpreted by us as reducing the probability of the rate of infusion information being consistently transmitted either to or from the nursing staff involved in this incident (i.e., RN #1 and RN #2). This aspect was also interpreted as reducing the probability of the rate of infusion information remaining correct in these nurses' heads.

Safety function 3: Fallible human transcription

As part of the events leading up to the incident, the report notes that human transcription of information affords the potential for errors to inadvertently occur [1, p33]. In this particular case a mistranscription of the *volume* of Fluorouracil to be infused apparently occurred as part of the drug preparation activities in the pharmacy part of the work-system (although it is unclear precisely how this particular mistranscription occurred) [1, p33]. 'Fallible human transcription' was conjectured as an aspect of the work-context that was readily applicable in a general way, as it is clearly in general unrealistic to expect human transcription to occur routinely with 100% accuracy. This contextual aspect was assumed to reduce the probability of the rate of infusion information being consistently transmitted either to or from any human participants in such a system. The patient did not 'transcribe' information, due to being the passive destination for the rate information, so was not included in the functional scope of this particular safety function.

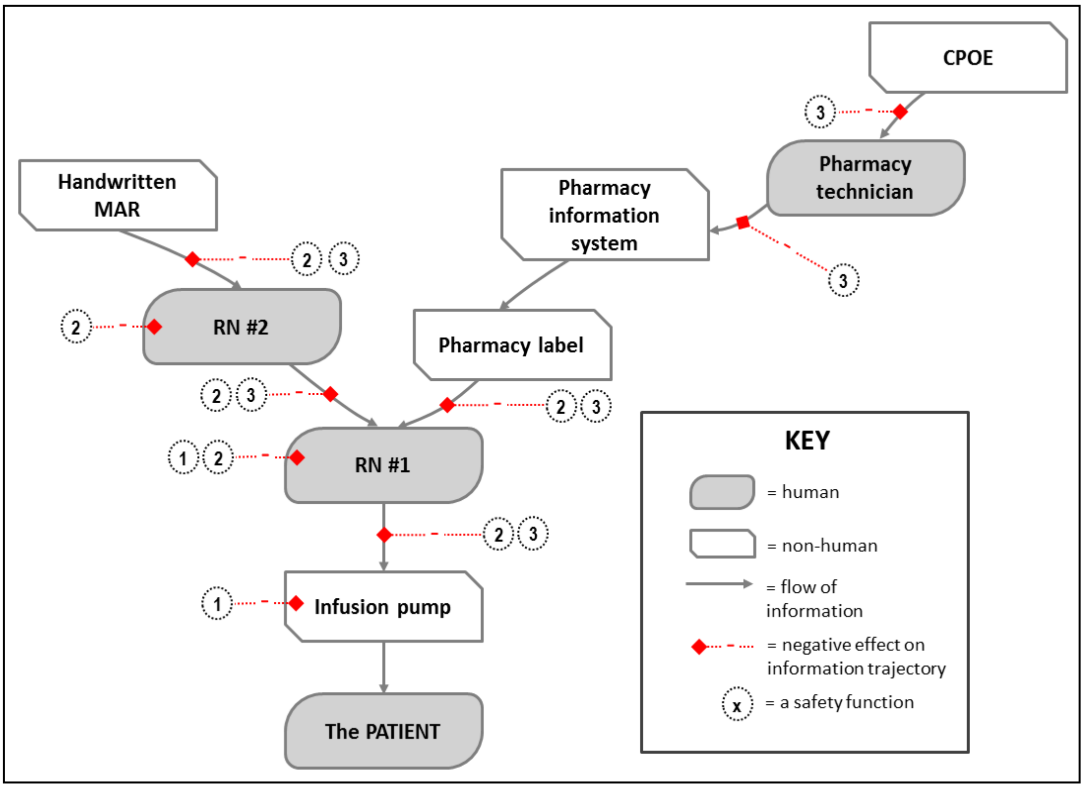


Figure 2: An Information Safety Method analysis of the safety functions effecting the flow of the *rate of infusion* information representation in the Fluorouracil incident situation. The numbered circles correspond to how the safety functions identified relate to the flows shown in Figure 1.

3. Information Safety Method analysis of the Vincristine incident situation

3.1 The information representation selected

We selected the *route of administration* (for the Vincristine drug) information representation for Information Safety Method analysis. This was the information representation eventually (wrongly) given to the patient. The reasoning by which the Information Safety Method analysis was derived is detailed below. Section 3.2 describes the reasoning leading to the information flows identified, and Section 3.3 describes the reasoning leading to the safety functions identified.

3.2 The information flows identified

Starting with the patient, the initial 'upstream' participant subsequently identified was Dr Morton, who administered the Vincristine intrathecally (i.e., via the spine) to the patient (Mr Jowett) [2, p29]. A number of other participants may have facilitated the route of administration information used by Dr Morton. Dr Mulhem confirmed this route information for the drug with Dr Morton [2, p29]. Dr Morton also consulted the patient's prescription chart [2, p29]. Route of administration information was included on the labelling affixed to the syringes used [2, Plate 1, p4]. We assumed that Dr Morton read from this syringe label before administering the Vincristine. Nurse Vallance also reportedly remarked to Dr Morton earlier about the (intrathecal) route of drug administration for the patient [2, p26]. Dr Musuka wrote out the patient's prescription chart [2, p24] (it was unclear who the original prescriber of the patient's chemotherapy treatment was). Dr Mulhem consulted the prescription chart [2, p28]. Dr Mulhem also read from the syringe label prior to handing the syringe to Dr Morton [2, p28]. We assumed that when Dr Mulhem took the packet containing the syringe with the Vincristine drug from Nurse Vallance [2, p27] he also looked at the syringe packaging label. The pharmacy database was used to generate both the syringe label, as well as the syringe packaging label [2, p13].

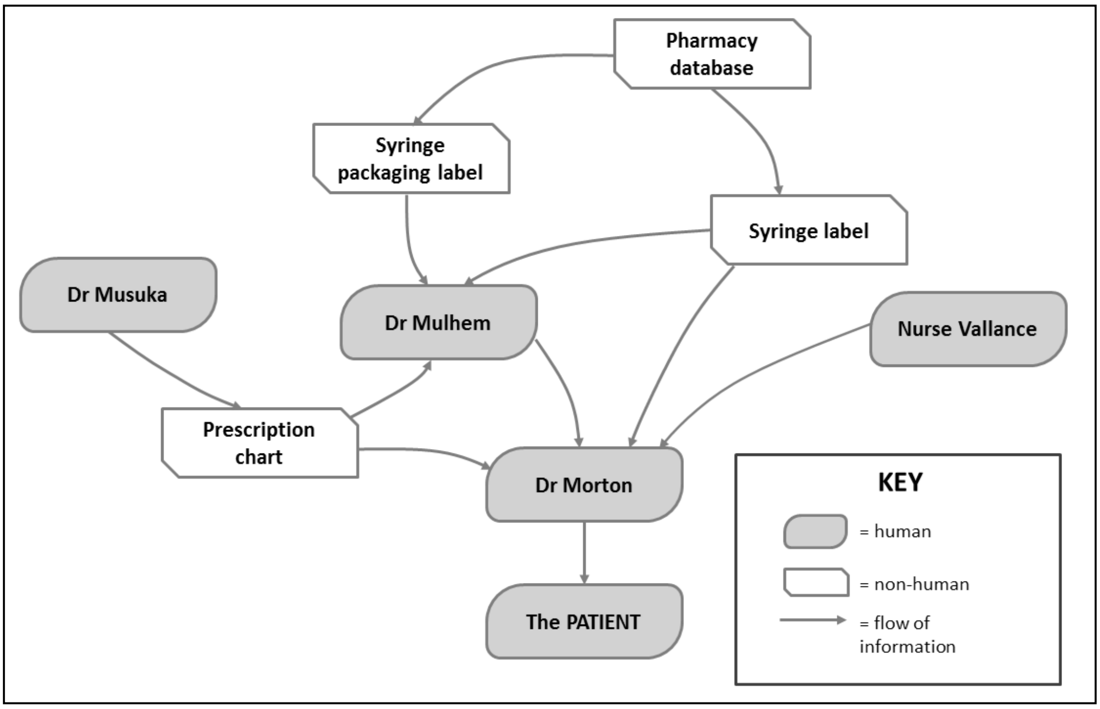


Figure 3: An Information Safety Method analysis of the flows of *route of administration* information.

3.3 The safety functions identified

Five safety functions were identified and reified with a degree of confidence from analysing the incident data in the report. These are detailed below. Figures 4 and 5 show how these safety functions were perceived to relate to the flow of *route of administration* information. Respectively without, and with the effects of safety function 3, originally identified through analysing the Fluorouracil incident.

Safety function 4: Constraints on the pharmacy database

The report states that the pharmacy database was constrained, such that only the three drugs used for intrathecal chemotherapy could be labelled for intrathecal use [2, p13]. Since the pharmacy database automatically generates both the syringe, and syringe packaging labels [2, p13], this aspect of the work-system was interpreted as a safety function that helps to preserve the consistency of the route of administration information – between its representation in the pharmacy database, and the two types of labels generated. Further specific details about how this constraint was achieved is not provided by the report, though a relatively strong enforcement mechanism is implied for preserving the consistency of route of administration information at this point in the overall flow.

Safety function 5: Physical and temporal separation of the packaging and supply of drugs to the wards

The intrathecal and non-intrathecal drugs (prepared in the Sterile Production Unit) are physically and temporally separated [2, p16], to help ensure that the route of administration displayed on both the syringe, and syringe packaging labels would always correctly reflect the intended route of administering the drugs prepared. This separation minimises the chances of inadvertent mix-ups between the labelling of drugs intended for different routes, and was interpreted as a safety function which increases the probability that the route of administration information displayed on these two types of labels would be correct.

Safety function 6: Physically bi-compatible syringe connection

Syringes containing intravenous drugs such as Vincristine may also be successfully connected to the spinal needles intended only for intrathecal administration [2, p14]. This physical bi-compatibility and indiscrimination is interpreted here as a safety function, which reduces the probability of the route of administration 'given' to the patient at the point of drug delivery being correct.

Safety function 7: Avoiding compromising patient care

In this incident, drugs intended for administration via different routes *were* in fact sent to the ward at the same time, to avoid compromising patient care [2, p36]; thus directly contradicting the temporal aspect of the normative temporal-spatial separation protocol of safety function 5. This was a 'workaround' employed by the pharmacy staff, who may have had to prepare the drugs on shorter notice than usual. Conditions existing at the time of the incident may have indirectly exerted pressure, to send these intrathecal and non-intrathecal drugs at the same time. In particular, we know that:

1) The patient's treatment information had not been entered into the ward manager's chemotherapy diary. As a result, the patient's chemotherapy had not, as was normal practice, been ordered in advance [2, p10];
2) The patient missed his planned appointment to see Dr Musuka on the morning of the 4th January 2001, and did not notify Ward E17 of his intention to arrive that afternoon [2, p10].

This 'workaround' directly negated the intended purpose of the normative temporal-spatial separation protocol, as described in safety function 5; thus representing an aspect of the system which increased the probability that inadvertent mix-ups between the labelling of drugs intended for different routes may occur.

Safety function 8: Lack of a rigorous checking procedure for the doctors

While the nurses had an explicit protocol to follow for checking the correctness of the route of administration information, the doctors did not [2, p35]. This lack of formalised checking procedure for the doctors, was interpreted as an aspect of the system that reduced the probability that the route information representation in the doctors' heads would be correct (i.e., they are less likely to self-correct). Dr Musuka was excluded from the functional scope of this safety function, because he was not directly involved in the drug delivery process.

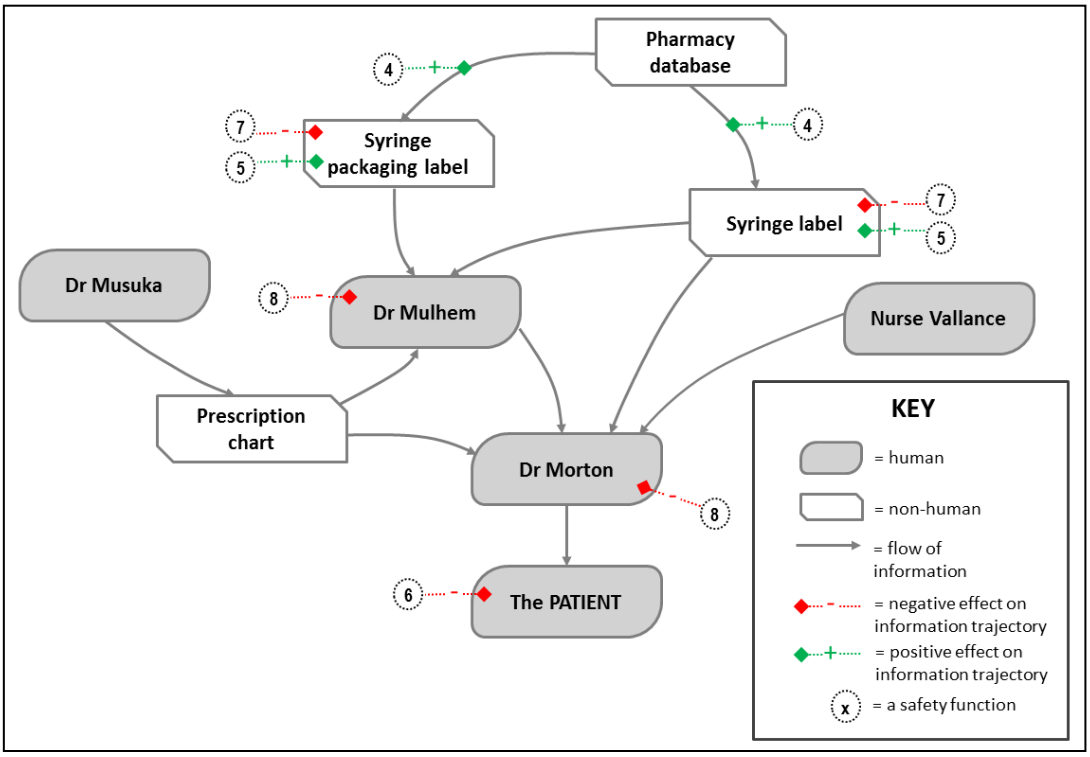


Figure 4: An Information Safety Method analysis of the safety functions effecting the flow of the *route of administration* information representation in the Vincristine incident situation. The numbered circles correspond to how the safety functions identified relate to the flows shown in Figure 3.

3.4 Generalising from the safety functions of the Fluorouracil incident situation

As part of the identification of safety functions, here, the three safety functions identified from Information Safety Method analysis of the Fluorouracil incident situation were considered in turn – for their applicability to the Vincristine incident situation. The three safety functions were:

- Low index of suspicion for unusual rate of infusion for new nurse (safety function 1),
- Complex workload and multitasking for nurses (safety function 2),
- Fallible human transcription (safety function 3).

From reading the Vincristine investigation report it was unclear to us the extent to which safety functions 1 and 2 were generalisable to the Vincristine incident situation. There were insufficient contextual details for a clear judgement of the applicability of these two safety functions, about *infusions* and *nurses* respectively. We judged safety function 3 to be sufficiently generic to be applicable to this Vincristine incident also. The analysis results which *include* safety function 3 (Figure 5) was considered to be the ‘final’ Information Safety Method analysis of the Vincristine incident situation.

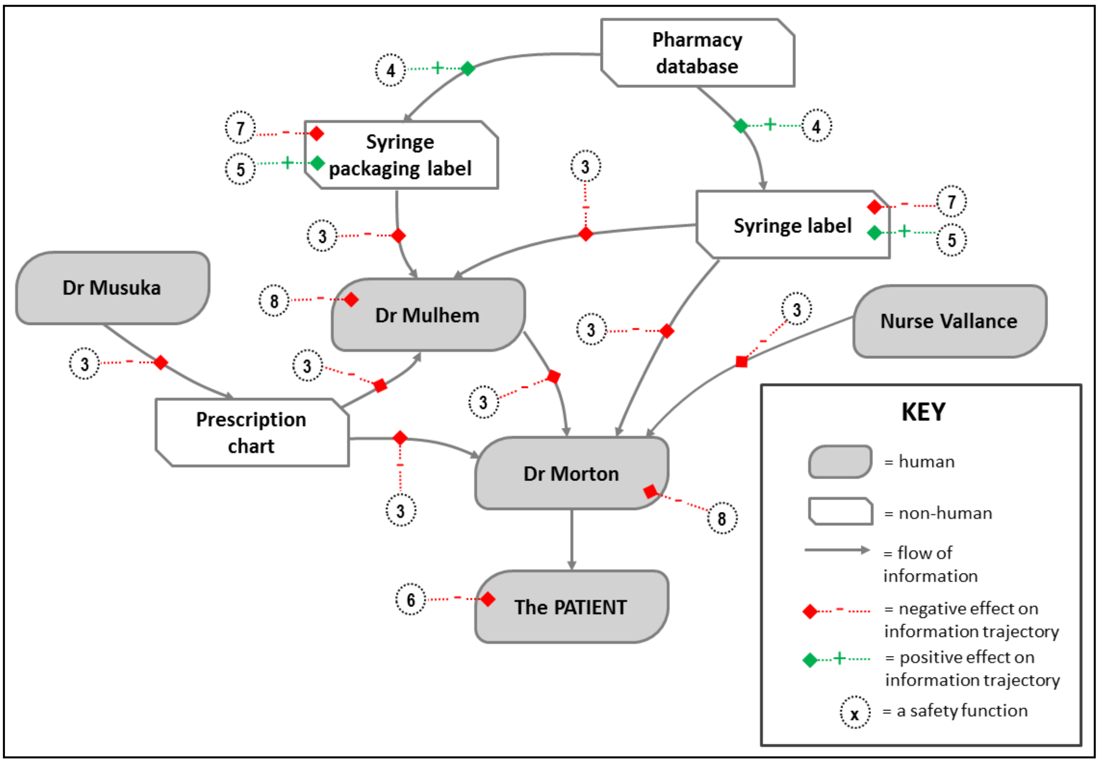


Figure 5: An Information Safety Method analysis of the safety functions effecting the flow of the *route of administration* information representation in the Vincristine incident situation. This figure includes the generalisation of safety function 3 from Section 2.3.

References

[1] ISMP Canada, 2007. *Fluorouracil Incident Root Cause Analysis.* (http://www.ismp-canada.org/download/reports/FluorouracilIncidentMay2007.pdf, accessed 20/11/2013).
[2] Toft, B., 2001. *External Inquiry into the adverse incident that occurred at Queen's Medical Centre, Nottingham, 4th January 2001.* United Kingdom Department of Health. (http://www.who.int/patientsafety/news/Queens%20Medical%20Centre%20report%20(Toft).pdf, accessed 20/11/2013)

Appendix A.4: Additional examples from the study reported in Chapter 4

Analysis of an incident situation involving a wrong drug being dispensed (1st incident situation analysed in the study)

In this incident situation, a patient (Mr P) was receiving ongoing medication to help manage Hepatitis C. As part of his treatment, the drug *Ribavirin* was prescribed; however the drug *Boceprevir* was dispensed in error instead. Both these drugs are used for treating Hepatitis C, but Ribavirin is the more standard medication option. As per standard practice, the drug dispensed was checked by both a pharmacist and an 'accuracy checker', before being given to the patient. During this dispensing and checking process, no-one realised that the wrong drug was dispensed; this error was later identified by the patient, who was concerned about the fact that his medication looked different. After contacting the outpatient clinic to seek advice, the patient brought the erroneous prescription in. He was subsequently put onto the correct (intended) original treatment regimen (involving the use of *Ribavirin*).

Figure A.4.1, Table A.4.1, and Table A.4.2 *together* show extracts from the full Information Safety Method investigative hypotheses developed. The hypotheses were in this case about how ***drug identity*** representations were coordinated during this incident, and also show the scoping of the various 'safety function' hypotheses relevant to *correct representation*, and *consistent coordination* of ***drug identity*** across the participants of this representation coordination system.

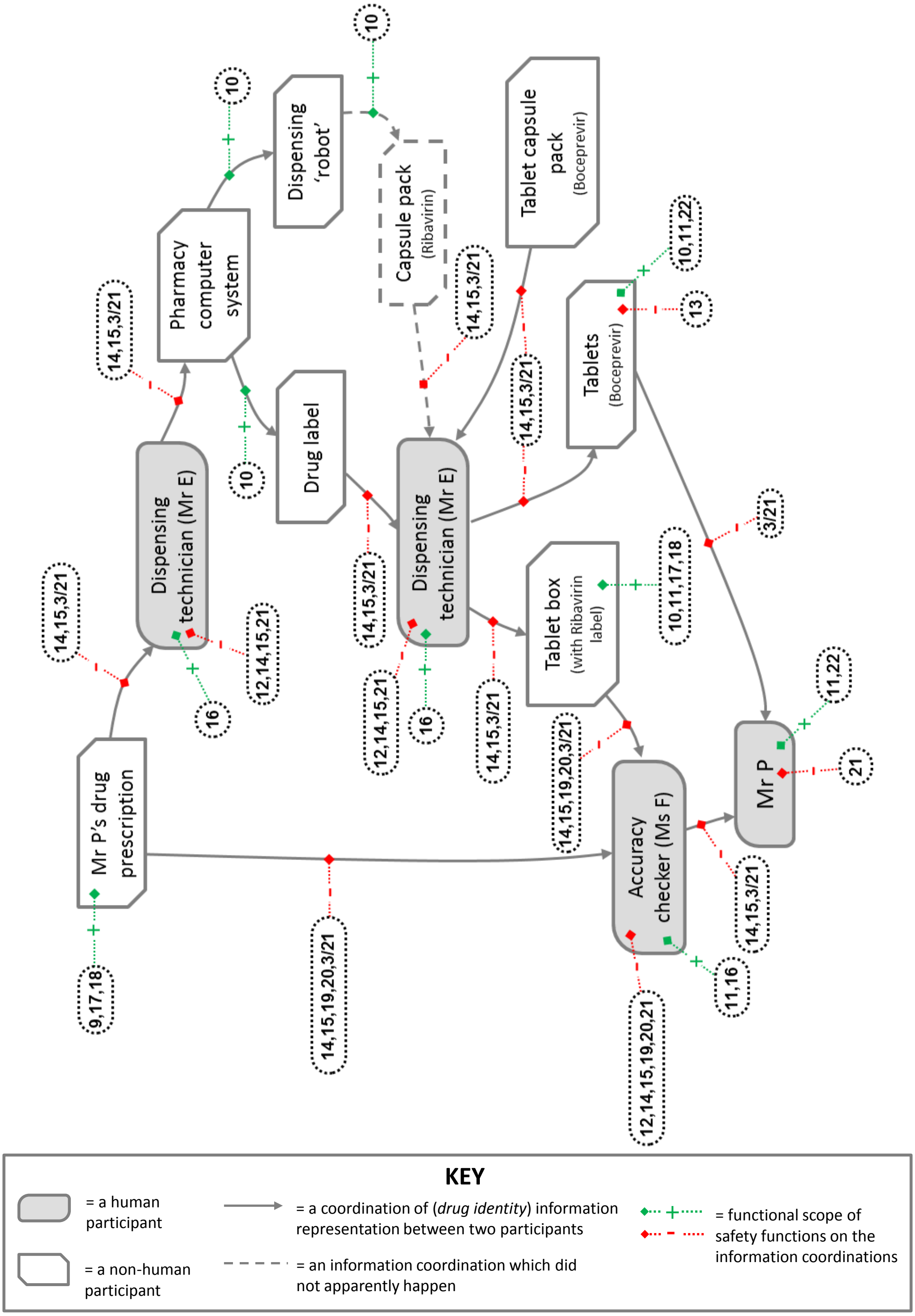


Figure A.4.1: Graphical part of the final Information Safety Method investigative hypotheses generated, showing both the information trajectory, and the safety function scoping relating to ***drug identity***.

Table A.4.1: Corresponding textual representation of the information trajectory shown in Figure A.4.1 (corresponding to each arrow in the figure, alphabetically ordered)

Links in the information trajectory (selected 'inconsistent information flows' are marked with ***CF***)	**The interaction(s) leading to the propagation and transformation of *DRUG IDENTITY* representation** (the two participants in each interactive 'flow' are indicated in **bold**)
Accuracy checker (Ms F) *to* Mr P	**Mr P** assumed that the drugs he was given were right, after being checked by the **accuracy checker (Ms F)**.
Capsule pack (Ribavirin) *to* Dispensing technician (Mr E) ***CF***	**Mr E** obtained (and looked at) the **Ribavirin capsule pack** dispensed from the 'robot'.
Dispensing 'robot' *to* Capsule pack (Ribavirin) ***CF***	The **dispensing 'robot'** automatically dispenses the correct **Ribavirin capsule pack**.
Dispensing technician (Mr E) *to* Pharmacy computer system	**Mr E** correctly enters drug identity information into the **pharmacy computer system**.
Dispensing technician (Mr E) *to* Tablets (Boceprevir)	**Mr E** puts **Boceprevir tablets** into the tablet box labelled for Ribavirin.
Dispensing technician (Mr E) *to* Tablet box (with Ribavirin label)	**Mr E** attached the Ribavirin label onto the **tablet box**.
Drug label *to* Dispensing technician (Mr E)	**Mr E** read the **Ribavirin drug label** before attaching it to the tablet box for the drug.
Mr P's drug prescription *to* Accuracy checker (Ms F)	The **accuracy checker (Ms F)** looked at **Mr P's original drug prescription**.
Mr P's drug prescription *to* Dispensing technician (Mr E)	**Mr E** correctly read the drug identity information on **Mr P's drug prescription**.
Pharmacy computer system *to* Dispensing 'robot'	This **'robot'** is linked to the **pharmacy computer system**, and dispenses automatically, based on the information entered into the pharmacy computer system.
Pharmacy computer system *to* Drug label	**Pharmacy computer system** automatically produces the **drug label** based on the prescription entered into it.
Tablets (Boceprevir) *to* Mr P	**Mr P** notices that his **tablets** looked different, and did not like the new colour of what he thought was Ribavirin.
Tablet box (with Ribavirin label) *to* Accuracy checker (Ms F)	The **accuracy checker (Ms F)** looked at the label on the **tablet box**.
Tablet capsule pack (Boceprevir) *to* Dispensing technician (Mr E)	**Mr E** obtained (and looked at) the **Boceprevir capsule pack** from out of the fridge in the dispensary, on the 'stores' side of the 'robot'.

Table A.4.2: Textual representation of an illustrative selection of safety functions (corresponding to the numerical identifiers shown in Figure A.4.1).

Safety function 'newly identified' [I], or extended [E]	**More elaborate description and explanation** (positive safety function to information trajectory associations are highlighted with **[+]**, and negative ones with a **[-]**)
9: Clinical checking of patient prescriptions by a pharmacist. **[I]**	This clinical checking "involves firstly checking the patient's allergy status to confirm the patient is not allergic to the medication prescribed. Next, the dose, frequency, route and length of treatment are reviewed" (quoted from the original incident investigation report) During this process, the checking pharmacist may serendipitously detect the wrong drug being used (e.g., if the drug is intuited to be particularly unusual for some reason?) **<u>Operationalising the Information Safety Method safety function definitions</u>** **[+]** This is a *correctness-enhancing* safety function, which can increase the probability of correct **drug identity** information representation in Mr P's drug prescription.
10: Automation of information transfer and coordination. **[I]**	The connection between the pharmacy computer system, and dispensing 'robot' is automatic; The generation of the drug label, and medication dispensation is also automatic. Ideally, this safety function helps to ensure that the drugs dispensed, and enclosing packaging mutually match. **<u>Operationalising the Information Safety Method safety function definitions</u>** **[+]** This is a *consistency-enhancing* safety function, which can increase the probability of consistent **drug identity** information flow between the following pairs of interacting participants: Pharmacy computer system -> Drug label; Pharmacy computer system -> Dispensing 'robot'; Dispensing 'robot' -> Capsule pack (Ribavirin) (***CF***). This is also a *correctness-enhancing* safety function, which can increase the probability of a correct **drug identity** information representation: in both Tablets (Boceprevir), and Tablet box (with Ribavirin label). Through reducing the chance of inconsistencies being introduced, between the drug and its packaging – as occurred in this incident.
11: Patient Question and Answer session, on conclusion of prescription delivery. **[I]**	At the end of the prescription delivery process, the patient has a short interaction with one of the pharmacy staff (assumed to be Accuracy checker Ms F). This provides an opportunity for serendipitous error detection – in the case that the wrong drug was prescribed or dispensed. **<u>Operationalising the Information Safety Method safety function definitions</u>** **[+]** This is a *correctness-enhancing* safety function, which can increase the probability of a correct **drug identity** information representation in/through the following four participants: Tablets (Boceprevir); Tablet box (with Ribavirin label); Mr P; Accuracy checker (Ms F).

13: ‘Accepted’ workaround in response to possible ‘robot dispensing’ delays. **[I]**	Periodically throughout a working-day, delays of up to 30-40 minutes could happen for the ‘robot’ that automatically dispenses the required drug. The workaround of obtaining the required drug from a different source rather than this robot, ‘overrides’ the intended consistent flow of **drug identity** information: from the pharmacy computer system, to the drugs dispensed. Thus the drugs are more likely to not be the right one, and places more reliance on the subsequent information trajectory participants to ensure its correctness. **<u>Operationalising the Information Safety Method safety function definitions</u> [-]** This is a *correctness-reducing* safety function, which can reduce the probability of correct **drug identity** information representation through the Tablets (Boceprevir) participant.
16: Substantive work-experience of pharmacy staff. **[I]**	The two pharmacy staff involved in this incident were both quite experienced. This may help them serendipitously catch errors. **<u>Operationalising the Information Safety Method safety function definitions</u> [+]** This is a *correctness-enhancing* safety function, which can increase the probability of correct **drug identity** information representation in the pharmacy staff.
19: Worrying about non-routine task to be done after the checking session. **[I]**	For the first time, the accuracy checker (Ms F) was tasked with contacting some interview candidates, after doing the checking session. **<u>Operationalising the Information Safety Method safety function definitions</u> [-]** This is a *correctness-reducing* safety function; in this case reducing the probability of correct **drug identity** information representation in Ms F. It also can reduce the probability of consistent information flow both to, and from Ms F; thus acting as a *consistency-reducing* safety function on the information flows directly relating to the accuracy checking process.
21: The ‘fallible human’ assumption. **[I]**	This is a suggested assumption of contemporary academic safety thinking; that it is unreasonable to expect 100% perfection from people all the time, and that occasionally people probably will make mistakes. (This safety function was identified in part as a response to reading in the corresponding report about completed ‘additional training’ requests for both Mr E and Ms F) **<u>Operationalising the Information Safety Method safety function definitions</u> [-]** This safety function negatively affects *all* human participants of this incident (including the patient Mr P); and the information flows to, and from them.

22: Patient's tacit knowledge of their 'routine' medication. **[I]**	As a patient gets familiar with their ongoing medication, they may develop expectations of what their drugs should look, and feel like. In this case, Mr P noticed that his 'Ribavirin drugs' looked different. In identifying this safety function, we assume that Mr P's subsequent discussion with clinicians eventually led to identifying that the wrong drug was in fact given. **Operationalising the Information Safety Method safety function definitions** **[+]** This is a *correctness-enhancing* safety function, which can increase the probability of a correct **drug identity** information representation in Mr P's head, as well as make sure that Tablets (Boceprevir) are/were indeed right (in this incident this turned out not to be the case).
Extending the scope of safety functions from Information Safety Method analyses prior to this current study (**3**, see Appendix A.3 for original)	
3: Fallible human transcription. **[E]**	**Operationalising the Information Safety Method safety function definitions** **[-]** Under similar semantics as described in Appendix A.3, this is a *consistency-reducing* safety function, which effects information flows either to, or from any human participants of an incident. Because Mr P is more of an 'active' participant in this incident, he is also included within the scope of this safety function, in the Information Safety Method analysis here.

<u>Analysis of an incident situation involving the wrong 'direction of venting' during heart transplant (2nd incident situation analysed)</u>

This incident situation was during a heart transplant operation for Mr G, the patient. As part of the first part of such an operation, a cannula is inserted into the heart – to drain or 'vent' any blood or air out of the heart before it is removed. This cannula is attached to a larger perfusion circuit, which takes over the circulatory function of the heart and lung during the transplant. In this case, the cannula blew blood/air into the heart; this was incorrect, and the cannula should have been draining instead. The patient suffered a stroke shortly after this operation. Although it is not clear whether the 'blowing' of the cannula during this operation was contributory to the stroke suffered, the hospital would like to prevent such 'wrong direction' errors from reoccurring in the future. For this reason, this episode was declared a Serious Untoward Incident, and an investigation subsequently conducted in response. For the Information Safety Method investigative hypotheses shown below, the ***direction-of-(blue)-pump-tubing*** refers to the direction of flow of liquid/air along this particular cannula – both before and after its connection with the perfusion circuit and insertion into the patient's heart.

Figure A.4.2, Table A.4.3, and Table A.4.4 together show extracts from the full Information Safety Method investigative hypotheses developed. The hypotheses were in this case about how ***direction-of-blue-pump-tubing*** representations were coordinated during this incident, and also show the scoping of the various 'safety function' hypotheses relevant to *correct representation*, and *consistent coordination* of ***direction-of-blue-pump-tubing*** across the participants of this representation coordination system.

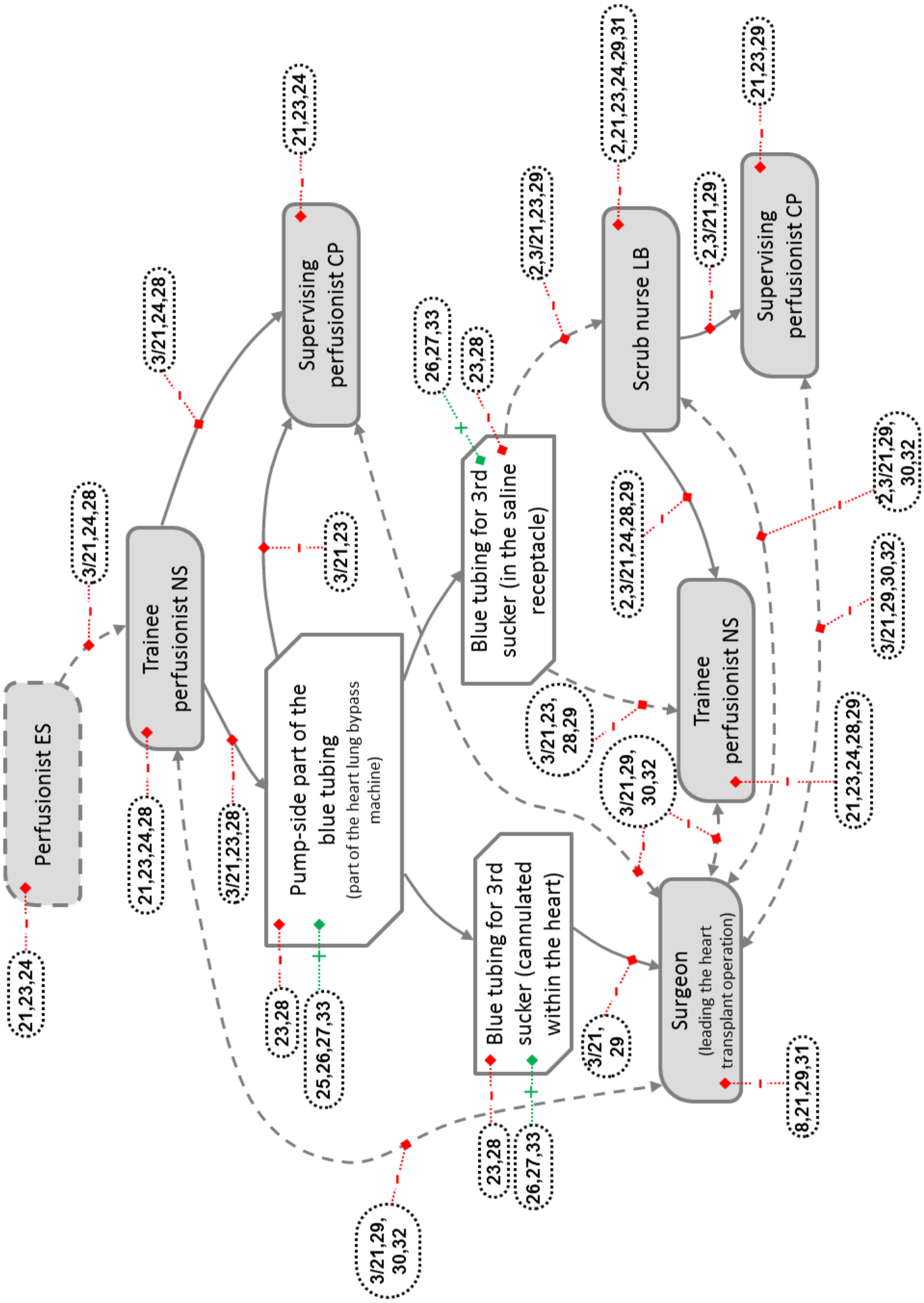


Figure A.4.2: Graphical part of the final Information Safety Method investigative hypotheses generated, showing both the information trajectory, and the safety function scoping relating to the ***direction-of-blue-pump-tubing***.

Table A.4.3: Corresponding textual representation of the information trajectory shown in Figure A.4.2 (corresponding to each arrow in the figure, alphabetically ordered)

Links in the information trajectory (selected 'inconsistent information flows' are marked with ***CF***)	**The interaction(s) leading to the propagation and transformation of *DIRECTION-OF-BLUE-PUMP-TUBING* representation** (the two participants in each interactive 'flow' are indicated in **bold**)
Blue tubing for 3rd sucker (cannulated within the heart) *to* Surgeon (leading the heart transplant operation)	On opening the heart up to relieve the increasing pressure within it, the **surgeon** discovers that the cannulated **blue tubing** appears to be blowing, when it ought to be sucking. (This is the point at which the surgery team discovered that the pump tubing was inserted in the wrong direction)
Blue tubing for 3rd sucker (in the saline receptacle) *to* Scrub nurse LB ***CF***	Ideally, **scrub nurse LB** ought to have carried out the wet test also for the **blue pump tubing**. In the case of this incident this did not apparently happen.
Blue tubing for 3rd sucker (in the saline receptacle) *to* Trainee perfusionist NS ***CF***	Ideally, **trainee perfusionist NS** ought to have had a clear line of sight during the wet-testing of the **blue tubing (within the saline receptacle)**. In the case of this incident this visual check did not apparently happen.
Perfusionist ES *to* Trainee perfusionist NS ***CF***	Before this heart transplant operation, **perfusionist ES** set up only the core oxygenator and circuit; ES then handed over to **trainee perfusionist NS**. We do not know whether information specifically about the *direction-of-tubing for the blue sucker/tubing* was explicitly discussed as part of this handover. It is important for this tubing-direction to be correct, given its role in cannulating any blood or air *out of*, and not *into* the heart as part of the transplant operation.
Pump-side part of the blue tubing (part of the heart lung bypass machine) *to* Blue tubing for 3rd sucker (cannulated within the heart)	The **blue tubing** is inserted into the **heart**, in anticipation of its imminent use in the heart transplant operation.
Pump-side part of the blue tubing (part of the heart lung bypass machine) *to* Blue tubing for 3rd sucker (in the saline receptacle)	Trainee perfusionist NS makes a physical connection between the **blue tubing** handed to her (by the scrub nurse), and the connection at the **pump** in the heart lung bypass machine. This physical connection allows potential inference about the direction of the tubing in the pump, without necessarily looking at the pump itself (through the 'wet test' using saline for example).
Pump-side part of the blue tubing (part of the heart lung bypass machine) *to* Supervising perfusionist CP	**Supervising perfusionist CP** inspects the perfusion circuit which is set up (this circuit includes the **pump-side part of the blue tubing**).

Scrub nurse LB *to* Supervising perfusionist CP	**CP** assumed that the direction of the blue tubing had been 'wet checked', based on overhearing **LB's confirmation** with trainee perfusionist NS about the wet test.
Scrub nurse LB *to* Trainee perfusionist NS	**Scrub nurse LB** verbally confirmed that (some?) suckers were 'wet tested'; **trainee perfusionist NS** seems to have assumed that the blue sucker/tubing was successfully 'wet tested' – which would indirectly signify that the blue sucker was in the correct direction.
Trainee perfusionist NS *to* Pump-side part of the blue tubing (part of the heart lung bypass machine)	**Trainee perfusionist NS** sets-up the blue '3rd' sucker tubing for the **pump (which is part of the heart lung bypass machine)**.
Trainee perfusionist NS *to* Supervising perfusionist CP	**Supervising perfusionist CP** confirmed that everything is ok with **trainee perfusionist NS**.
(***CF***) 5 other selected 'inconsistent information flows' were additionally included as part of this Information Safety Method analysis (the double-headed dotted arrows in Figure A.4.2). These flows were between the **Surgeon (leading the heart transplant operation)**, and all of the other members of the 'live' surgery team included in Figure A.4.2. **Perfusionist ES** was involved only with surgery *preparation*, and not part of this 'live' team, and thus discounted from these selected flows.	

Table A.4.4: Textual representation of an illustrative selection of safety functions (corresponding to the numerical identifiers shown in Figure A.4.2).

Safety function 'newly identified' [I], or extended [E]	**More elaborate description and explanation** (positive safety function to information trajectory associations are highlighted with **[+]**, and negative ones with a **[-]**)
26: Provide a fluid challenge to each sucker. **[I]**	This is one of four key standard checks that are expected to be undertaken before the perfusion tubing/suckers are used 'live' with a patient. With the main aim to ensure that the direction of flow is both correct and safe. This check did not seem to have been done by trainee perfusionist NS in this incident. **<u>Operationalising the Information Safety Method safety function definitions</u> [+]** This is a *correctness-enhancing* safety function, which can increase the probability of correct **direction-of-blue-pump-tubing** information representation in *all* the pump tubing related non-human participants (e.g., the *Pump-side part of the blue tubing*; *Blue tubing for 3rd sucker (cannulated within the heart)*; and *Blue tubing for 3rd sucker (in the saline receptacle)* participants.
29: Busy and high-pressured working-environment (e.g., in the 'live' operation room). **[I]**	On this occasion, a large number of people were concurrently working in the operating room. In this incident a member of the surgical team happened to physically be in the way, preventing a visual confirmation of the 'wet test' check. In addition, the scrub nurse was dealing with requests from the surgeons to pass equipment, concurrently with her perfusion circuit checking duties. This kind of very busy/high-pressured working-environment could negatively effect non-flows of information, which may otherwise have taken place; it could also lead to inadvertent information misrepresentation by each of the people involved. **<u>Operationalising the Information Safety Method safety function definitions</u> [-]** This is a *consistency-reducing* safety function, which can reduce the probability of consistent flow of **direction-of-blue-pump-tubing** information between two interacting participants where at least one is human. In principle, this safety function can affect the *consistency* of all links of the information trajectory which are within the 'live' operation room at the time of the heart transplant operation (i.e. the interactions shown in the bottom half of Figure 5.2). This is also a *correctness-reducing* safety function, which can reduce the probability of correct information representation in each of the interacting human participants, during the 'live' part of this transplant operation.

30: (Perceived) surgeon/doctor 'dominance', over 'lower' parts of the medical hierarchy (e.g., nurses, junior doctors, perfusionists etc.). **[I]**	Rightly or wrongly, some of the more junior medical staff may be reluctant to disrupt the cultural norm of hierarchical 'dominance': from 'higher' members (e.g., senior doctors, surgeons etc.). The consequent reluctance for these 'junior' members to speak up, could prevent the creation of helpful information flows to provide safety redundancy. Beyond the scope of this specific incident (i.e., in other work-contexts), this safety function could also generally reduce the chance of existing information flows (between staff from different parts of the medical hierarchy) being recreated in the future. **Operationalising the Information Safety Method safety function definitions** **[-]** This is a *consistency-reducing* safety function, which can reduce the probability of consistent information (i.e., 'break' the information flow) to, or from 'more junior' participants concurrently working with 'more senior' medical staff (i.e., the surgeon). Perfusionist ES did not directly work with more senior colleagues in this case, so is excluded from the scope of this safety function. **Additional comments** In this case the analyst decided to treat the supervising perfusionist CP as a 'more junior' member of the medical hierarchy. This interpretation may or may not be appropriate and 'accurate', and could be further clarified in principle.
33: Surgeon's medical knowledge/expertise, with respect to the expected physical behaviour of the heart – after 'vent suction' has commenced. **[I]**	As happened in this incident, the physical behaviour of the heart may contravene the physical behaviour expected by the surgeon. **Operationalising the Information Safety Method safety function definitions** **[+]** This is a *correctness-enhancing* safety function, which can increase the probability of correct **direction-of-blue-pump-tubing** information representation, in each of the tubing-related non-human participants in this incident; Here the surgeon's medical knowledge/expertise (serendipitously?) helped to trigger a 'safety-preserving' query. **Additional comments** In this case, this safety function seemed to only have been partially effective, where the level of 'blowing' – thought to be sucking – was in fact briefly increased, before the *wrong-tubing-direction* error was then detected/realised). Although intuitively probable, similar *correctness-enhancing* safety functions were not identified in this Information Safety Method analysis for the other medical staff involved. This was because the corresponding incident investigation report did not seem to document any obvious 'observed' indications of the positive effects of their expertise – with respect to the **direction-of-blue-pump-tubing** information representation.

Extending the scope of safety functions from Information Safety Method analysis prior to this current study (**2, 3, 8,** see Appendix A.3 for original)	
2: Complex workload and multitasking for nurses. **[E]**	Given the role of a scrub nurse, scrub nurse LB is also likely to have had a complex workload, and be required to multitask in this incident. **Operationalising the Information Safety Method safety function definitions [-]** This is a *correctness* and *consistency-reducing* safety function here. Similar to the incident context from which this safety function was originally identified, here this safety function could affect scrub nurse LB, and information flows to and from her. **Additional comments** This safety function is related to, but not identical to safety function 29.
3: Fallible human transcription. **[E]**	This safety function is judged to be relevant to the current incident analysis, and is partly subsumed under safety function 21 (see Table 5.3). **Operationalising the Information Safety Method safety function definitions [-]** This is a *consistency-reducing* safety function, effecting information flows both to, and from each human participant in the current incident.
8: Lack of a rigorous checking procedure for the doctors. **[E]**	As a whole, the material presented in the corresponding incident investigation report suggest that whilst perfusionists have a number of mandatory checks to follow (e.g., safety functions 25, 26 and 27), no similar such rigorous checking procedures were in place for the surgeon leading this operation. **Operationalising the Information Safety Method safety function definitions [-]** This is a *correctness-reducing* safety function, which can reduce the probability of correct **direction-of-blue-pump-tubing** information representation in the surgeon leading the heart transplant operation.

<u>Analysis of an incident situation involving a late diagnosis of Acute Kidney Injury (3rd incident situation analysed)</u>

In this incident situation, a patient (Mr K) was admitted to the hospital following a fall from a caravan roof whilst attempting to clean it. On entry to the hospital, the patient was initially treated for a bone fracture. During the time spent in hospital, he subsequently developed Acute Kidney Injury (AKI). This condition was eventually picked up, on the night of the 28th July, 2013, and the patient underwent renal replacement therapy for several days in response. In conducting an investigation into this incident situation, the hypothesis was that the detection of the patient's AKI condition, and subsequent (appropriate) response could have perhaps occurred earlier.

Figure A.4.3, Table A.4.5, and Table A.4.6 together show extracts from the full Information Safety Method investigative hypotheses developed. The hypotheses were in this case about how both the ***Creatinine-level*** and ***Glomerular Filtration Rate*** representations were coordinated during this incident situation. They also show the scoping of each safety function as relevant to *correct representation* or *consistent coordination* (of ***Creatinine-level*** or ***Glomerular Filtration Rate***) across the participants of the representation coordination system. In the case of this particular incident analysis, the same set of investigative hypotheses were identified for both ***Creatinine-level*** and ***Glomerular Filtration Rate***; both were part of *Mr K's blood test results (of the 26th)* (depicted using the same figure of Figure A.4.3).

<u>Abbreviations and acronyms used in interpreting the incident situation</u>

AKI – **A**cute **K**idney **I**njury

MEWS – **M**odified **E**arly **W**arning **S**core (this is a useful approximate indicator for detecting patient physiological deterioration, e.g., see Gardner-Thorpe et al. 2006)

SHO – **S**enior **H**ouse **O**fficer

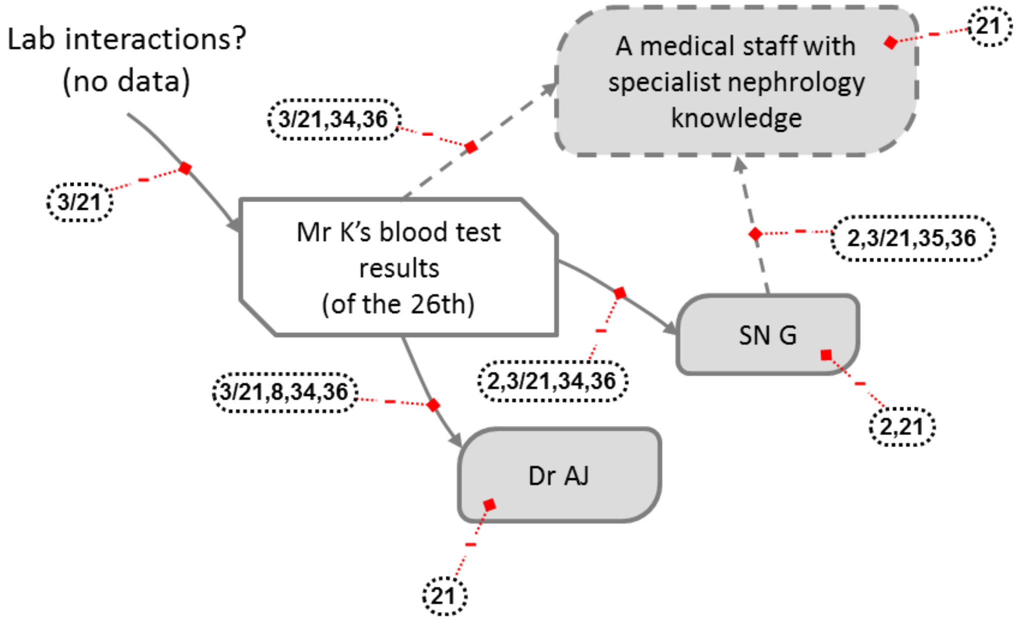


Figure A.4.3: Graphical part of the final Information Safety Method investigative hypotheses generated, showing the information trajectory, and the safety function scoping (for both ***Creatinine-level***, and ***Glomerular Filtration Rate***).

Table A.4.5: Corresponding textual representation of the information trajectory shown in Figure A.4.3 (corresponding to each arrow in the figure, alphabetically ordered).

Links in the information trajectory (selected 'inconsistent information flows' are marked with ***CF***)	**The interaction(s) leading to the propagation and transformation of *CREATININE-LEVEL* and *GLOMERULAR FILTRATION RATE* representations** (the two participants in each interactive 'flow' are indicated in **bold**)
Lab interactions? (no data) *to* Mr K's blood test results (of the 26th)	Based on the incident data available, there was no clear answer to the 'upstream mapping' question (e.g. Section 4.3.2) of: "Where did the *Creatinine-level* information 'in' **Mr K's blood test results** (stored in the electronic results system) come from?" Both *Glomerular Filtration Rate*, and *Creatinine-level* information was represented as part of the same set of **blood test results** in this incident. These **blood test results** were ordered by the operating surgeon responsible for a surgery (on the 25th) to deal with Mr K's 'initial illness' of a bone fracture. These **test results** were stored and accessed via the 'electronic results system' at the Trust.

Mr K's blood test results (of the 26th) *to* A medical staff with specialist nephrology knowledge ***CF***	**A medical staff who is particularly familiar with nephrology-related issues** reviews **Mr K's blood test results**. Acute Kidney Injury (AKI) is not a medical situation which is currently well-defined, and there is as yet no 'gold standard' for its diagnosis (National Confidential Enquiry into Patient Outcome and Death 2009, p11; National Clinical Guideline Centre 2013, p11). Consequently, it is probably reasonable to only expect **medical staff with at least a nephrology specialism** to be particularly sensitive to recognising and acting on symptoms that may be indicative of Acute Kidney Injury (i.e., *Creatinine-level*, and/or *Glomerular Filtration Rate* information, see Stevens et al. 2006 for more detailed explanation). It is unclear from the corresponding investigation report whether SN G or Dr AJ was particularly sensitive, by training, to issues of nephrology.
Mr K's blood test results (of the 26th) *to* Dr AJ	**Dr AJ** was the on call SHO, who had visited the ward earlier (where Mr K was) in the early hours of 28th July. Her review of **Mr K's blood test results** took place on a subsequent visit later this day, at around 22.32. This was due to another clinical staff's 'escalation', on finding out that Mr K had not passed urine for a substantive amount of time.
Mr K's blood test results (of the 26th) *to* SN G	**SN G** reviewed **Mr K's blood test results**. Based on the incident understanding obtained, these **blood test results** did not propagate any further through this part of the work-system, beyond **SN G**.
SN G *to* A medical staff with specialist nephrology knowledge ***CF***	**SN G** informs **a medical staff who is particularly familiar with nephrology related issues**, about Mr K's blood test results. Such a person is most qualified to appropriately act on *Creatinine-level*, and/or *Glomerular Filtration Rate* information. The motivation for stating this 'inconsistent information flow' was similar as for the other 'inconsistent information flow' entry in row 2 of this table.

Table A.4.6: Textual representation of an illustrative selection of safety functions (corresponding to the numerical identifiers shown in Figure A.4.3).

Safety function 'newly identified' [I], or extended [E]	**More elaborate description and explanation** (positive safety function to information trajectory associations are highlighted with **[+]**, and negative ones with a **[-]**)
34: Lack of routine focus on propagation of **creatinine-level** and **Glomerular Filtration Rate** information through the work-system (these are two related key indicators of Acute Kidney Injury (Stevens et al. 2006, National Clinical Guideline Centre 2013). **[I]**	The MEWS and observation charts are (related) routine aids to support monitoring of the physiological status of a patient. The two relevant organisational policies both encourage routine recording of a number of physiological parameters. However, neither the **creatinine-level** nor **Glomerular Filtration Rate** information are required to be routinely recorded as one of these physiological parameters. This reduces the likelihood that blood tests results – such as Mr K's routine ones (of the 26th) – would be routinely examined/reviewed by medical staff. **Operationalising the Information Safety Method safety function definitions** **[-]** This is a *consistency-reducing* safety function, which can reduce the probability of consistent information flow: from *Mr K's blood test results (of the 26th)*, to all medical staff involved in this incident. **Additional comments** Given the central importance of both the **creatinine-level** and **Glomerular Filtration Rate** information in supporting early diagnosis of Acute Kidney Injury; perhaps it would be helpful to include either, or both of these physiological parameters as part of routine patient monitoring and charting, in cases where the relevant blood test results are already available?
35: The substantively different nature of the original illness requiring entry to the hospital. **[I]**	Mr K's 'original' injury, on entry to hospital, was an orthopaedic one (i.e. a bone fracture). On face-value, this has little to do with Acute Kidney Failure, which is known to have relatively 'hidden symptoms', compared with more immediately obvious internal injuries (such as failure of the heart or lung, for more details see *National Confidential Enquiry into Patient Outcome and Death 2009, p7*). The substantively different nature of Mr K's original injury, could reduce the likelihood of the relevant information being 'escalated' to (other) medical staff with appropriate nephrology knowledge – through reducing medical staff's sensitivity to AKI. **Operationalising the Information Safety Method safety function definitions** **[-]** This is a *consistency-reducing* safety function, which can reduce the probability of consistent information flow to *A medical staff with specialist nephrology knowledge*, from *SN G* in the case of this incident. **Additional comments** We assume that *SN G* is not a nephrology specialist here.

<table>
<tr><th colspan="2">Extending the scope of safety functions from Information Safety Method analysis prior to this current study
(2, 8, see Appendix A.3 for original)</th></tr>
<tr><td>2: Complex workload and multitasking for nurses.
[E]</td><td>Depending on the workload at particular times of the day, this safety function can have a negative effect on the flow of patient care information. The degree to which it was relevant in this particular case is not clear from the corresponding incident investigation report; further investigation would be needed to (dis)confirm the investigative hypothesis represented by this safety function.

<u>Operationalising the Information Safety Method safety function definitions</u>
Like in the Information Safety Method analysis through which this safety function was originally identified, this consistency-reducing safety function can effect information flows either to, or from the nursing staff identified in this incident analysis (e.g., SN G).
This correctness-reducing safety function can also reduce the probability of correct information remaining correct in SN G's head.</td></tr>
<tr><td>8: Lack of a rigorous checking procedure for the doctors.
[E]</td><td>Relating to the point made in part of the corresponding incident investigation report, it seems possible that there were also no rigorous checking procedure for the doctors in the case of this incident (at least with respect to checking the blood test results). However, 'checking' is used here in a slightly different sense, from the Information Safety Method analysis through which this safety function was originally identified. Here this safety function refers to checking for the existence of creatinine-level/Glomerular Filtration Rate information (irrespective of its 'correctness'), as opposed to checking for whether the particular creatinine-level/Glomerular Filtration Rate representation 'received' is correct.

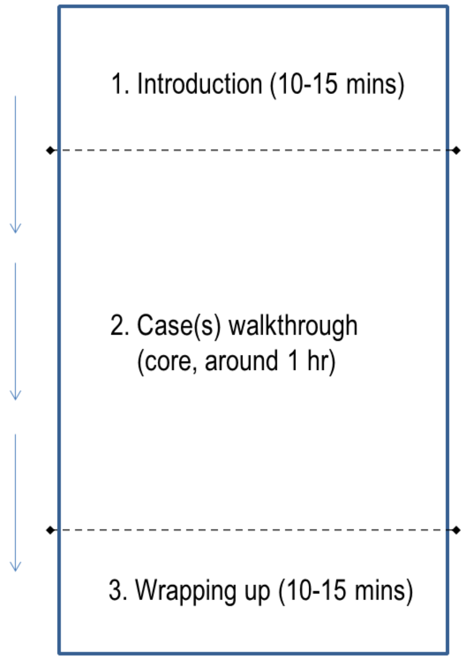
<u>Operationalising the Information Safety Method safety function definitions</u> [-]
This is a consistency-reducing safety function here, which can reduce the probability of consistent information flow to Dr AJ.

<u>Additional comments</u>
Further investigation would be needed to (dis)confirm this investigative hypothesis.</td></tr>
</table>

Extending the scope of safety functions from Information Safety Method analysis of the 1st incident situation (**21**, see Table A.4.2 for the original identification)	
21: The 'fallible human' assumption. **[E]**	This safety function is relevant to this incident. Its effects partially overlap with safety function 3 (see Table 4.2). **Operationalising the Information Safety Method safety function definitions [-]** Similar to for the incident context from which this safety function was originally identified, here this safety function also negatively affects *all* human participants of this incident; and the information flows to, and from them. **Additional comments** Like for safety function 3, if *Mr K's blood test results (of the 26th)* were entered by a person, then this safety function extends to that link in the information trajectory too. Otherwise this safety function does not apply to that link. Like for safety function 3, here we again assume that a person transcribed Mr K's blood test results into the 'electronic results system'.

Appendix B.1: A self-contained and anonymised version of the interview schedule used to support the interviews reported in Chapter 5

OVERVIEW



A graphical overview of the basic plan for each interview

Research Question addressed
What are the significant concepts for patient safety incident investigators in their investigative practice?

Each interview is designed to give insight into the interviewee's (current) investigative approach in practice. In the following, [Q] indicates possible questions to be asked. Indentation levels indicate different lines of potential questioning/probing.

Investigative *process* information is elicited first and foremost through the 'grand tour' style timeline-annotation (described in **Section 2.1**); the subsequent bit (**Section 2.2**, **Script-appendix**) will focus non-exclusively, on issues relating to investigative *rationale* and *decision-making* (in the context of the particular incident at the time).

1. Introduction (10-15 mins)

1.1 Prelude

< briefly exchange pleasantries >

... Thank you very much for giving up your time to talk with me today. For our discussion (today), I'd like to find out a bit more about how patient safety incidents are investigated in practice. {As you know, I've been working with investigator A to analyse the two incidents you kindly provided, using a new analysis approach we've developed, in our research as part of a patient safety research project}(this part is just for the second interview). As developers of our new approach, we unfortunately know very little at the moment, about issues faced by investigators such as yourself – in real investigations. Our conversation today will hopefully give us more insight into patient safety investigation work.

(Just before we start, I'd like to just quickly check, that you are still happy for our conversation to be recorded) ......

...... I also just wanted to say that we will be transcribing our conversation today, as part of the research project. But we will make sure to fully anonymise all specific names mentioned (of people, institutions etc.) when we transcribe – along the lines of the incident reports which you kindly provided for me.

Also, at any time, if you don't want to answer particular questions, it is perfectly fine to tell me, and for us to move on to other aspects of our conversation. These parts would be edited out of our transcripts.

It's also fine, if you need to take a bit of time to consider your answers at any point in our conversation.

So, before we get started, are there any quick questions, about today, you'd like to ask?

...... (pause for answers etc.)

1.2 Transitioning

[Q] To get us going, could you briefly remind me a bit about your background, and how you came to be working as an (patient safety) investigator here?

[12] < Ask about:

- length of investigation experience?
- is investigation your main and only job at the moment? >

[12] Throughout this appendix, this kind of progressive indentation towards the right hand side of the page is used to indicate alternative ways to further develop the ongoing conversation.

[Q] For yourself, what is the principal aim of a Serious Untoward Incident investigation, in a few words?

< note the one or more aims in this space above >

[Q] Could you tell me about the kind of investigation, or safety training which you have taken part in, to support your work?

[Q] Which aspects (of this training) did you find particularly helpful?
How did this help your investigation work?

[Q][13] As an investigator, how do you see yourself fitting into the 'big picture' – in terms of your particular role, and contribution to providing safe healthcare for patients?
[Q] How does your past education and training help with your investigation work?
[Q] Are there any drawbacks to having this particular background experience (in doing investigations)?

2. Case(s) walkthrough (approximately 1hr)

< make available a copy of each of the relevant 2/3 investigation reports at this point >

... For the rest of our session, I'd like for us to talk through one or two incidents in detail. Given that I'm already familiar with the incidents you kindly provided, I thought it would be best for us to focus on (one of) those. I have paper copies of each of the reports here – if we need to refer to them at any point. Is it alright with you? ... if I carry on noting down a few notes as we go through (like I did just now) – to help me remember some points which we may come back to later?

[13] Optional question; Could come back to this later at wrap-up (in Section 3).

Let’s start with ......

<u>NOTE TO SELF:</u>

In this part of the interview, make sure to be sensitive, to potential probing of degree of interleaving (or not) – between various parts of the investigative process outlined by the interviewee (in Section 2.1).

In cases where we are discussing at a very low level of descriptive detail, without obvious significant insight being gained into investigative process, rationale and decision-making, I will just let the thread of (descriptive) conversation fizzle-out naturally; and then move on to other discussions.

Also remember to try to say which part(s) of the investigation is being referred to in the discussions – to help in identifying what was being specifically referred to in transcribing the audio afterwards.

2.1 Overview of investigation process (10-15 mins? including minor <u>descriptive</u> clarifications)

[Q] In two or three sentences, could you describe for me what was the incident here (in this case).

[Q] Very roughly, how many hours (or days/months) of work do you reckon this investigation took?

[Q] With the aid of annotating on this timeline < referring to Appendix B.2 >, could we talk through the major parts of this particular investigation, and the work you did in each part? The dates or times don’t have to be very precise, it’s just to help us get a shared understanding of roughly what happened when, and in what order - in terms of your investigation work for this incident.

< As account develops, note down *<u>decision points</u>* for later – in the space below >

[Q] Briefly, what were the main challenges[14] in conducting this investigation? (simply get them to enumerate/state at this point, without getting into details).
< write down below >

< come back to this list later, as part of probing issues of process, rationale, and decision-making >

2.2 More details about specific parts

- often better to ask about 'how' or 'what informed ...' questions.

[Q] Could you talk me through how your understanding of this incident developed, as the investigation progressed – as we move through each of the parts outlined here? (referring to the timeline (i.e. Appendix B.2) being annotated)

[Q] What did you use to help you with XXX ?

--- [For earlier/less-certain parts of the investigation] ---

[Q] At this point (referring to a particular part), how did you decide what further information you needed, to better understand the incident?

--- [For near-to-end parts of the investigation] ---

[Q] How did you decide when enough was known about this incident? (to respond appropriately to it?)

[Q] What do you do if there is insufficient information available to support firm conclusions (at this point)?

--- [To elicit knowledge about uncertainties? and how they were dealt with in each part as investigation progressed] ---

[Q] What were your (main?) concerns regarding the investigation at this point?

[Q] How was XXX addressed?

[Q] What additional kind of information could have been helpful at this point?

[14] Consider the potential kinds of challenges and my responses here.

[Q] Did Root Cause Analysis help at this point?

How? Why-not?

< In this part, perhaps ask about:

1. Supporting conceptual-tools/diagrams/documents? And their roles/contributions to investigation process?
2. Focus on rationale/decision information in this part (e.g., how ‘fact collection’? how incident analysis and inference?); also see **Script-appendix** section) >

3. Wrapping up (10-20 mins)

3.1 Transitioning

[Q] Having led the investigation of each of these two incidents, do you think either of them could happen again?

[Q] Why? Why not?

< probe around how their investigation helped to (in principle) prevent future (re)occurrences >

[Q] You mentioned earlier that the principal aim of a Serious Untoward Incident investigation is to XXX (referring to the aim noted earlier in the **1.2 Transitioning** section); in (each of) the (two) incident(s) we went through today, how was this aim achieved?

< If rapport is good: How do you think patient safety investigations can be improved ? >

[Q] What would you consider to be the key criteria, in conducting a high quality investigation?

< If rapport is good: then probe around the degree to which they perceive the investigation(s) we’ve just discussed to have satisfied their own stated criteria >

[Q] In a few words, could you help me understand what it means for something to ‘cause’ something else?

3.2 Final wrap up

... thank you very much for having me here today, we’ve covered a lot of ground I think. I’d just like to get a few final thoughts before finishing up ...

[Q] For yourself, is there such a thing as a ‘typical investigation’?

< If YES: ask about perceived typical characteristics?
If NO: why not? >

[Q] For yourself, is there such a thing as a ‘typical incident’?

< If YES: ask about perceived typical characteristics?
If NO: why not ? >

[Q] In your opinion, does intuition or creativity have a role in your investigative work ?

[Q] How? Why?/Why-not?

Finally, is there any significant aspect of the way you approach your investigation work, which we've not managed to touch on today?

END OF INTERVIEW

A couple of other potentially useful questions (optional)

[Q] Could you very briefly talk me through a memorable success story from the investigations you've led ? (probably to be put somewhere in the INTRO of Section 1 ?)

[Q] From your perspective, how have the investigations done here improved the safety of patient-care at this Trust? (probably to be put somewhere in WRAP-UP of Section 3)

Script-appendix: Some potential stubs for probes

<u>'What' questions</u>

What are the benefits of XXX ?
What are the drawbacks of XXX ?

What informed ... decision XXX ?
the way you XXX ?

What was your strategy for ... (overcoming some difficult aspect of the investigation) ?
[Alt.-form] What strategy did you use to XXX ?
What alternatives (for doing XXX) did you consider at this point ?
[Alt.-form] Were other approaches to XXX possible at this point ?
What factors informed the particular choice you made (here) ?

<u>'How' questions</u>

How did you ... (do) XXX ?
go about XXX ?
make decision XXX ?
make sense of XXX ?

How did XXX help – at this point ? (where XXX is an action/choice/decision)
Did XXX turn out to be helpful ?
How? Why? Why not?

How do you generally do/decide XXX ? (← A probe for more generalised heuristics, inductively based on concrete specifics; <u>this will be used only sparingly</u>, to open up perceived significant generic aspects of investigative *process*, *rationale* or *decision-making*)

How did this part of the investigation influence the other/later parts ?
[Alt.-form] How did part XXX of this investigation affect the subsequent investigation ?

<u>'Why' questions</u>

Could you talk me through the reasons for XXX ? (e.g., doing-XXX / deciding this way)

<u>Prompting for alternatives and elaborations</u>

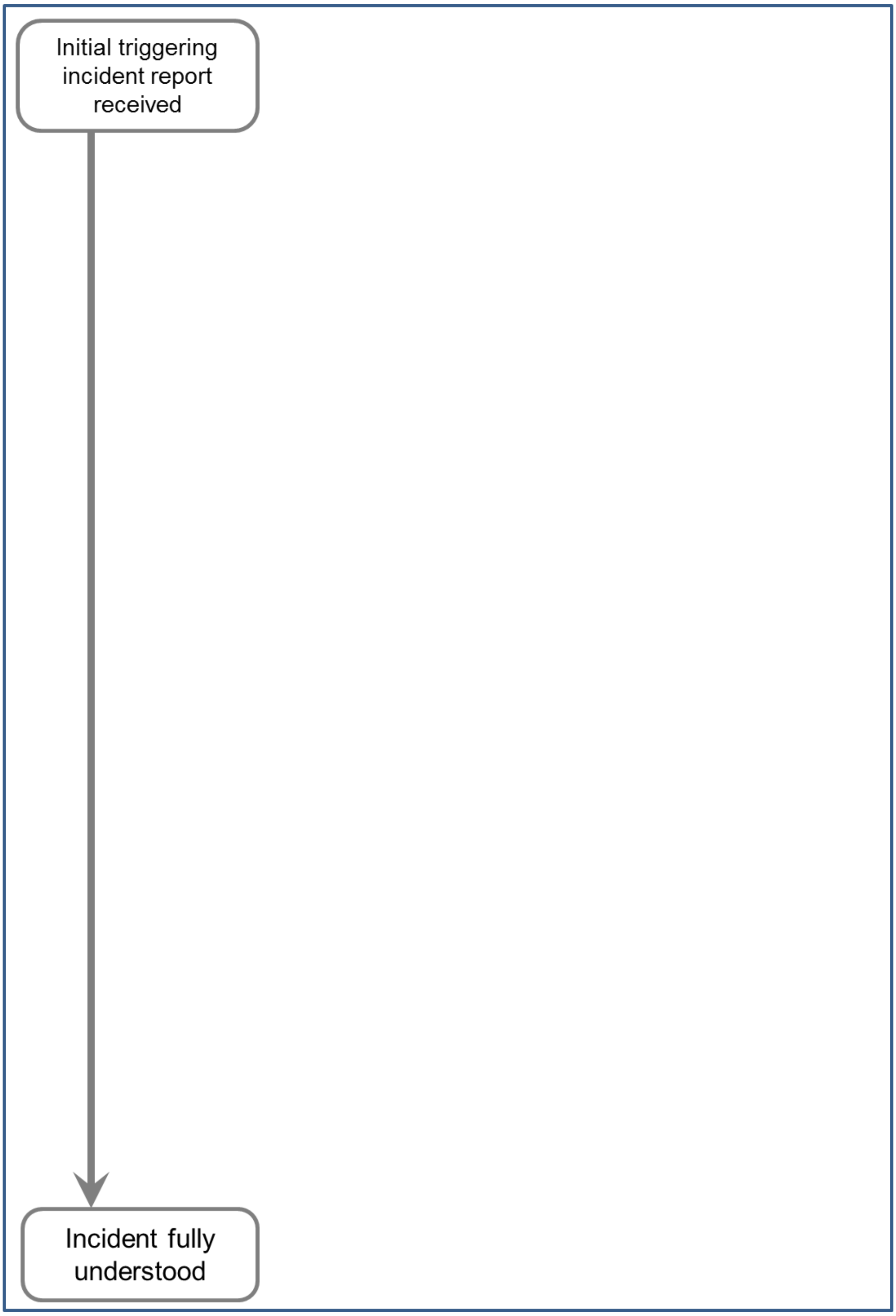
In retrospect, would you have done anything differently in how you approached this part ? (of the investigation)
< If answers YES: probe more into the motivations, reasons etc. for this bit >

Were there any complications ... (in doing/attempting XXX) ?

Did you use information from past incidents to help with XXX ?
< probe into: what information ?
how was it used ?
other aspects of *rationale*, and *benefits*/*drawbacks* of using this information ? >

Could you tell me a bit more about the role of ... (some artefact or conceptual support) ?
How did XXX help ?
When did you use ... (some artefact or conceptual support) ... in this investigation ?
(e.g., throughout entire investigation, parts of it, etc.?)

Appendix B.2: The interactive A4 timeline used to support each interviewee's recall of the past



Appendix C.1: The 'systemic Root Cause Analysis' investigation, used as primary data for the conduct of the Systematic Reanalysis Method analyses

(Adapted from **Huang** et al*.* 2013b)

A chronological record of the data collection and analysis part of a Root Cause Analysis investigation into a parking incident

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CONTENTS

1. Introduction

[i-1]

This appendix is based on early notes providing a detailed *chronological* account of how a full system-based understanding of an everyday incident evolved using the Root Cause Analysis (RCA) investigative approach. The incident investigated was one where a car parking space was paid for, but the driver forgot to display the ticket showing proof of purchase of a parking space. The incident occurred on Monday 10/9/2012.

[i-2]

The investigation into this incident followed the RCA approach as described in [1]. The information presented in this appendix represent the investigative findings of the lead investigator (first author), who was also the driver involved in this incident. In this case the investigator was operating as both investigator and information-provider, so different terminology is used to represent each role throughout this appendix. '*A1*' represents the investigator operating in the role of information-provider, and '*investigator*' represents the investigator operating in the role of a novice RCA-user.

[i-3]

In this investigation, over 17 man-hours were dedicated specifically to fully evolve a satisfactory investigative understanding of the system. On top of this, over 28 additional hours were spent on reviewing, consolidating and writing up these results to ensure a faithful account of the investigative process which took place. No artificial time limit was imposed for this process, and the investigator was able to take as much time as necessary to do the RCA, until satisfied with the overall investigative understanding of the system.

[i-4]

This evolving understanding of the system was based on applying steps 1-6 (out of 8) of the RCA manual [1, p22], and completed by the end of the 27th day (7/10/2012) after the occurrence of the incident (10/9/2012). After completing step 1-6 out of 8, the investigator has finished fully understanding all of the potential factors under consideration [1, p28] with respect to this incident. The results of steps 7-8 of the RCA process prescribed by [1] will be discussed elsewhere, as they consist simply of using the existing understanding of the incident from the first six steps to derive a set of appropriate responses to improving system safety for the future.

[i-5]

The entirety of [1] was used to inform and guide this RCA-based investigation. The investigator considered the following sections of [1] to have particularly significantly informed, and shaped the way in which this investigation was carried out:

- The main procedural guidance used in facilitating the RCA was described in the '*Root Cause Analysis Process*' section of [1, p22];
- An overview of the main purpose and role of RCA (last 2 paragraphs of the *Preface* section [1, p4-5]), as well as some key properties of a thorough and credible RCA-based investigation (expressed in the *Essentials of Root Cause Analysis* section [1, p10]) were important broader considerations kept in mind throughout the investigation described in this appendix;

- The triggering categories recommended in Appendix C of [1] (see [1, p44] and [1, p13]) were used to inform how the contributory causal factors and root causes leading up to this incident were investigated (step 6 out of 8 according to [1, p22]).

[i-6]

The results from applying steps 1-6 of the Root Cause Analysis [1] are presented in section 2 of this appendix, which gives a detailed account of how the understanding of the incident evolved in this investigation. Throughout this appendix 'contributory factors' and 'contributory causes' are used interchangeably (in a synonymous way).

[i-7]

This appendix has been through a series of revisions. All were in the interests of reducing unintended communicative ambiguities only. On each revision, particular care was taken to not make any semantic changes to the detailed account of the evolving actions and findings of the investigation done.

[i-8]

2. An account of the evolving system-based understanding using RCA [1]

2.1 Gather information

[1, p23]

[a-1]

The first step of the investigative process prescribed by [1] is to gather some initial information. The investigator was the *"...one or two key individuals to collect and review the information and construct an initial understanding of the event for analysis..."* [1, p23]. Initial incident information was gathered by the investigator on-site at the time of finding the parking ticket (on the same day the incident occurred), and reflectively consolidated later on that evening.

2.2 Initial understanding

[1, p23]

[a-2]

The second step of the investigative process prescribed by [1] is to form an initial understanding of the incident based on the initial information gathered. The initial understanding derived from the information initially gathered is presented in Figure 1.

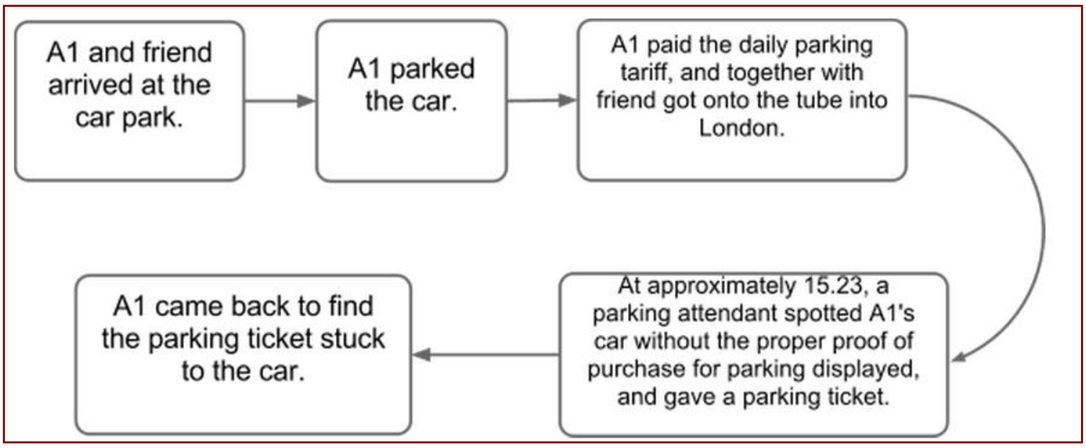

Figure 1: An ‘initial understanding’ of the parking incident

[a-3]

The accompanying narrative prose is provided below:

On Monday the 10th of September, 2012, A1 and friend arrived at a car park near a London tube station. A1 parked the car, and then together with A1’s friend got on to the tube going into London. At approximately 15.23, a parking attendant spotted the car without a valid proof of purchase for parking displayed, and gave a parking ticket for this. Later in the day, A1 came back to find the parking ticket stuck on the car.

2.3 Collecting additional information

[1, p23]

[a-4]

The third step of the investigative process prescribed by [1] is to gather more detailed information about the incident, based on the initial understanding obtained as a result of the previous steps. To collect further information a return visit was made to the incident site [1, p23], and photographic evidence[15] was collected and reviewed as part of this third step. The review of these photographs supported reflection on the contributory causes leading up to the occurrence of this incident - when the proof of purchase for the parking space failed to be displayed. [1] suggests that this is done by *“...exploring such things as possible contributory factors and suggestions for preventive measures and barriers...”* [1, p24]. The initial question used to help focus the collection of additional information was:

‘Why did A1 forget to display the proof of purchase for parking after paying’?

[a-5]

The investigator felt that on its own, this initial question was too vague to ensure all the appropriate information and evidence would necessarily be collected from the return visit to the incident-site. In the interests of maximising the productivity of this return site-visit, five additional causal hypotheses based on this initial question were used to support the collection of additional information.

[15] The first author is happy to make this photographic evidence available on request, for the purposes of independent scientific usage only and no other purpose.

[a-6]

A1 forgot to display the proof of purchase for parking after paying because ...

For CATEGORY 1: Human factors (communication)
A1 was not aware of the need to display after paying at the time.

For CATEGORY 2: Human factors (training)
The two previous car parks used by A1 were under the same management as the one used in this incident. As a result, A1 was expecting that the general procedure with respect to car parking was probably going to be the same.

For CATEGORY 3: Human factors (fatigue/scheduling)
A1's friend was in a bit of a rush to get into London quickly. So A1 was inclined to try to get the parking sorted as fast as possible.

For CATEGORY 4: Environment/equipment
The signage in the car park was far from perfect. In particular, there was only incomplete signage coverage of the car park, as well some old signs which were still inappropriately there. The writing on all the related 'don't-forget-to-display' signs were quite small too. A1 felt that the signage was particularly ineffective given that the car park was situated right next to a busy tube station - perhaps the car park management ought to have taken into consideration users who may be rushing to get into the station quickly.

For CATEGORY 5: Rules/policies/procedure
There was only one full densely-written sign nearby with the full terms and conditions of car park usage. However, the density of the writing on these signs is likely to put people off fully reading and digesting these conditions - this was the reason why A1 did not read this sign in any kind of detail at the time. At the time of parking and paying, A1 was thus unaware of both the potential penalty charge amount, and the various associated conditions under which this penalty may be given.

2.4 Literature review

[1, p24]

[a-7]

The fourth step of the investigative process prescribed by [1] is to perform a literature review, to gain some understanding into the broader context within which this incident occurred. For example, relevant protocols and similar cases in the past may be of particular relevance in informing the investigative focus and process in this investigation. As an everyday incident was investigated, rather than an industrial example, there was not much directly relevant case-based literature found to inform the investigation of this incident. There were also very few *"leading practices or evidence-based guidelines relevant to the critical incident"* ([1], p24) to help inform investigative procedure in the context of this everyday scenario. The most relevant and useful resources found were ones such as [2], [3], and [4].

[a-8]

[2, 3, 4] resulted from a Google search for existing literature of relevance to this case. Search phrases used included:

- “preventing forgetting to display in future”,
- “remembering to display parking ticket”,
- “forgetting to display parking tickets”,
- “parking fines”,
- “parking fines what to do if you have paid but forgot to display”.

[a-9]

These kinds of search phrases generated a large number of hits from the Google search engine. Most results returned were however relatively similar (the last section of this appendix shows a representative sample of some of the more relevant results), and concentrated predominantly on how to better fight, or appeal against tickets issued by a variety of public and private authorities, for a variety of reasons. No directly-relevant material was found in the half-day or so used to search on Google for results specifically related to cases where ‘*a parking space was paid for, but the proof of purchase failed to be displayed*’. Given the apparent complete lack of relevant results at the end of the time spent searching on Google, the investigator judged that it wasn’t sensible to spend any more investigation-time attempting to find directly-relevant literature in the context of this particular investigation.

2.5 Timeline and ‘final understanding’

[1, p24]

[a-10]

The fifth step of the investigative process prescribed by [1] is to use all the information gathered so far (including any relevant information from the literature review described in section 2.4) to construct an appropriate final understanding of the incident, this forms the basis for exploring the contributory factors and root causes leading up to the incident (described in section 2.6 of this appendix). Using the information collected from the previous steps, such as the photographic evidence collected in the *Collecting Additional Information* step (see section 2.3 of this appendix), the final understanding ‘narrative timeline’ is shown in Figure 2 - taking into account also the contributory factors identified in the investigation so far [1, p24].

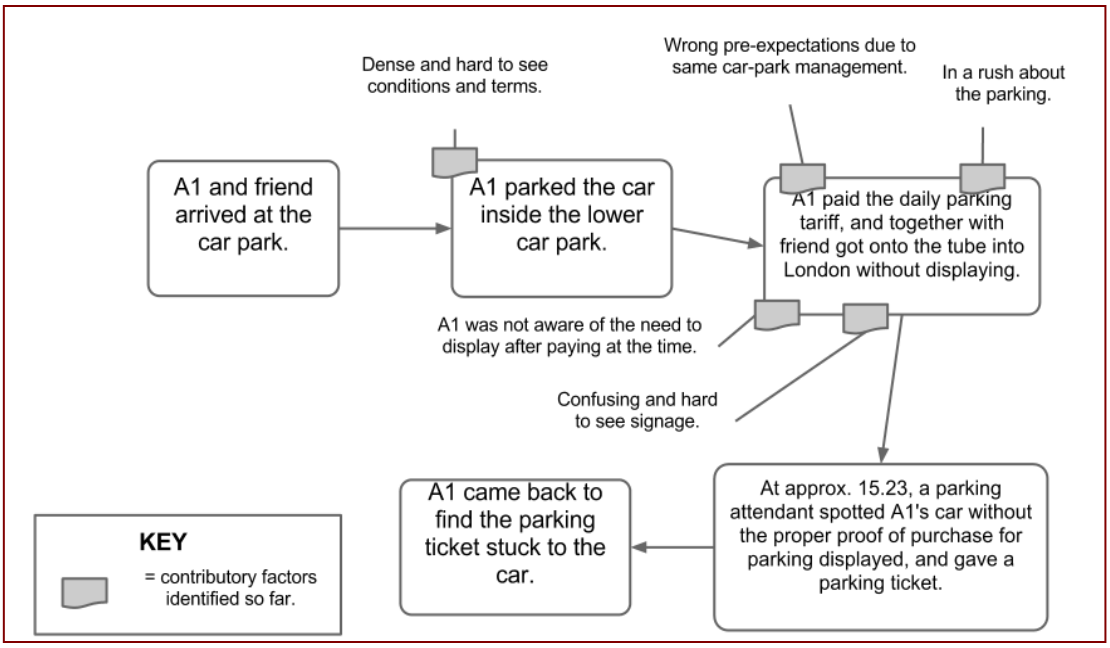

Figure 2: A 'final understanding' of the parking incident

[a-11]

The supporting prose narrative is below:

> *On Monday the 10th of September, 2012, A1 and friend arrived at the lower car park near a London tube station. There were no terms and conditions displayed at the entrance to the car park (i.e., 'dense and hard to see conditions and terms'), but A1 parked inside anyway thinking that everything would be fine. A1 then paid the daily parking tariff and got onto the tube into London having paid the appropriate amount, but without displaying the proof of purchase.*
>
> *There were a number of reasons that A1 articulated for forgetting to display the paid-for ticket:*
> *- he was in a rush to help the friend get into London quickly;*
> *- he was not at the time aware of the need to display the proof of purchase for parking;*
> *- he had previously used two car parks owned/managed by the same company. On both times, the parking was not a pay-and-display based one, but one where the user of the car park was expected to take the proof of purchase with them. He had a preconception that this car park would operate in the same way;*
> *- The signage regarding/reminding users to pay and display was both slightly confusing, and also hard to see (small signs, and signs did not cover all of the car park).*
>
> *In the afternoon, a parking attendant spotted the car without a valid ticket displayed whilst out on their rounds. At around 15.23, the attendant wrote out a parking ticket for this car. Later that evening, A1 came back to find a parking ticket stuck to the car, and was rather unhappy at the whole affair.*

[a-12]

The investigator felt that it was not necessary to construct a table with specific timings of events [1, p25] for this investigation, as the sequence of events leading up to this incident was relatively simple. Suffice to say that the final understanding presented here was predominantly based on the investigator/A1 reflecting and recalling the relevant events, supported and corroborated by the substantial documents and evidence collection resulting from his previous preparation for an appeal against the apparently excessive penalty charge of £75 which was levied. This holistic evidence base formed the data on which this investigation is founded.

[a-13]

The investigator previously found very little directly relevant case-based literature relating to conducting a RCA-based investigation into a car parking everyday incident (see section 2.4). As such, he judged the literature review step, in this case, to have had relatively little practical effect on the subsequent steps and findings of this particular investigation.

2.6 Determining the 'contributory factors' and 'root causes'

[1, p26]

[a-14]

The sixth step of the investigative process prescribed by [1] is to use all the information gathered so far to explore the possible contributory factors and root causes leading up to the incident. The Ishikawa ([1, p27]) diagram was chosen in preference to the tree diagram ([1, p27-8]) due to the fact that it provided a much more specific and structured representational framework with which to represent the evolving system understanding relevant to this incident. The assumption/choice made by the investigator here is that the usage of the more structured diagramming alternative is likely to produce relatively more, and higher quality investigative results for subsequent analysis and discussion. The 'triggering categories' used in the Ishikawa diagram template provided in [1] draws on Appendix C [1, p44], which includes a 'barriers' category that is discussed only towards the latter parts of Appendix C, but not in the initial sections of Appendix C.

2.6.1 An understanding of the major contributory factors

[a-15]

Figure 3 presents the initial 'top-level' understanding of the causal relations in this incident. In this diagram, the contributory causes previously identified in Figure 2 (in the grey 'call-out' boxes) are re-couched in terms of the system perspective encouraged by the Ishikawa diagram template given in [1]. At this point of this investigation, the investigator was satisfied that all the relevant major causes were identified.

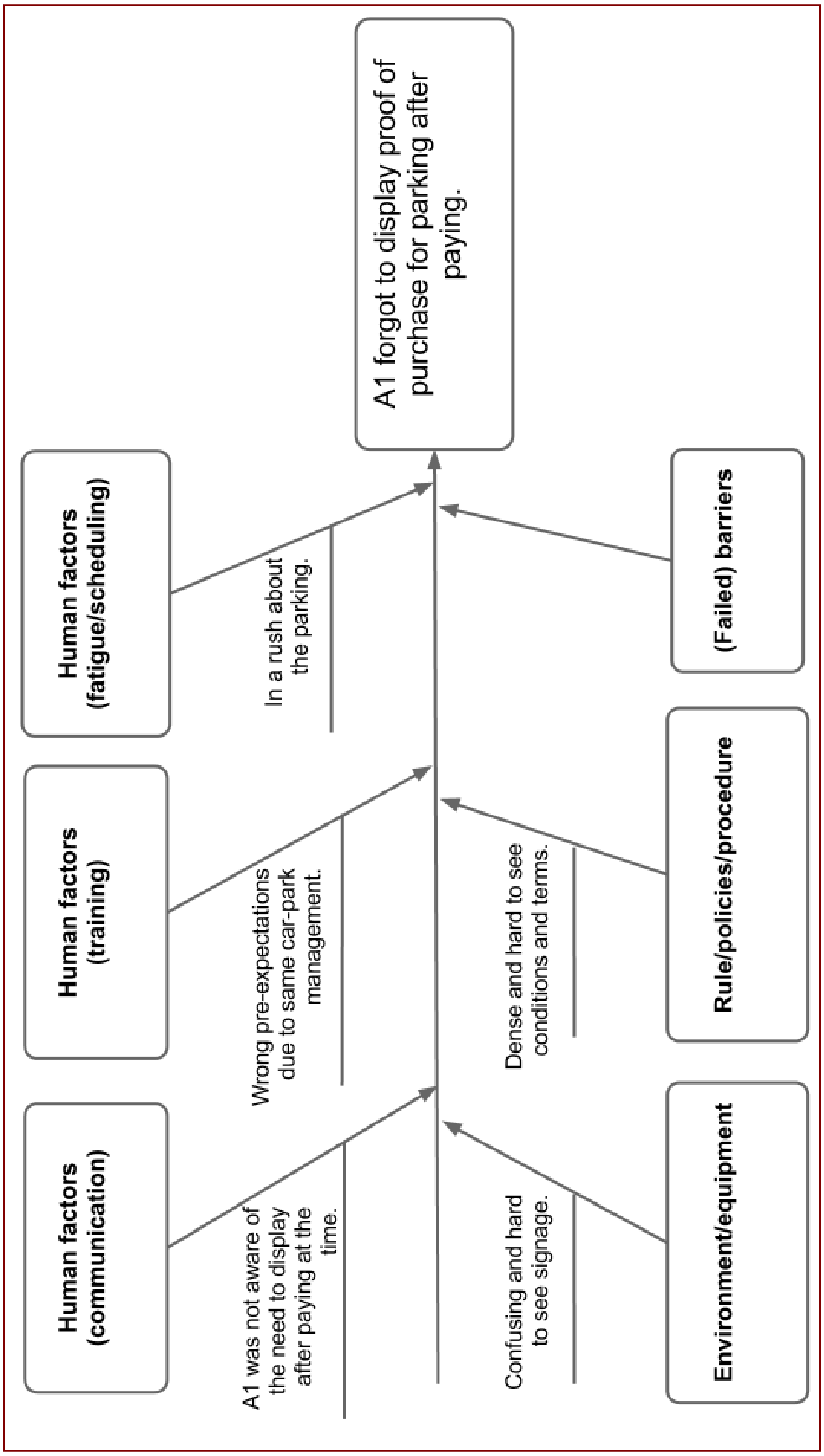

Figure 3: An Ishikawa diagram overview of the parking incident

[a-16]

Table 1 shows the 1-to-1 mapping between the contributory causes identified in Figure 2, and the causal-categories used in Figure 3 [1, Appendix C].

Table 1: From the triggering questions ([1], Appendix C) to causes.

Contributory causes in Figure 2	Causal categories in Figure 3
Dense and hard to see conditions and terms.	Rules/policies/procedure.
Wrong pre-expectations due to same car-park management.	Human factors (training).
In a rush about the parking.	Human factors (fatigue/scheduling).
Confusing and hard to see signage.	Environment/equipment.
A1 was not aware of the need to display after paying at the time.	Human factors (communication).
None identified at this point.	(Failed) barriers.

[a-17]

From this initial level of incident understanding, the investigator then faithfully carried out a RCA-based investigation on the (five) major causal factors leading up to this incident, using a 'breadth-first' search strategy to systematically explore all the contributory causes in turn. The level of procedural guidance for the RCA process prescribed by [1] is predominantly more towards the 'goal-based' rather than 'action-based' level [5], as such there is not much guidance in [1] at an 'action-based' level of procedural detail. As such the investigator feels that this part of an investigation based on [1] (i.e., this *'Determining the 'contributory factors' and 'root causes'* step of the process prescribed by [1]) may be subject to much variable implementation.

2.6.2 Operationalising the stopping rule prescribed in [1]

[a-18]

To sensibly scope the exploration of the more latent causes leading up to an incident, a reasonably clear operational understanding of the 'stopping rule' to apply is needed. [1] prescribes the following for this 'stopping rule':

> "*It is crucial to ask "why" at each level of cause and effect until there are no more questions, knowledge becomes limited, or until the issues identified fall outside the scope of the RCA*" [1, p27].

[a-19]

From carefully deconstructing this stopping-rule, the investigator arrived at a set of 'operational stopping criteria' (see Table 2) to help appropriately scope the investigative exploration of the latent causes contributing towards this incident. The stopping rule above [1, p27] was interpreted in an inclusive-OR style, where the search for root causes along a particular path of the causal tree is terminated if at least one of the three judgements on the LHS of Table 2 is deemed to be true.

Table 2: Interpreting the prose-based stopping rule in [1] *for operational usage in this investigation.*

Operational stopping criteria used	**Stated stopping criteria according to [1]**
1) There are no obvious further 'whys' to be asked with respect to the cause being currently considered.	*"there are no more questions".*
2) Either: - It is dubious to the investigator whether the current causal conjecture was true given the incident knowledge and evidence obtained, - or there is no evidence at all to suggest or support the 'current' causal conjecture under consideration.	*"knowledge becomes limited"*
3) Either: - The investigator is unlikely to be able (or sometimes to want) to change or intervene with respect to the contributory cause, - or the potential causal explanation is no longer a 'benign' one (i.e., '*company purposely facilitating customers to be misled*').	*"the issues identified fall outside the scope of the RCA"*

2.6.3 Continuing the investigation: exhaustively exploration of all the contributory factors in a 'breadth-first' fashion

[a-20]

Figure 4 shows the results of reasoning about why A1 was not aware of the need to display after paying at the time. This figure presents the investigative results gained from investigating the only contributory cause in the *Human factors (communication)* category in Figure 3.

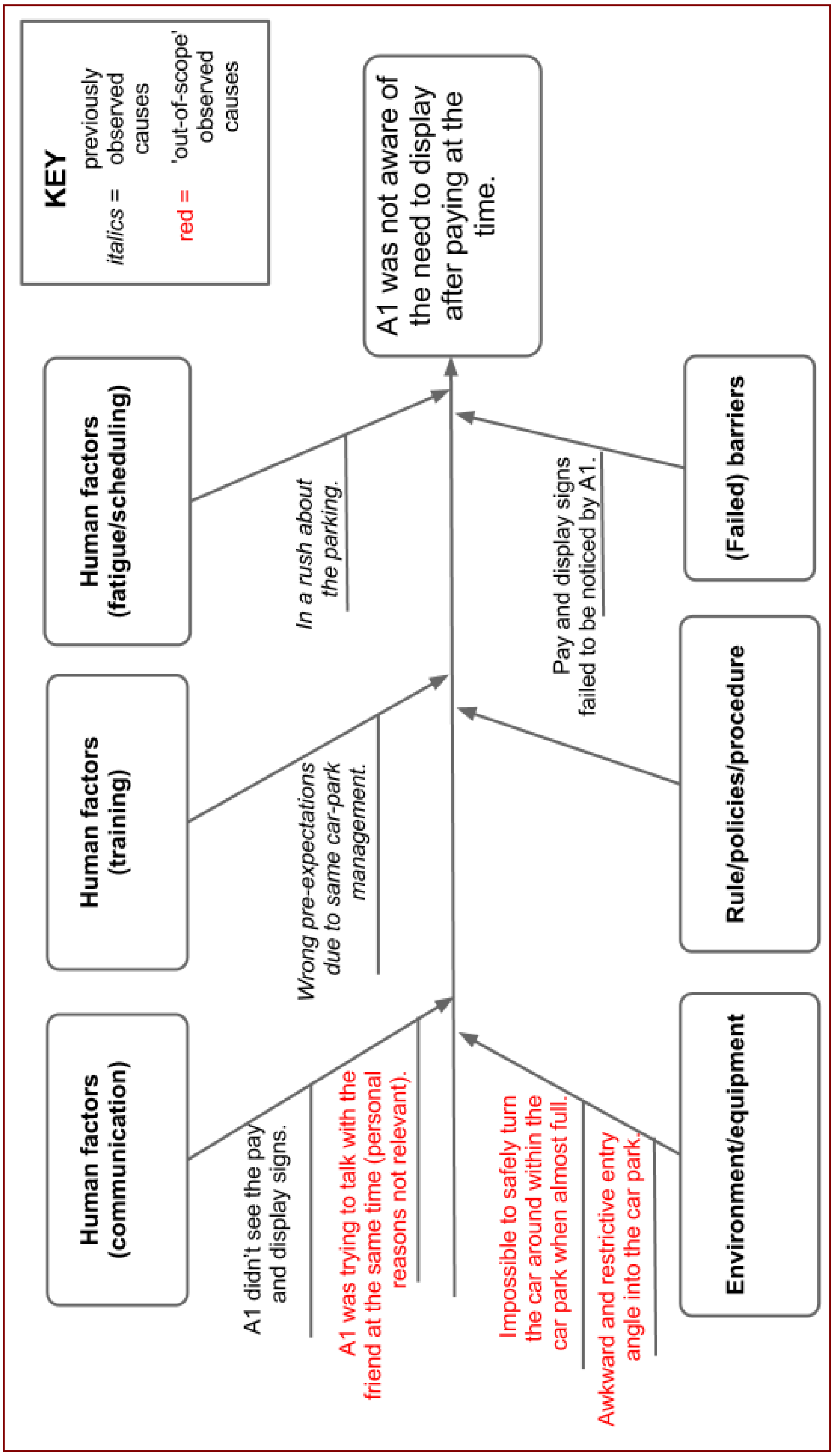

Figure 4: Why was A1 not aware of the need to display?

[a-21]

As an illustration of how the investigator applied the stopping rules, in Figure 4 the causal factors regarded as beyond the scope of this investigation were the following, where A1 was not aware of the need to display after paying at the time partly because:

-- A1 was trying to talk with the friend (this cause was beyond scope because A1 was unlikely to not want to talk with friends in the car in general);
-- It was impossible to safely turn the car around within the car park when almost full (this cause was beyond scope because the investigator has little direct influence on intervening in the management of the car park);
-- There was an awkward and restrictive entry angle into the car park (this cause was beyond scope because the investigator has little direct influence on intervening in the management of the car park).

[a-22]

These three causes were not investigated any further due to them being deemed as beyond the scope of this RCA-based investigation.

[a-23]

Also in Figure 4 were two causes already previously considered (in Figure 3), where A1 was not aware of the need to display after paying at the time partly because:

-- A1 was in a rush about the car parking;
-- A1 had wrong pre-expectations due to the same car-park management.

[a-24]

Finally the one new 'latent-cause' uncovered at this step was:

-- A1 didn't see the pay and display signs.

The investigator judged this 'new' contributory factor to be reasonable to be also included in the 'failed barriers' causal-category. In this incident, the existing pay-and-display signs obviously failed to prevent non-display of the proof of purchase for the parking space.

[a-25]

An observation made by the investigator at this point in the investigation, was that the set of triggering categories used here (from [1, Appendix C]) may conceptually overlap. In particular Figure 4 suggests that the 'failed barrier' category may perhaps be a more abstract conceptual category than the other five - evidenced by the fact that it is reasonable here to include "*A1 didn't see the pay and display signs*" under both the 'Human factors (communication)' and '(Failed) barriers' sections in this figure.

[a-26]

Exploring the causes of the *"wrong pre-expectations due to same car-park management"* contributory factor (in Figure 3) triggered the realisation by the investigator that this statement was actually in itself a mini causal statement, as opposed to a 'simple' contributory factor like the other 4 contributory causes in Figure 3. Upon realising this fact in the investigation, this 'composite-factor' was revised into a 'simple factor', resulting in the revised top-level causal relations represented in Figure 5, where this top-level contributory cause is replaced instead with A1's *"wrong expectations of the parking scheme"*.

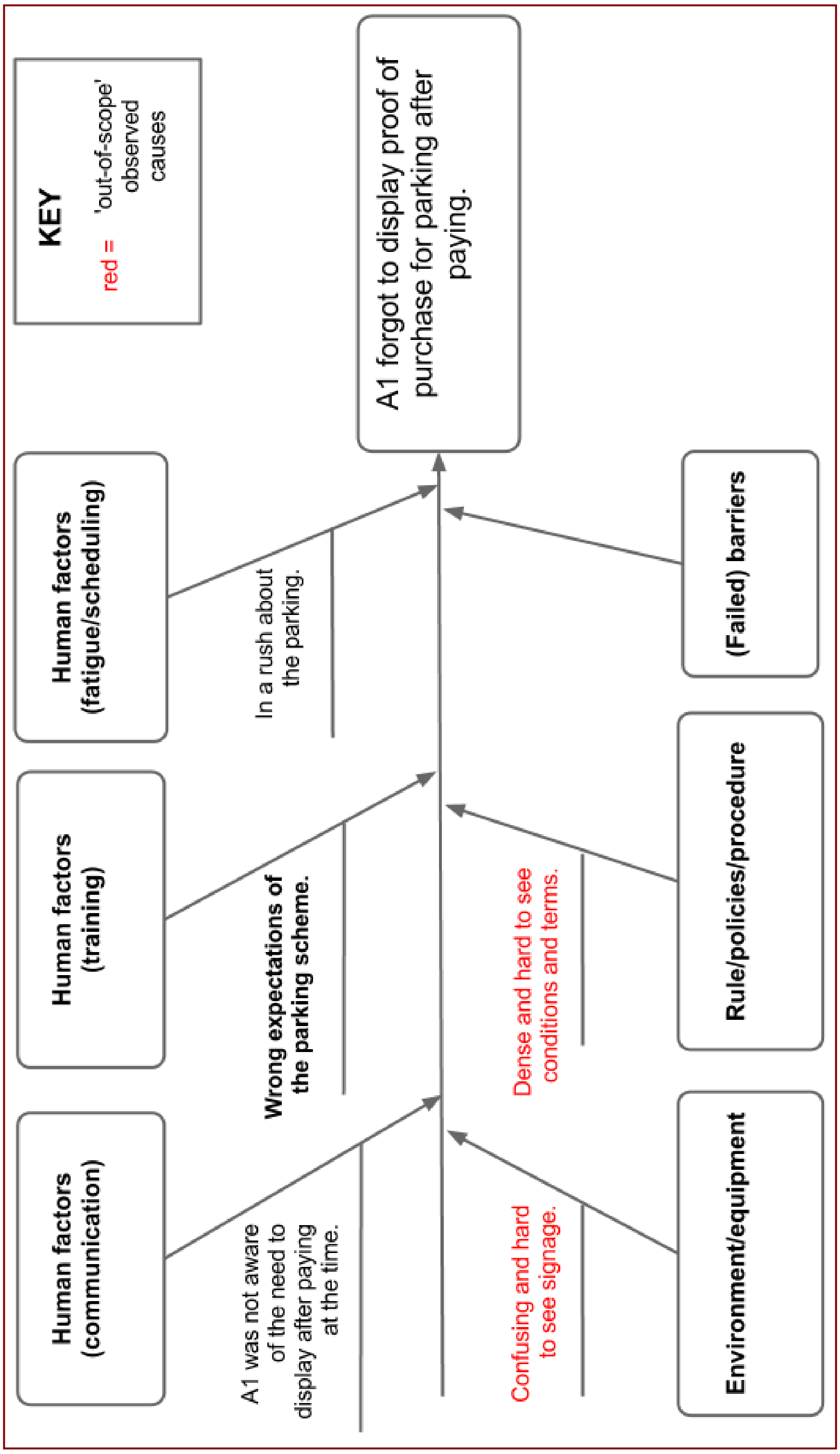

Figure 5: Revised Ishikawa diagram overview of the parking incident.

[a-27]

In Figure 5, the *"confusing and hard to see signage"* and *"dense and hard to see conditions and terms"* both fulfilled operational stopping criteria number 3 (see Table 2 of this appendix), and were regarded as beyond the capabilities of the investigator to intervene upon. Neither of these contributory causes were regarded as within the scope of this RCA-based investigation.

[a-28]

The next step was to further investigate this revised *"wrong expectations of the parking scheme"* contributory factor. These wrong expectations were judged to be because of the causes shown in Figure 6.

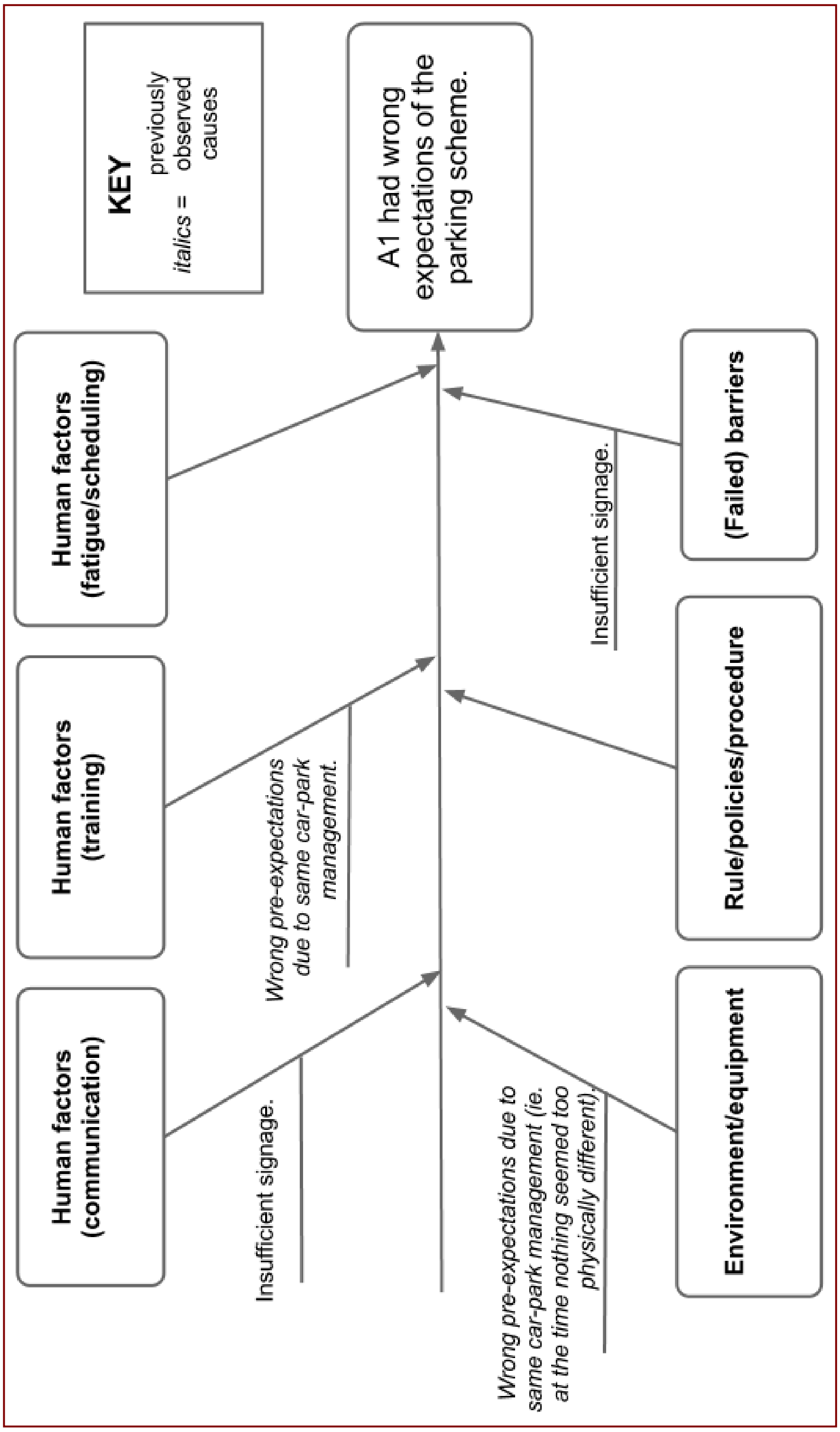

Figure 6: Why did A1 have wrong expectations of the parking scheme?

[a-29]

Here two contributory factors were found to have caused A1 to have had the wrong expectations, these were:

-- *“Wrong pre-expectations due to same car-park management”, and*

-- *“Insufficient signage”.*

Both these contributory factors were included under multiple causal-categories - in this case they were included under 2 causal-categories each.

[a-30]

Figure 7 is the investigative results following from exploring the *“in a rush about the parking”* contributory cause in Figure 5. This was found to be because A1’s friend needed to get to London fairly quickly. This contributory cause was beyond the scope of this RCA due to the fact that this was a more personal reason that the investigator was not willing to try to intervene on.

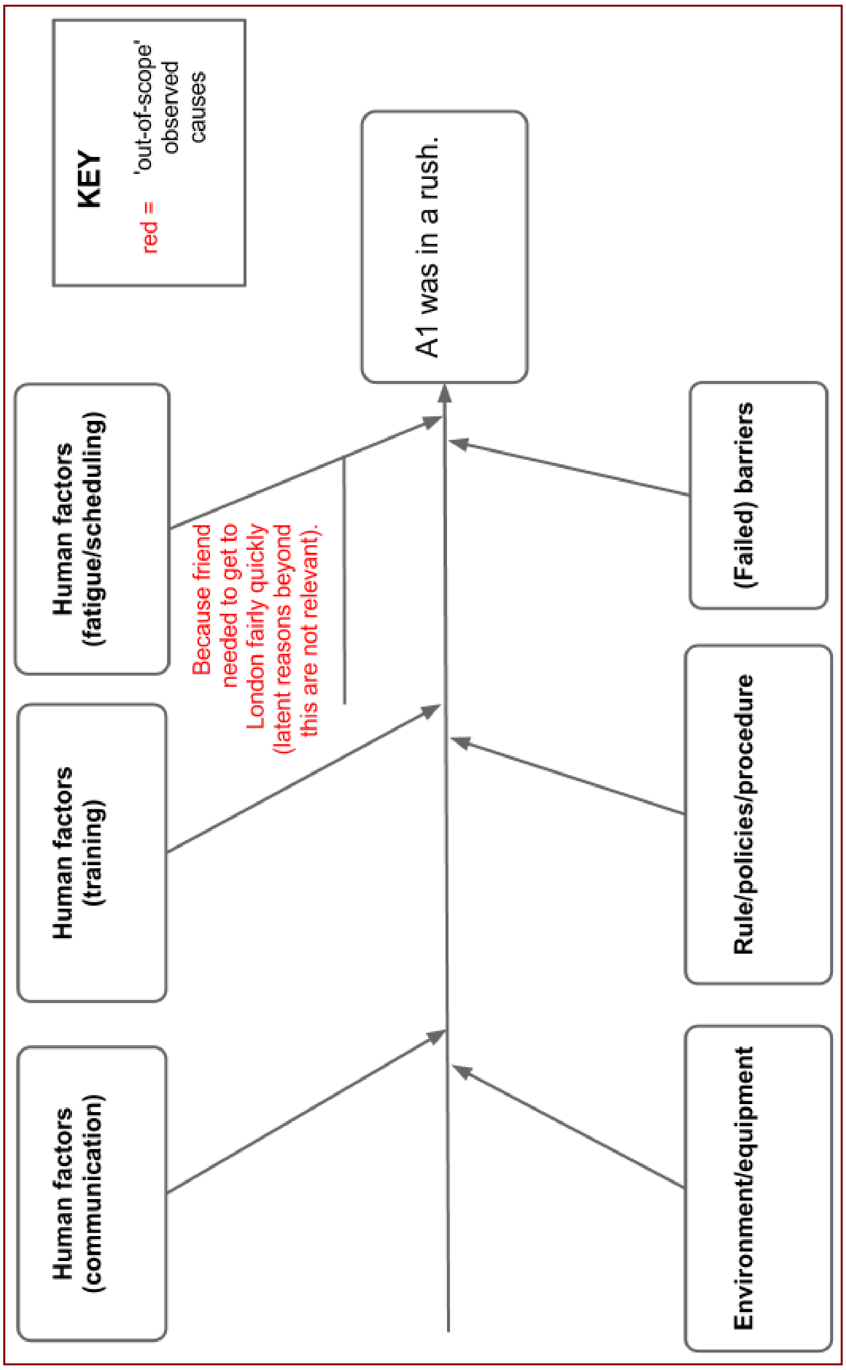

Figure 7: Why was A1 in such a rush?

2.6.4 Exploring additional contributory factors beyond the scoping prescribed by [1]

[a-31]

"The signage was confusing and hard to see" and *"dense and hard to see conditions and terms"* were two contributory causes from Figure 5 that were actually out of scope for the stopping rules used in this RCA-based investigation. This was because the investigator was unlikely to be able to intervene on these conditions. These two contributory factors were however accidentally explored in detail during this investigation, and for completeness the results of these investigations are shown in Figures 8 and 9.

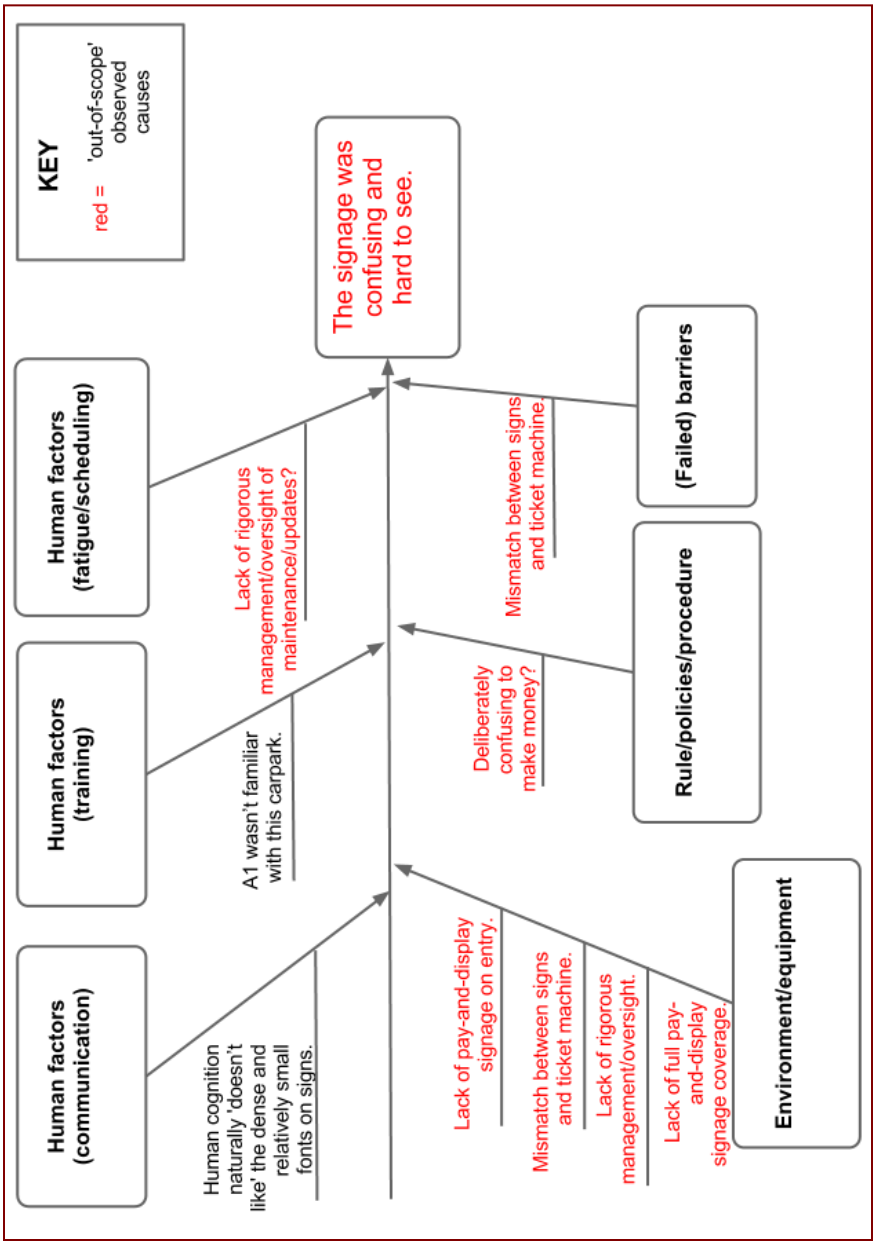

Figure 8: Reasons for confusing and hard to see signage

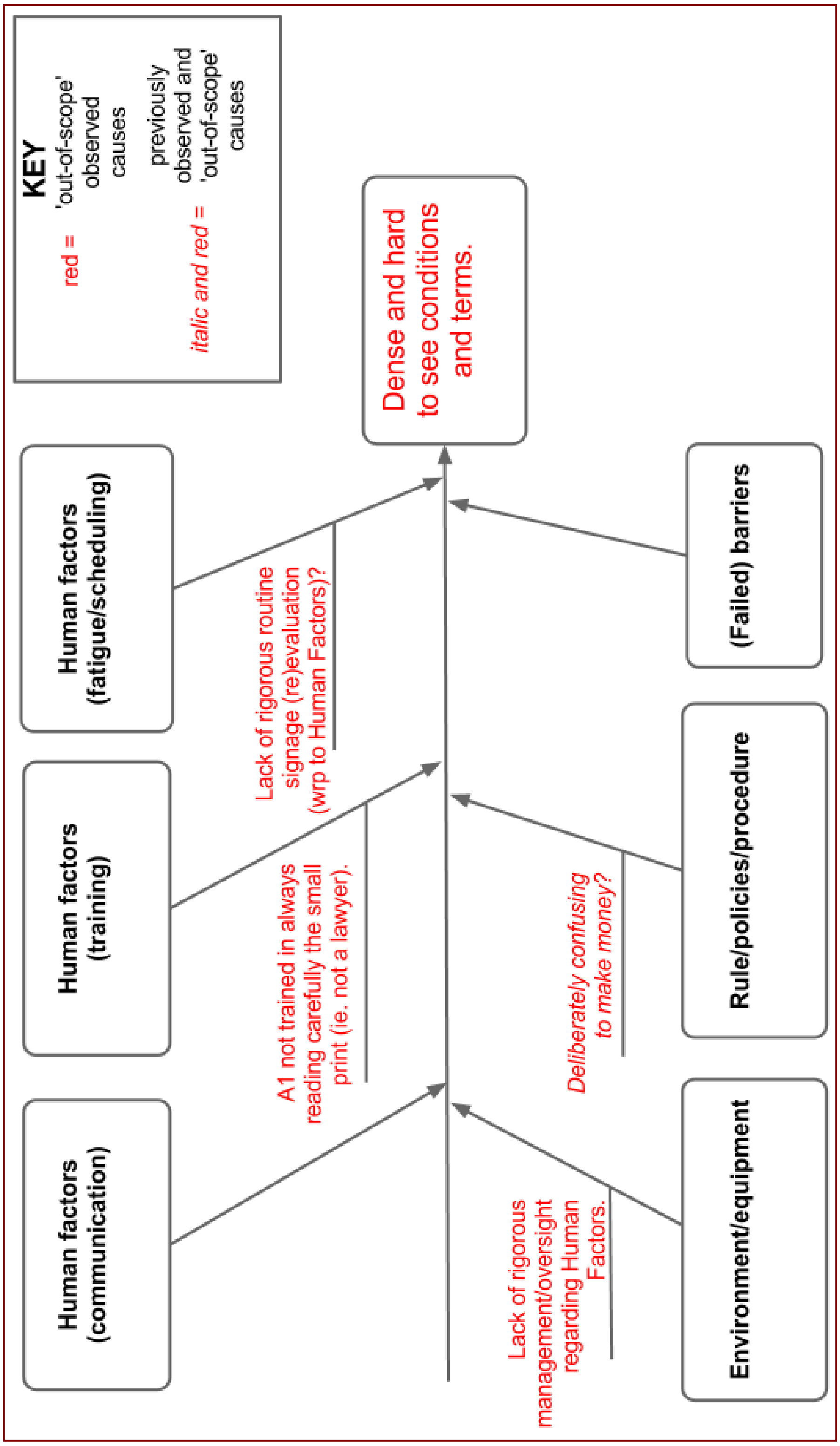

Figure 9: Reasons for dense and hard to see conditions and terms

2.6.5 Continuing the main investigation

[a-32]

We now continue from the main investigations described in 2.6.3. Figure 10 represents the investigation of the only remaining cause to be further explored from Figure 4. This was the fact that A1 didn't see the pay-and-display signs. As all the contributory causes in Figure 10 are either 'beyond scope' or already investigated, this part of the causal-chain was not explored any further.

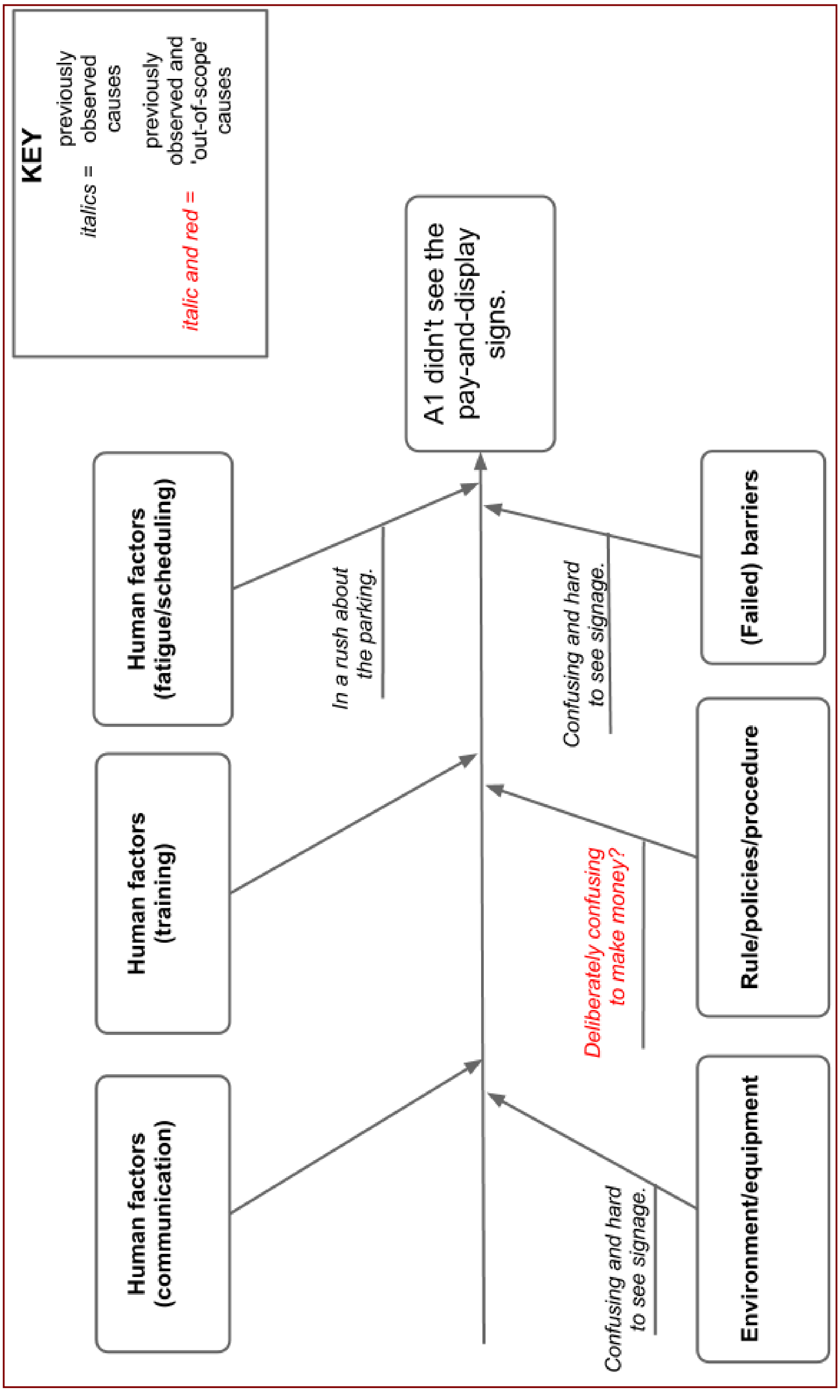

Figure 10: Why did A1 not see the signs?

[a-33]

Figure 11 presents the results of further exploring the “insufficient signage” issue highlighted in Figure 6, leading to contributory causes that were all judged to be out of scope. This terminated this part of the search for root causes.

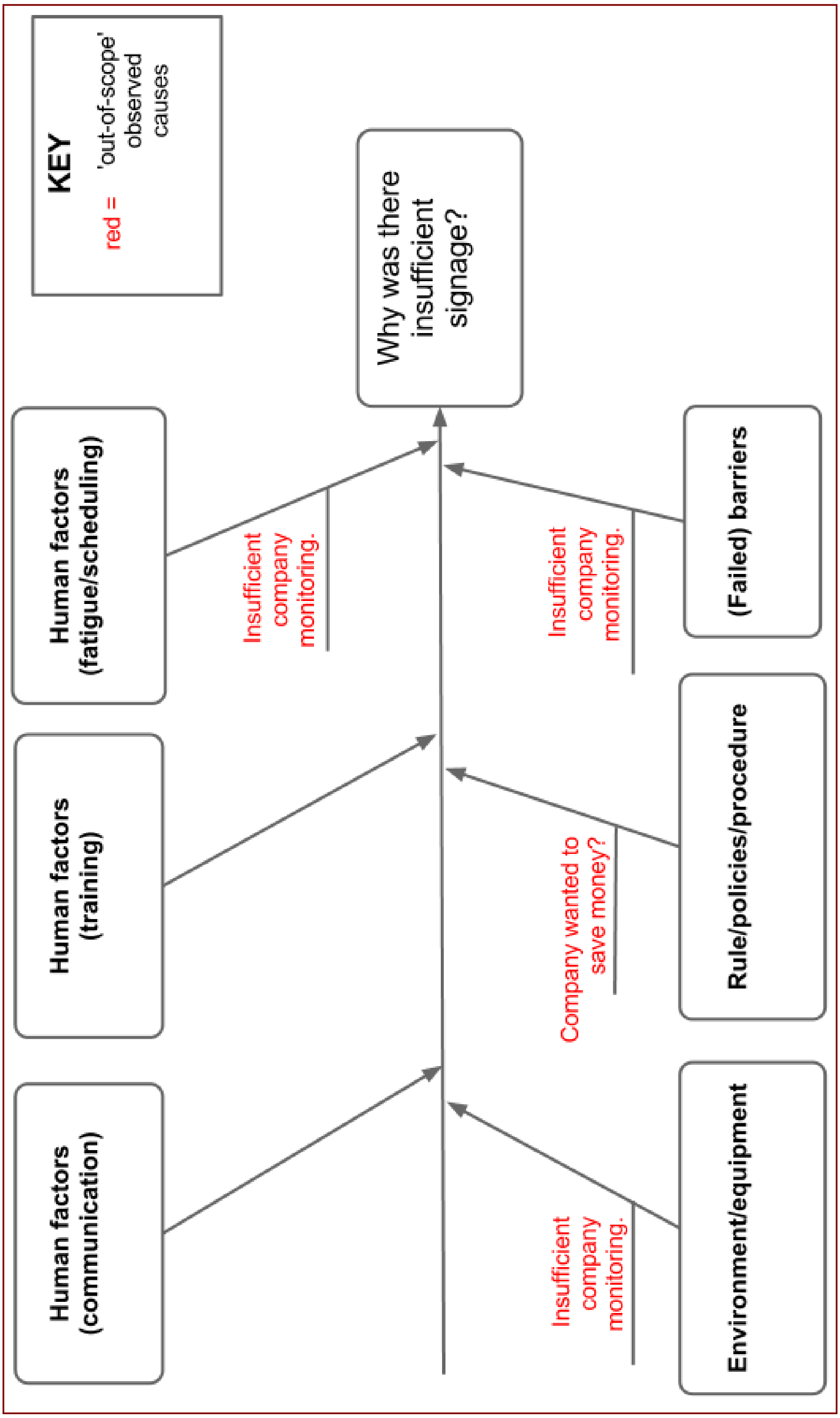

Figure 11: Why was there insufficient signage?

[a-34]

This concluded the investigator's initial determination of all the relevant contributory factors and root causes – all the 'whys' were fully explored until the stopping-rule prescribed by [1] was fulfilled (i.e., systematically reaching all the 'leaf nodes' of the causal tree being explored/investigated). *There were no incidental findings [1, p28] uncovered at this point*.

2.7 Consolidation using a causal-tree based understanding of the incident

[a-35]

To re-check and reflect on the validity of the causal reasoning done so far, the investigator printed off all of Figures 1-11, laid them all out on the floor, and holistically derived a sensible causal tree based on these 11 figures. The resulting entire tree, in the style prescribed by [1, p28] is shown in Figure 12. The investigator notes that this investigative step is not a step explicitly specified by [1], nevertheless it was carried out in the interests of facilitating a high-quality RCA-based investigation of this incident.

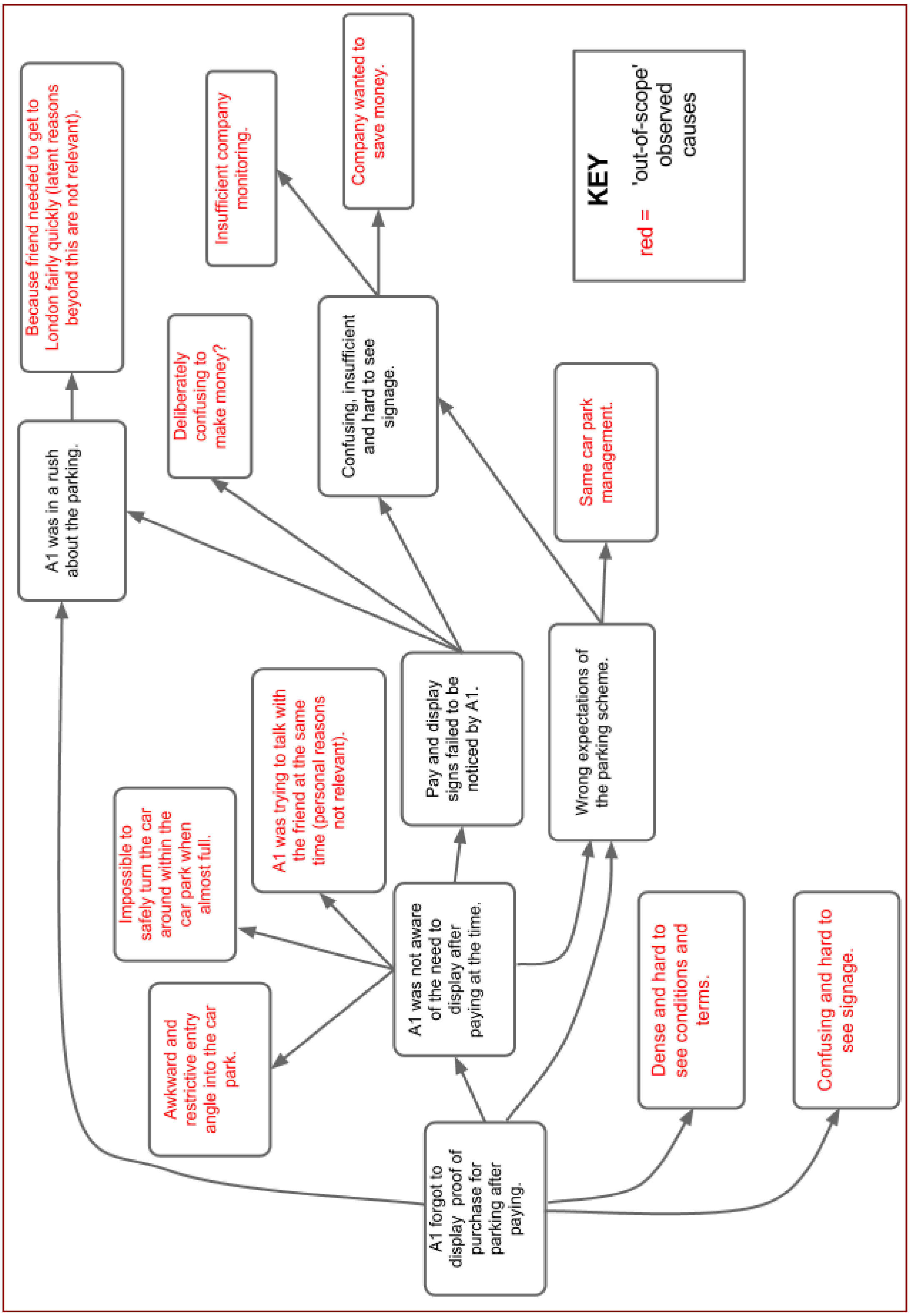

Figure 12: Consolidated full incident understanding in the form of a causal tree

[a-36]

Figure 12 was produced by simply drawing together all the prior information contained in the previous figures representing the evolving system understanding of the RCA-based investigation. This holistic drawing together of all the causal conjectures in Figure 1-11 had the benefit of making sure that the entire causal tree based representation of the system was sensible with respect to the investigative process outlined in [1].

[a-37]

In the incident understanding represented by Figure 12, only minor changes from the previous figures were deemed necessary, including the following:

1) The *"wrong pre-expectations due to same car management"* 'mini-cause' was decomposed into its two component parts of *"wrong expectations of the parking scheme"*, and *"same car park management"*.

2) Figure 6 was also 'heuristically-folded-in' to Figure 12 – most notably incorporating the *"insufficient signage"* cause into the *"confusing and hard to see signage"* cause in Figure 5 (resulting in *"confusing, insufficient and hard to see signage"* in Figure 12). It was difficult to decide whether the *"confusing, insufficient and hard to see signage"* cause in Figure 12 ought to be within scope of this RCA-based investigation or not. This is because a prior appeal by the investigator (against the £75 parking penalty charge levied) may be interpreted in some sense as an attempt to contribute towards some form of intervention with respect to this particular cause, thus suggesting that this signage situation may perhaps be partially within the scope and capabilities of the investigator to change.

[a-38]

Information from Figures 8 and 9 were not included in the consolidated 'causal-tree' in Figure 12, as they were only found by accident due to our inexperience at doing a RCA-based investigation according to [1]. The results in both these figures were generated from (further) causal exploration that directly leads *only* from a cause that fulfilled the stopping rule prescribed by [1]. This suggests that additional causal exploration such as the kind encapsulated in Figures 8 and 9 are in some sense 'bonus parts' of the exploration of the causal-tree that is unlikely to consistently occur in all RCA-based investigations.

[a-39]

At this point, the investigator judged the evolving incident understanding to be complete. Applying steps 1-6 (out of the 8 investigative steps prescribed by [1, p22-p31]) led to a full system-based understanding of an everyday incident based on an investigation using the RCA methodology [1]; Steps 7 and 8 [1, p28-31] consist only of re-organising, appropriately communicating, and responding to the findings resulting from such an investigation. No further system understanding will be gained from applying steps 7 and 8 [1, p28].

[a-40]

This concludes the evolution of a full system-based incident understanding according to [1].

ACKNOWLEDGMENTS

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REFERENCES

[1] **ISMP Canada (2006).** *Canadian Root Cause Analysis Framework: A tool for identifying and addressing the root causes of critical incidents in healthcare.* (http://www.ismp-canada.org/rca.htm, accessed 28/9/2012).
[2] **Rizi, Elham (2011).** *Private Parking...* (http://www.bbc.co.uk/blogs/watchdog/2011/04/dvla_driving.html), accessed 25/10/2012).
[3] **MoneySavingExpert.com (2012).** *Fighting Private Parking Tickets*. (http://www.moneysavingexpert.com/reclaim/private-parking-tickets, accessed 25/10/2012).
[4] **PePiPoo (2001-2012).** *Helping the motorist get justice.* (http://www.pepipoo.com/, accessed 25/10/2012).
[5] **Hale, A and Swuste, P (1998).** *Safety rules: procedural freedom or action constraint.* Safety Science 29(3): 163-177.

An illustrative sample of websites watched/read for the literature review

- http://www.moneysavingexpert.com/reclaim/private-parking-tickets (accessed 25/10/2012)
- http://forums.moneysavingexpert.com/showthread.php?t=2214803 (accessed 25/10/2012)
- http://www.youtube.com/watch?v=oZg7SI7xAY0&feature=fvwrel (accessed 25/10/2012)
- http://www.appealnow.com/private/ (accessed 25/10/2012)
- http://www.youreable.com/forums/archive/index.php/t-363.html?s=2c0c6c339cc831a21f4afd2ed5d0f8c4 (accessed 25/10/2012)
- http://www.thisismoney.co.uk/money/cars/article-1708393/How-fight-parking-ticket.html (accessed 25/10/2012)
- http://ezinearticles.com/?How-to-Gather-Evidence-to-Successfully-Contest-Parking-Tickets&id=7125448 (accessed 25/10/2012)
- http://www.moneysavingexpert.com/travel/parking-rules (accessed 25/10/2012)
- http://www.disabilitynow.org.uk/living/motoring-section/tv-advice-just-isnt-the-ticket (page not found, 25/10/2012)
- http://www.pepipoo.com/ (accessed 25/10/2012)

END OF THIS APPENDIX

Appendix C.2: An overview of the outcomes from two independent applications of the Systematic Reanalysis Method, and the wrap-up session

There are seven columns in the summary table presented in this appendix. Reading from the left:

- The first column states the normalised form (see Section 6.4) of the methodological criticism used to analyse the ISMP Canada (2006) manual (the original forms are provided instead where this normalisation wasn't applicable); in this first column the Systematic Reanalysis Method 'phrase templates' are greyed out to help the reader pick out the parts of investigation encapsulated within each methodological criticism.
- The second column denotes 'contextually limited' criticisms that relate to *a priori* factors beyond the investigator's control – implying an *a priori* lack of methodological freedom before the investigation even began.
- The third column denotes criticisms considered to be too vague to be effectively analysed against the manual.
- The fourth and fifth columns denote the annotations originally assigned by each Systematic Reanalysis Method analyst.
- The sixth column denotes whether the investigative actions or findings contained within each methodological criticism was found to be *constrained*, *strongly afforded*, or *weakly afforded* by the manual based on the (Systematic Reanalysis Method) comparative analyses done.
- Finally, the seventh column describes any significant findings and changes resulting from the wrap-up session discussions – after the two independent Systematic Reanalysis Method analyses.

The greyed out rows in the table denote where methodological criticisms were not comparatively analysed due to being *contextually limited*, *too vague to be effectively analysed*, or *being either subsumed by, or effectively duplicating a previously analysed criticism*. The notion of *validity* here is with respect to the particular manual [1] embodying the investigative method used.

Abbreviations used

The following abbreviations are used in the table. 'Methodological criticisms' (e.g., Section 6.3) are labelled using references given in curly brackets (e.g., {AC1}, {BC4}). Those originally generated by analyst A (the author) are prefixed with **AC**, and ones by analyst B (the independent second Systematic Reanalysis Method analyst) are prefixed with **BC** in indexing each methodological criticism.

CL denotes criticisms relating to contextual limitations (‘y’ indicates where this is true).

V denotes criticisms considered too vague for analysis (‘y’ indicates where this was assigned).

M denotes criticisms that may affect the validity of the investigative *procedure*.

F denotes criticisms that may affect the validity of the investigative *findings*.

M/F denotes criticisms that may affect the validity of either/both the investigative *procedure* and/or *findings*.

G denotes *general* criticisms considered to potentially have a non-local effect on the validity of the investigation done.

S denotes *specific* criticisms considered to potentially have only a local effect on the validity of the investigation done.

Cstr denotes investigative actions and/or findings found to be *invalid* with respect to the manual used, due to contravening the methodological specification expressed in the manual used (i.e., ‘constrained’).

Waff denotes investigative actions and/or findings found to be *neither conclusively invalid or valid* with respect to the manual used, due to methodological ambiguity (i.e., ‘weakly afforded’).

Saff denotes investigative actions and/or findings found to be *valid* with respect to the manual used, due to explicit methodological support for the particular action done and/or finding obtained (i.e., ‘strongly afforded’).

References such as `[i-5]` refer to specific paragraphs in the account of the RCA investigation of the car parking incident [2]. `[i-5]->[i-6]` indicates a range of paragraphs between the given labels. Throughout this appendix, the following numeric ‘paper references’ are used:

[1] **ISMP Canada (2006).** *Canadian Root Cause Analysis Framework: A tool for identifying and addressing the root causes of critical incidents in healthcare.* (http://www.ismp-canada.org/rca.htm, accessed 28/9/2012)

[2] **Appendix C.1**

Note: The weblink for reference [1] was subsequently updated with a 2012 version of the RCA manual. The 2006 version of the manual used for this research may be provided on request.

Normalised methodological criticism	***CL? (y/-)***	***V? (y/-)***	***M, F or M/F?***	***G or S?***	***Cstr, Waff or Saff ?***	***Significant issues from the post-analyses wrap-up session***
{AC1} The investigative choice of using the entirety of [1] to inform and guide the investigation was invalid.	-	-	M	G	Waff	-
{AC2} The investigative choice of prioritising the following sections of [1] for critically guiding the investigation was invalid: - *Root Cause Analysis Process* section [1, p22]; - *Preface* section [1, p4-5], last two paragraphs; - *Essentials of Root Cause Analysis* section [1, p10]; - The triggering categories from *Appendix C* of ISMP Canada (2006) (see [1, p44] and [1, p13]).	-	-	M	G	Waff	-
{AC3} The investigative choice of basing the core steps of this investigation primarily on the *Root Cause Analysis Process* section [1, p22-p31] was invalid.	-	-	M	G	Saff	-

{AC4} The investigative choice of performing each of the 8 steps outlined on [1, Figure 4, p22] as strictly sequential, rather than more iteratively was invalid.	-	-	M	G	Waff	-
{AC5.1/12} The investigative choices made at each of the six steps accounted for in the record of the investigation were invalid.	-	y	M	S	-	-
{AC5.2} The investigative findings obtained for each of the six steps accounted for in the record of the investigation were invalid.	-	y	F	S	-	-
{AC6} The investigative choice of understanding steps 7/8 and 8/8 of the process as prescribed in [1, p28-p31] as developing no further system-based incident understanding was invalid.	-	-	M	S	Saff	Our discussion found that the interpretation of the end of step 6/8 as the point at which no further system-based incident understanding will be developed was arguably not strongly afforded, since the manual used never specifies explicitly where/when investigators should stop developing additional understanding. Despite the strong implication of the first sentence of the *Formulate Causal Statements* section of the manual [1, p28], we erred on the conservative side and reassigned this methodological criticism as Waff.

{AC7} The investigative choice to impose no predetermined time limit for completing the evolution of a system-based understanding of the incident was invalid.	-	-	M	G	Waff	-
{AC8} The investigative choice in terms of taking around 45 hours in total for completing the evolution of a system-based understanding of the incident was invalid.	-	-	M	G	Waff	-
{AC9} (Original) Incident participant, RCA investigator and information provider are same person.	y	-	-	-	-	-
{AC10} (Original) Investigating a car-parking incident using RCA.	y	-	-	-	-	-
{AC11} (Original) Singular evolution of RCA-based incident understanding.	y	-	-	-	-	-
{AC12} is subsumed under **{AC5.1}**	-	-	-	-	-	-

{AC13} The investigative choice of using a flow-diagram and a supporting narrative for forming and consolidating the initial understanding of the incident was invalid.	-	-	M	S	Saff	-
{AC14} The investigative choice of only making a single return visit to the incident site for the 'additional information' step (step 3/8 of [1, *Root Cause Analysis Process* section]) was invalid.	-	-	M	G	Waff	-
{AC15} (Original) The use of reflective recall as primary source of understanding about incident.	y	-	-	-	-	-
{AC16} The investigative choice of collecting only photographic evidence on the return site visit was invalid.	-	-	M	G	Waff	-

{AC17} The investigative choice/finding-obtained of using the 'fact' below as the starting point of the exploration of the contributory factors and root causes was invalid: *"Why did A1 forget to display the proof of purchase for parking after paying"*?	-	-	M/F	G	Waff	-
{AC18} The investigative choice of using five of the triggering categories from [1, Appendix C] to support the collection of additional information was invalid.	-	-	M	G	Waff	-
{AC19} The investigative choice of not using the sixth 'barriers' category of the triggering categories from [1, Appendix C] to support the collection of additional information was invalid.	-	-	M	G	Waff	-
{AC20} The investigative choice, where the depth and quality of the contributory factors in each of the five triggering categories used were not explicitly checked, was invalid.	-	-	M	S	Waff	-

{AC21} (Original) Choice of Google-search only as a basis for this literature search.	y	-	-	-	-	-
{AC22} The investigative choice of carrying out a literature search based only on protocol and case based literature only was invalid.	-	-	M	G	Waff	-
{AC23} The investigative choice of conducting a literature search only for informing investigative procedure and the subsequent investigative understanding was invalid.	-	-	M	G	Saff	The review and usage of literature is mentioned also as part of the guidance relating to team discussions (see [1, p21] and [1, Table 4] for example). As such we found that the arguably more restrictive interpretation used in the investigation was perhaps less strongly afforded than at first thought. This part of the investigation was revised as Waff by the manual used.
{AC24} The investigative choice of always using all prior understanding built up in all of the prior steps for each new step in the investigation was invalid.	-	-	M	G	Waff	-

{AC25} The investigative choice of using search terms such as the ones listed in the record of the investigation was invalid (reproduced below for reference): - “preventing forgetting to display in future”, - “remembering to display parking ticket”, - “forgetting to display parking tickets”, - “parking fines”, - “parking fines what to do if you have paid but forgot to display”.	-	-	M	S	Waff	-
{AC26} The investigative choice of spending only half a day or so on the literature search part of the investigation was invalid.	-	-	M	S	Waff	-
{AC27} The investigative choice of stopping the literature search after finding a lack of apparently relevant results was invalid.	-	-	M	S	Waff	-
{AC28.1} The investigative choice of using ‘call-out’ boxes in the final understanding flow-diagram was invalid.	-	-	M	S	Saff	-

{AC28.2} The investigative choice of using only the flow-diagram and narrative to express the final understanding of the incident was invalid.	-	-	M	S	Waff	-
{AC29} The investigative choice to not construct an analogous table to [1, Table 5, p25] was invalid.	-	-	M	S	Waff	-
{AC30} The investigative choice to do nothing further with respect to gaining a broader contextual understanding of the incident, when there is little apparent literature found in the literature search, was invalid.	-	-	M	S	Waff	-
{AC31} The investigative choice to use the Ishikawa diagram rather than the tree diagram for representing the causal relations of the contributory factors in the system was invalid.	-	-	M	G	Saff	-

{AC32} The investigative choice to not look for any further 'major causes' in addition to the five causal-conjectures originally used to support the collection of additional incident information was invalid.	-	-	M	G	Waff	-
{AC33.1} The investigative choice of using only intuitive investigator satisfaction for appropriately scoping the initial exploration of the (most proximal) major causes leading up to the incident was invalid.	-	-	M	G	Waff	-
{AC33.2} The investigative choice of using only the following stopping rule from [1, p27] as a global 'stopping rule' was invalid: "*It is crucial to ask "why" at each level of cause and effect until there are no more questions,* *knowledge becomes limited, or until the issues identified fall outside the scope of the RCA*" ([1, p27]).	-	-	M	G	Waff	-

{AC33.3/38} The investigative choice of using the particular interpretation of the following stopping rule was invalid: "*It is crucial to ask "why" at each level of cause and effect until there are no more questions,* *knowledge becomes limited, or until the issues identified fall outside the scope of the RCA*" ([1, p27]).	-	-	M	G	Waff	-
{AC34} The investigative choice of interpreting the guidelines prescribed by [1] for searching for contributory causes as similar to breadth-first search was invalid.	-	-	M	G	Waff	-
{AC35} The investigative choice of interpreting the following rule in an inclusive-OR style was invalid: "*It is crucial to ask "why" at each level of cause and effect until there are no more questions,* *knowledge becomes limited, or until the issues identified fall outside the scope of the RCA*" ([1, p27]).	-	-	M	S	Saff	-

{AC36} The investigative choice of not using the following rule in a holistic way was invalid: "*It is crucial to ask "why" at each level of cause and effect until there are no more questions,* *knowledge becomes limited, or until the issues identified fall outside the scope of the RCA*" ([1, p27]).	-	-	M	G	Waff	-
{AC37} The investigative choice of not re-exploring 'previously seen' causes again was invalid.	-	-	M	G	Waff	-
{AC38} was the same criticism as **{AC33.3}**	-	-	-	-	-	-
{AC39} The investigative choice to include the same contributory factor under multiple triggering category headings was invalid.	-	-	M	G	Waff	-
{AC40/41} The investigative choice to slightly update the initial level of 'major causal factors' due to the evolving investigative understanding of the incident was invalid.	-	-	M	G	Waff	-

{AC42} The investigative choice to assume that the 'correct' RCA-based procedure was to curtail investigation of 'more-latent' causes as soon as a stopping rule is satisfied was invalid.	-	-	M	G	Waff	-
{AC43} The investigative finding of 'no incidental findings' was invalid.	-	-	F	S	Cstr	We agreed that it would be sensible to make sure to include all investigative findings at least as part of the 'incidental findings' part of the RCA.
{AC44/45} The investigative choice of doing a 'holistic' drawing together, consolidation and summary step as described in Section 2.7 of the record of the investigation was invalid.	-	-	M	S	Waff	-
{AC46} The investigative choice of not including the 'accidental' investigative findings (Section 2.6.4 in the record of the investigation) as either 'incidental findings', or as part of the consolidated overall causal understanding of the incident (in Figure 12, Section 2.7 in the record of the investigation) was invalid.	-	-	M	S	Cstr	Related to C43.

{AC47} The investigative findings obtained of having no more than one contributing factor in each triggering category (for some steps of the RCA) were invalid.	-	-	F	S	Waff	-
{AC48} The investigative choice of using the same set of six triggering categories in the Ishikawa-diagram example given at [1, Figure 8, p27], for/at all 'layers' of the RCA-based exploration of contributory factors and root causes was invalid.	-	-	M	S	Waff	-
{AC49} The investigative choice of using only photographic and documentary evidence to support a RCA-based investigation according to [1] was invalid.	-	-	M	G	Saff	-
(Intentionally left blank to separate the two sets of Systematic Reanalysis Method analysis results)						
{BC1} The investigative choice of not including a proper justification for the use of RCA, for example through the decision tree method, was invalid.	-	-	M	G	Cstr	We agreed that it would be useful to go through the decision tree of [1, Figure 2] to gain further confidence about whether this investigation is basically within the scope of the RCA manual used.

{BC2} The investigative choice of not including the photographic evidence that is relevant to the investigation was invalid.	-	-	M	S	Waff	-
{BC3} The investigative choice of attributing blame to the failure of the incident's main participant's memory as a starting premise to aid gathering further information was invalid.	y	-	M	S	Cstr	Our discussion found that this methodological criticism was one due to the occasional ambiguity in [2] when distinguishing between the incident participant role, and the investigator role. The manual does encourages the investigator to avoid jumping to conclusions, so an investigative assumption of a failure in the participants memory would clearly be constrained by the manual used. This methodological criticism was changed to Waff after analyst A explained that the memory failure was the equivalent of 'interview data', and did not express investigative assumption in this case. The manual used provides no explicit guidance on the situation where the investigator also participated in the incident – which is in fact a contextual limitation of this incident investigation. We agreed that it would be perhaps useful to make sure such ambiguities were fully explicitly clarified throughout the record of the investigation.
{BC4} The investigative choice/findings-obtained from not specifying explicitly if a piece of critical knowledge was held by an affected actor in the incident at the time of the incident, was invalid.	-	-	M/F	S	Cstr	Changed to Waff for the same reasons as in **{BC3}**.

{BC5} The investigative choice/findings-obtained of attributing blame to equipment involved in the parking system rather than describe in full the reasons participant A1 had difficulty reading the signage, was invalid.	-	-	M/F	S	Cstr	The manual used encouraged a need to fully explore latent factors throughout. Our discussion found that it may be useful to try to further explore the reasons why participant A1 had difficulty in reading the signage. Analyst B suggested perhaps a return site visit, or comparison with signage in other car parks, may give a deeper understanding than that found so far with respect to this part of the investigation.
{BC6} The investigative choice of not interviewing all participants was invalid.	-	-	M	S	Cstr	Due to a more narrow interpretation of "all staff involved in the incident" [1, p23], analyst A (in the role of investigator) failed to identify the friend who also arrived at the car park as a potential source of additional information and verification. We agreed that this was something which was now sensible to simply accept as a limitation of the investigation. Even if the friend was contacted, the intervening time from when the incident occurred would render any information gained of dubious accuracy.
{BC7} The investigative choice of not employing a thorough literature review method as suggested in the RCA framework manual was invalid.	-	-	M	S	Cstr	Our discussion found that the guidance for the specific nature and scoping of the literature review was not clearly articulated, nor particular imperative. This methodological criticism was consequently changed to Waff.
{BC8} The investigative choice of not constructing an accurate table of timings for the events was invalid.	-	-	M	S	Cstr	Our discussion found that the guidance relating to the construction of an accurate table of timings similar to [1, Table 5] was not strongly imperative in the manual used. Consequently this methodological criticism was changed to Waff instead. Due to the relatively simple nature of this incident, we also agreed that a specific table of timings would add little value beyond the sequential information already presented in [2].

{BC9} The investigative choice of not positing any possible failures of safety barriers in the 'initial causes' diagram of [2, Figure 3] was invalid.	-	-	M	S	Cstr	Our discussion found that the notion of 'safety barriers' was only vaguely defined in the manual used, and used in other parts of the RCA done. We also found that this particular methodological criticism was in fact perhaps more reflective of the nature of the system under investigation, rather than identifying a flaw in the validity of the investigation process. In particular, analyst B conceptualised such barriers as a strong physical preventative measure, of which there didn't seem to be any obvious ones in this case. Consequently this investigative choice was changed to Saff instead, as in light of the discussion, we now agreed that the investigation choice made of not positing any initial 'failed safety barriers' was strongly likely given the guidance of the manual used. Analyst B did suggest that it may however be useful to revisit the incident site to verify that no strong physical 'safety barriers' were inadvertently missed.
{BC10} The investigative findings obtained of finding one of the principal causes of the incident being beyond the scope of an RCA investigation given that the scope of the system we are investigating is not clearly defined, was invalid.	-	-	F	G	Saff	-

END OF THIS APPENDIX