LESSONS LEARNT FROM USING ACCIMAPS AND THE RISK MANAGEMENT FRAMEWORK TO ANALYSE LARGE-SCALE SYSTEMIC FAILURES

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In this paper we describe our experiences in using AcciMaps and the Risk Management (ActorMap) framework (RMF) to analyse two recent accidents – the infection outbreaks which occurred at the Maidstone and Tunbridge Wells NHS Trust and the 2005 Stockwell Shooting incident. We first review previous work using AcciMaps and the RMF, followed by an account of our goals and the procedure used to carry out the accident analyses and the differences in our use of the methods. Finally, we reflect on these differences in order to develop of a set of criteria which could be used to scope more detailed guidelines for the selection and use of the two methods.

Introduction

Over the years a large number of accident analysis techniques have been developed that recognise the importance of considering the environmental context and the role played by systemic failings at differing organisational levels. Some of these approaches are presented as frameworks or philosophies (e.g., Reason. 1990) while others are presented as methods (e.g., STAMP - Leveson, 2010; the Risk Management Framework - Rasmussen, 1997; AcciMaps – Svedung and Rasmussen, 2000). These techniques have been used to analyse a wide variety of domains and accident scenarios. The prevalence of different methods, and the numerous interpretations of each is most likely a result of the complexity bound within these domains, but it can also prove to be a challenge to those seeking some form of 'route map' of the territory as it applies to the analysis of systemic failure.

In this paper we consider the use of the methods originally developed by Jens Rasmussen – the Risk Management (ActorMap) Framework (RMF) and AcciMaps. The paper came about as the result of the authors using these techniques independently in order to analyse two very different domains (Healthcare and Policing). Our specific objectives are: (1) To compare and contrast examples of recent applications of the RMF and AcciMap techniques for accident analysis; (2) To consider the differences in applications of the RMF and AcciMap techniques in terms of any assumptions underlying their use (e.g., types of data, methodology, differing goals driving use of the techniques); (3) To systematise common features and differences in use of the techniques in order to provide a set of overarching criteria for selecting and using the methods for accident and disaster analysis.

AcciMaps and the Risk Management (ActorMap) Framework

AcciMaps is an accident analysis methodology that is used to represent graphically the causal factors involved in a particular accident or safety-compromising incident, occurring within complex socio-technical systems. The approach also captures the preconditions and actions behind that causal chain of events. AcciMaps are diagrams developed to support vertical integration across the control levels of a socio-technical system. The AcciMap approach differs from typical accident analysis approaches in that, rather than identifying and apportioning blame, it is used to identify and represent the causal flow of events and the planning, management and regulatory bodies that may have contributed to the scenario, with a view to improving system design and safety (Svedung and Rasmussen, 2000). Rasmussen (1997) also developed a more general modeling framework (the Risk Management (ActorMap) Framework) for understanding the dynamic interaction between these types of components within a large-scale sociotechnical system. Table 1 summarises some of the studies which have made use of AcciMaps and the risk management framework.

Table 1: Summary of studies using AcciMaps and the RMF

Source	Scope	Characteristics of application
Rasmussen (1997)	RMF	Outline of RFM with components representing Government, regulators, company, management, staff, work context.
Rasmussen & Svedung (2000)	AcciMaps	Government, regulators, company, management, staff, work context; detailed examples of AcciMaps.
Vicente & Christofferen (2006)	RMF and AcciMaps	Mapping of contributory factors leading up to the outbreak using the RMF and AcciMaps
Hopkins (2000)	AcciMap	Causal diagram of contributory factors leading up to accident using AcciMaps
Salmon et al. (2010)	RMF and AcciMaps	Comparison of AcciMap and RMF models with Root Cause Model for led outdoor activity domain

Case studies

Both case studies have been described in detail in earlier papers presented at the Ergonomics Society Annual Conference in 2009, alongside separate papers published in the journal *Ergonomics* in 2009 and 2010 (Waterson, 2009; Jenkins et al., 2010). For this reason, we focus here on the application of the RMF and AcciMaps rather than provide a detailed account of the background or details of the incidents which were the subject of analysis.

The C. difficile outbreaks within the Maidstone and Tunbridge Wells NHS Trust

During the period between April 2004 and September 2006 an estimated 90 people died at the Maidstone and Tunbridge Wells NHS Trust as a result of becoming infected with the *Clostridium difficile* (*C. diff.*) bacteria (HC, [5, p.5]). The Healthcare Commission report identified a number of factors that contributed to the outbreaks that occurred with the Trust. These can be summarised in terms of five main themes: the role played by external organisations; management of the trust; clinical management on the hospital wards; the role played by the infection control team; and, equipment and hygiene factors. Figure 1 depicts some of these contributory factors using the Risk Management Framework.

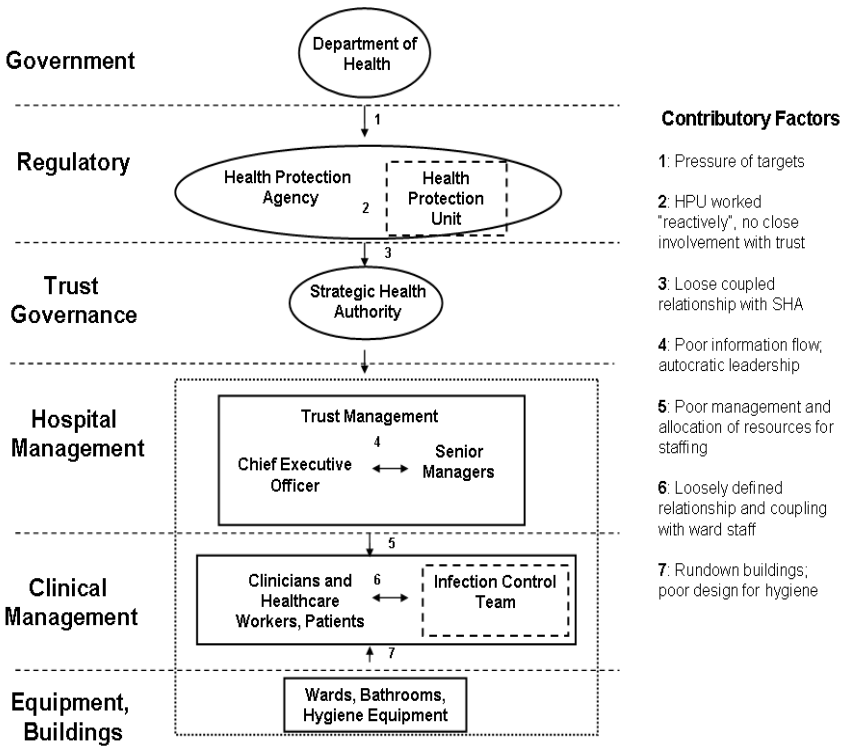

Figure 1: Applying the RMF to the infection outbreaks (Waterson, 2009)

The Stockwell shooting incident

The Stockwell shooting incident which took place in late July 2005 followed on from a set of earlier terrorist bombings in London. Figure 2 shows part of a larger AcciMap which was developed using reports written by the Independent Police Complaints Commission and the Metropolitan Police Authority. The events within the AcciMap are coded according to when they occurred (e.g., pre-operation, pre-JCdM(Jean Charles de Menezes) leaving the flat). Figure 2 is made up of six levels; each of these levels involved various failures which ultimately led up to the shooting.

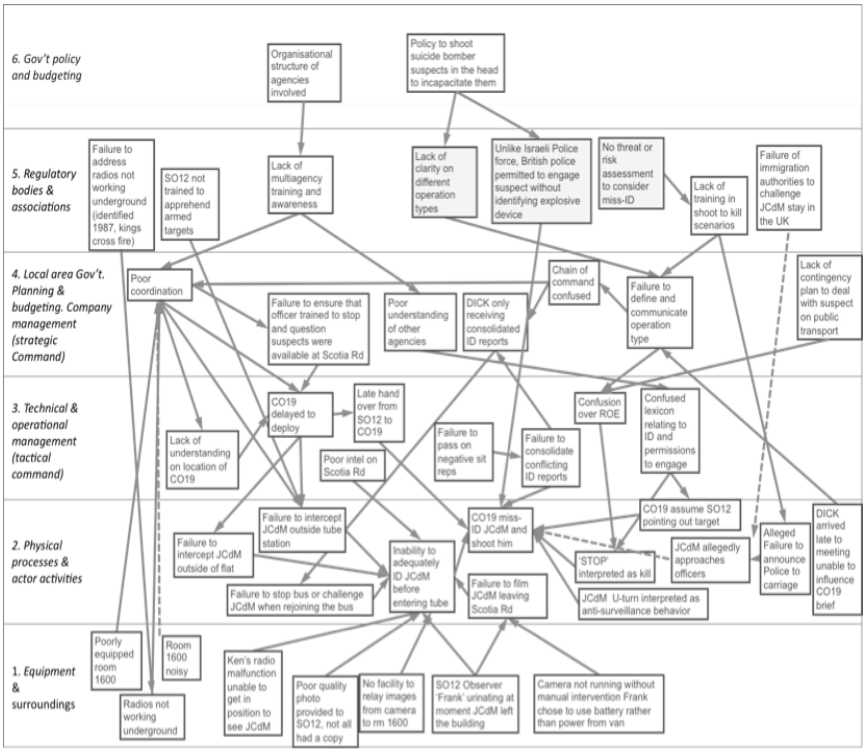

Figure 2: Example AcciMap applied to Stockwell shooting incident

Comparing our use of AcciMaps and the Risk Management Framework

Our use of the RMF and AcciMaps showed some clear similarities and differences both in terms of the procedure which was used to carry out the analysis and the conclusions that were drawn regarding the causes of the accidents and incidents. Table 2 compares our use of the methods as they relate to our goals, intentions of use and procedure.

The clearest differences in the use of the methods relates to the goals and intentions behind the analysis of the two accidents. In the case of the Stockwell shooting, one of the goals was to capture the dynamic nature of communication and decision-making as it took place over a short period of time. Much of the data which formed the AcciMap was directly taken from the various reports

written about Stockwell. This is especially the case at lower levels of the AcciMap (i.e., levels 1-3). By contrast, the Infection case study was motivated by the need to explore a set of more loosely defined factors that could be linked together to explain the recurrence of the outbreaks. Part of the intention was to go beyond some the dominant explanations of infection outbreaks (e.g., compliance to hygiene protocols) and seek explanations from the findings relating to similar organisational issues within accident research. Accordingly, the infection case study tended to identify explanations at higher levels of the RMF. Data covering the outbreaks was less detailed as compared to Stockwell and partly motivated the need to see explanations across levels of analysis. The timescale for the outbreaks was also much longer (2 years), as compared to the minute-by-minute unfolding of activities in the Stockwell shooting.

Table 2: Summary of studies using AcciMaps and the RMF

	AcciMaps (Jenkins et al., 2010)	RMF (Waterson, 2009)
Context of use	Command and Control – Policing Anti-Terrorism	Healthcare – Hospital Acquired Infections
Goals and intention of use	Modelling of the events leading up to the shooting (e.g., capturing aspects of decision-making, communication, use of equipment and physical resources)	Use of the systems approach to analyse and explain causes of the outbreaks; to further understand causal linkages and dependencies across system levels
Procedure	1. Description of events leading up to shooting: (i) Social network diagramming of actors and linkages; (ii) Chronology (timeline) of events; (iii) Summary of observation statements; (iv) Diagram of police office and witness locations; 2. AcciMap analysis - Annotation of causal factors according to temporal aspects of the incident	1. Systems description: (i) Timeline; (ii) Summary of contributory factors in HC (2007): 2. Systems analysis -use of the Risk Management (ActorMap) framework focusing on:(i) Cross-level relationships related to previous findings in the literature; (ii) Whole system relationships related to previous findings in the literature.

Aspects of our goals and intentions of use with the methods, as well as the nature of data and the domain in question shaped the procedure used in the accident analysis. In many ways our use of the methods appeared to be guided by implicit assumptions about their scope and suitability of their use for the two case studies. In the final section of the paper we focus on a set of criteria which could be used to judge the suitability, as well as scoping the procedural aspects, of the RMF and AcciMaps methods.

Implicit assumptions underlying use of the methods

In using the RMF and AcciMaps we were struck by the large range of alternatives and options for configuring and reconfiguring the original components set out by Rasmussen in his original description of the RMF and AcciMaps methods. This flexibility led us to attempt to articulate a set of criteria which could help potential users to judge the suitability of one method, or type of procedure, against another. This type of 'front end' guidance contrasts with the type of support provide by Branford et al. (2009) which attempts to lay out a set of guidelines for building AcciMaps.

An additional difference is that we focus not only the procedural aspects of systems analysis, but also on some of the conceptual choices and options which may be open to the analyst. Other methodologies for the analysis of complex work systems have benefited from the development of similar guidelines and considerations (e.g., Cognitive Work Analysis – Naikar et al., (2006). A final consideration is that the criteria are not intended to be prescriptive, rather, the intention is to support the flexible and sometimes exploratory nature of the two methods.

Establishing the purpose of the analysis

The most important step before beginning the analysis is to establish its purpose and overall goals. With the infection outbreak case study the intention was primarily to explore the interplay between the various causal factors leading up to the outbreaks. These factors unfolded over longer timescales as compared to Stockwell and what Turner called the 'incubation period' (Turner, 1978) for the outbreaks was much longer. These types of considerations shaped the choice of the method in this case (RMF), as compared to Stockwell where the dynamics of the shooting required a more distributed, 'time-stamped' representation within the AcciMap.

Consideration of the role of causality, intentionality and the nature of system error in the analysis

The distributed nature of error alongside the differences in time-scale within the two case studies also shaped the outcomes from the analysis. The RMF was also chosen because it facilitated consideration of cross-level causal
connections and linkages between macro and micro elements of the overall system. Error in this context was difficult to pin down to specific individuals, instead it manifested itself as a set of shared attitudes which infiltrated the culture of the hospital and blocked organisational learning. Organisational error in this form was easier to conceptually explore using the RMF. With Stockwell by contrast, the AcciMap format was more suited to building a 'causal map' bringing together processes of decision-making and communication.

Domain specific considerations

The nature of the two domains and the structural properties of the systems and sub-systems within the case studies also played a role in shaping the choice of method. The infection outbreak involved a widely distributed and diverse set of organisations and actors. Coupling between the various actors within the overall system was often very loose. Within Stockwell the degree of coupling was similarly loose at upper levels of the AcciMap, but tighter within the lower levels. Consideration of issues of coupling between levels, as well as the

communication requirements of actors in the system, also shaped the choice of the methods.

Data and information inputs to the analysis

Our use of the two methods showed some procedural similarities. Both cases started out by carrying out what might be called 'domain analysis', that is, developing an understanding of the domain independent of the accident or disaster in question. This may involve reading accounts of similar accidents (e.g., other infection outbreaks, the report on the Kings Cross fire). Documentary inputs into the analysis can determine the nature of the method used. The RMF for example, was used for the Infection case study partly because information was unavailable regarding the specific actions of individuals (e.g., health care managers). Similar information on decision-making, communication was available for the Stockwell and was therefore more appropriate for analysis using AcciMaps.

Constructing RMF and AcciMap representations

The most extensive set of guidelines for using and constructing AcciMaps are available in Branford et al. (2009). These cover a set of prompts and questions to be used at levels within the AcciMap. These types of support for analysis can be very useful; however, there is also an additional need to build some form of wider options for choices which may be possible at each level. This is especially the case where the specific prompts or questions to bask at each level are dependent on characteristics of the domain or the nature of error in the system. Our experience of using the methods is that these guidelines could be extended to cover options for potential modifications to the methods (e.g., the use of multi-level theory, decision-ladders).

Reviewing and validating the analysis

The issue of the reliability and validity of the AcciMaps and RMF methods has been raised by a number of authors (e.g., Johnson and de Almeida, 2008). Our experience is that in some cases, for example where the primary motivation for using the method is exploratory (e.g., in infection outbreaks case study), extensive validation may not be necessary. Branford (2007) found that these are difficult with AcciMaps and that there is a need to acknowledge the subjective nature of analysis. Her findings suggested that there is a need to capture the underlying process and rationale during AcciMap judgments and decisions.

Future work

The criteria outlined need further refinement and development. We hope to use some of the other examples of use of the RMF and AcciMaps as a basis with which to develop more detailed and extensive guidance regarding the possibilities for using, tailoring and configuring components of the methods. Similarly, a clear priority is that further work needs to be conducted on the provision of support in order to improve the reliability and validity of the two methods. Our current work involves a set of studies aimed at examining not only reliability, but also usability issues associated with the AcciMap method. This work involves examining how different configurations of the method (e.g., procedure, sue of different types of maps), as well as support for recording additional information (e.g., decision-rationale), impact on usage characteristics and outputs generated by AcciMap analysts.

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