Diagnosing Co-ordination Problems by Modelling the Emergency Management Response to Disasters

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Abstract

In the United Kingdom, there is a system for the co-ordination of the emergency services in response to disasters - The Emergency Management Combined Response System (EMCRS). It is a complex three tier command and control system. It was set up in response to a need for better co-ordination between agencies, when they respond to disasters.

This research has developed models of the EMCRS that support diagnosis of co-ordination problems between agencies. Data for the modelling was acquired by means of training exercises. The co-ordination problems were identified through behaviour conflicts between the agencies. For example, the Fire Service behaviours of setting up a cordon around the disaster site conflict with the Ambulance Service behaviours of accessing the site for treatment of casualties.

In the course of EMCRS model development, the scope of an existing framework was extended to accommodate EMCRS characteristics, which are general to: (i) systems with more than one level of operation and interactions between the levels; (ii) systems that do not have stable membership; and (iii) systems where there are trade-offs between different parts of the system that affect performance. For example, the framework extension for (ii) is to include time lines and a symbol that denotes additional structures.

The EMCRS models constitute substantive Human Computer Interaction design knowledge, that is, knowledge that is both explicit and supports design. Such knowledge supports design practice directly, as the diagnosis of design problems, and indirectly, as the prescription of design solutions. An initial method for coordination design problem diagnosis by means of EMCRS models is also proposed. The strengths and weaknesses of the research are identified and discussed. Future work would be to apply the extended framework to data from an actual disaster to validate the EMCRS models.

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For my father

Chapter 1

Research Background

This research is intended to constitute Human Computer Interaction (HCI) substantive design knowledge, in the form of models that support diagnosis of specific design problems, and reasoning about potential solutions to these problems. One view of HCI (Long, 1996), is that of an engineering design discipline, whose research validates design knowledge, both substantive and methodological. Design knowledge supports design practice as the diagnosis of design problems and the prescription of design solutions. Long and Dowell (1989) propose the discipline of HCI as the application of HCI knowledge, to support design practices, intended to solve HCI design problems. They identify validated engineering principles as a type of knowledge that best supports HCI practice. These principles would therefore support the design of general solutions to general classes of HCI design problems. The development of such principles represents a long-term goal for an engineering design discipline of HCI. Design-oriented frameworks are one form of HCI knowledge, which is both explicit and is intended to support design directly. Such frameworks provide the basis for modelling specific design problems. Their purpose is to enable designers to reason more effectively about potential design solutions. Frameworks lack the 'guarantee' of validated engineering principles. Instead, they support the practices of 'specify-and-implement'. That is, practices where design proceeds through iterations of successive cycles of specification and implementation. Such frameworks support the designer in producing better specifications at an earlier stage of design, thus reducing costly iteration. These frameworks produce models of the systems under investigation, that support diagnosis of design problems, and reasoning about design solutions. The aim of the current research is to develop such models for the Emergency Management Combined Response System (EMCRS) – a system that manages the response of the emergency services to disasters, that support diagnosis of EMCRS coordination design problems and reasoning about design solutions to these problems.

Introduction

This chapter presents the aims and the background to the research, presented in the following chapters. The research is carried out within the field of HCI, and the domain studied is emergency management. Section 1 gives a brief introduction to the domain of study and theoretical background to the research. Section 2 presents the aims of the research. Section 3 gives a detailed description of the emergency management system to be studied. Section 4 presents background literature from HCI and other relevant areas of study. Section 5 gives a brief outline of the framework, applied for use in this research. Section 6 gives a summary of the chapter.

1.1 Background

1.1.1 Domain of study

Emergency management is an example of a multi-user planning environment, which requires operators to deal with emergency situations. Controlling these situations requires the co-ordination of numerous agents, who share the various specific tasks, which fulfil the overall goal of making the situation stable. These tasks involve a number of people, often geographically distributed, working simultaneously (rather than sequentially) as a team towards the achievement of shared goals. The development of systems for emergency management, therefore, demands the analysis and modelling of co-operative work tasks, placing strong emphasis on the capture and representation of concurrent task activities, involving multiple agents.

On 11th September 2001, terrorist attacks on the World Trade Centre left 343 fire fighters dead. The enquiry into the emergency services response to the disaster, by McKinsey consultants (McKinsey 2002), found that the fire fighters had little or even no co-ordination within their service. Many crews proceeded to the Twin Towers without first informing their commanders. Once inside the building, the crews were unable to communicate with their commanders, due to equipment failures. There was also little or no co-ordination with other services, such as Police and Ambulance. The report made 12 recommendations for changes in training and procedures for the Fire Service - intended to produce a more effective system of inter-agency co-ordination. This report, then, identifies co-ordination as a major problem in the emergency services' response to the disaster.

In the United Kingdom, there exists a system for the co-ordination of the emergency services in response to disasters, such as explosions, air crashes etc. - the Emergency Management Combined Response System (EMCRS) (Dealing with Disaster 1994, 2001). This system manages, that is, plans and controls, agencies, such as Fire and Police, when they respond to disasters. The EMCRS was set up to support better co-ordination between agencies responding to disasters. However, a succession of enquiries into disasters e.g. Hidden (1989), Fennel (1988) have identified problems with EMCRS co-ordination, not dissimilar to those revealed by the McKinsey report.

The background to the domain of study has now been presented. The next section presents the background to the theoretical basis of the research.

1.1.2 Grounding in HCI

As stated in the introduction to the thesis, one view of HCI (Long, 1996) is that of an engineering design discipline, whose research acquires and validates design knowledge, both substantive and methodological. Design knowledge supports design practice as the diagnosis of design problems and the prescription of design solutions (Long, 1996). Long and Dowell (1989) propose the discipline of HCI as the application of HCI knowledge, to support design practices, intended to solve HCI design problems. However, existing knowledge in the form of craft and applied science (Long and Dowell, 1989) has serious shortcomings. First, craft knowledge exists implicitly in the expertise of experienced designers. Thus, it is not publicly available for inspection and development and has an unknown scope of application. Second, applied science knowledge from relevant academic disciplines (such as Psychology, Linguistics and Sociology), although it may be scientifically validated, supports design only implicitly and indirectly. The knowledge supports explanation and prediction, and so understanding, rather than diagnosis and prescription, and so design. (Smith et al, 1997). Long and Dowell (1989) describe a third type of knowledge to support HCI practice: engineering principles. Such principles would be validated with respect to their support for design. They would support the design of general solutions to general classes of HCI design problems. The development of such validated engineering principles represents a long-term goal for an engineering design discipline of HCI. Design-oriented frameworks are one form of HCI knowledge, which is both explicit and is intended to support design directly, unlike craft and applied science. Such frameworks provide the basis for modelling specific design problems. Their purpose is to enable designers to reason more effectively about potential design solutions. Frameworks lack the 'guarantee' of validated engineering principles. Instead, they support the practices of 'specify-and-implement'. That is, practices where design proceeds through iterations of successive cycles of specification and implementation. Such frameworks support the designer in producing better specifications at an earlier stage of design, thus reducing costly iteration.

1.2 Aims

The aim of the present research is to develop models of the EMCRS that support the diagnosis of EMCRS co-ordination design problems and the reasoning about solutions to these problems. To develop such models a design-oriented framework is required, that supports modelling of the EMCRS - a distributed cognitive planning and control system, comprising more than one user, or groups of users, whose activities must be co-ordinated for effective performance. One such framework was developed for a class of HCI design problem, expressed as the planning and control of multiple task (HCI-PCMT) work in office administration (Smith et al., 1997) (see later for details). The office administration domains previously modelled by the HCI-PCMT framework were single user planning and control systems. Application of the HCI-PCMT framework to model the EMCRS would, thus, extend the scope of the framework to accommodate multi-user planning and control systems. The models produced would identify planning and control co-ordination design problems and thus diagnose ineffective performance. A diagnosis method for application of the framework will also be proposed. Performance is expressed as a function of the task quality of the work (how well it is performed), and the resource costs (workload) of the worksystem. The modelling framework enables performance diagnosis by making a distinction between the worksystem (and its resource costs) and the work domain (and its task quality). Thus, the EMCRS model is intended to constitute HCI substantive design knowledge to support the diagnosis of EMCRS design problems. Prescription of solutions to these problems will not be attempted, as this is beyond the scope of the current research, but suggested prescriptions will be proposed to clarify the nature of the diagnoses.

1.3 Emergency Management for Disaster Response

Emergency Management is the management of the multiple emergency services in response to emergency situations, in the case of this research, specifically disasters. In the context of emergency planning, the definition of disaster adopted here is as follows:

'Any event (happening with or without warning) causing or threatening death or injury, damage to property or environment or disruption to the community, which because of the scale of its effects cannot be dealt with by the emergency service and local authorities as part of their day-to-day activities (Dealing with Disaster, 1994).'

This definition encompasses those used by the emergency services for a 'major incident'. In defining a major incident, the emergency services recognise that there will be a need for special arrangements to be brought into play, in response to such an incident for: the rescue and transport of a large number of casualties; the involvement, either directly or indirectly, of large numbers of people; the handling of a large number of enquiries, likely to be generated by both the public and the news media, usually to the Police; and any incident that requires the large scale combined resources of the three emergency services; the mobilisation and organisation of the emergency services and supporting organisations, e.g. Local Authority, to cater for the threat of death, serious injury or homelessness to a large number of people (Emergency Planning College,

1996). However, not every major incident will become a disaster; for example, a serious accident on a motorway will be a major incident, if it demands special arrangements on the part of the Police, Fire and Ambulance Services, but unless it has some wider ranging effects on the community, it is unlikely to be regarded as a disaster. Causes of disaster may be sudden and unpredictable. However, certain kinds of industrial activity carry known risks and are subject to legal requirements for emergency planning. These cases include known chemical or nuclear hazards at fixed locations, where the most probable types of incident, and their likely consequences, are largely foreseeable. It is, therefore, possible to make detailed plans in advance for the appropriate action to be taken. There are also specialist emergency service units, often on the industrial site, who will initially react to any incident. The general emergency service teams from the wider area will not necessarily become involved in such incidents. Therefore, these types of incident will not be covered by this research, as it focuses on the emergency system set up for the management of more wide-ranging disasters/major incidents.
The initial response to a disaster is usually provided by the emergency services, supported by the local authority, but many agencies can become involved. The common objectives to a disaster response, as declared by the Home Office are:

- To save life.
- To prevent escalation of the disaster.
- To relieve suffering.
- To protect property.
- To safeguard the environment.
- To facilitate criminal investigation and judicial, public, technical or other inquiries.
- To restore normality as soon as possible.

Each service or agency working at the scene of a disaster has its own role and functions: (Dealing with Disasters, 2nd Edition 1994).

- The Police co-ordinate all those responding at and around the scene.
- The Fire Service are to rescue people and to prevent further escalation of the disaster by tackling fires or dealing with other hazards.

- The Ambulance Service, with the medical incident officer and medical teams seek to save life, through effective emergency treatment and transporting the injured in order of priority to hospital.
- HM Coastguard initiates and co-ordinates civil maritime rescue, which includes mobilising, organising and dispatching resources to assist people in distress at sea or in danger on the cliffs or shoreline.
- The Local Authorities support the emergency services, as well as the local and wider community and co-ordinate the response by organisations, other than the emergency services.
- Volunteers contribute to a wide range of activities, either as individuals or as members of a voluntary organisation.
- Industrial or commercial organisations may play a direct part in the response to disaster, if their personnel, operations or services have been involved.
- Military assistance may be used in support of civil authorities.
- Central government may provide advice or support.

More specifically the role of the Police is:

- The saving of life in conjunction with other emergency services.
- Co-ordination of the emergency services and other organisations, during the immediate response phase.
- Protection and preservation of the scene.
- Investigation of the incident in conjunction with other investigative bodies.
- Collation and dissemination of casualty information.
- Identification of victims.
- Restoration of normality.

The role of the Ambulance Service is:

- The saving of life in conjunction with other emergency services.
- To provide a focal point for all National Health Service and other medical resources.
- The treatment and care of injured persons.
- Determination of the priority evacuation of the injured.
- Determining the main receiving and supporting hospitals.

- Arranging and ensuring the most appropriate means of transporting the injured.
- Restoration of normality.

The role of the Fire Service is:
- The saving of life in conjunction with other emergency services.
- Tackling fires, released chemicals and other hazardous situations.
- Rescue of trapped casualties.
- Safety of all personnel, involved in the rescue work.
- Information gathering and hazard assessment.
- Assisting the Ambulance Service at casualty loading points.
- Assisting the Police with recovery of bodies.
- Restoration of normality.

There is a continuum by which the emergency services distinguish different types of accident. The classification of the incident will determine the type of system that is set up to deal with it. For a simple accident, the emergency services have their own plans. For a major incident, the emergency services have different planning procedures, which allow the interaction between all the emergency services. With disasters, it is different again. There is a senior co-ordinating group (comprising a senior Police, Fire and Ambulance Officer), who oversee the work of the emergency services. The more serious the situation is perceived to be, the more levels of planning are put into operation. Overall control is taken away from the actual emergency services dealing with the disaster situation.

The planning and control system, which is set up for emergency response to a disaster, is that of the 'combined' response. The combined response system has a command and control organisation with a three tier structure. This system will be referred to as the EMCRS (Emergency Management Combined Response System). The EMCRS is a generic management framework, which has been agreed nationally which:
- Defines relationships between differing levels of management.
- Allows each agency to tailor its own response to plans to interface with the plans of others.

- Ensures all parties involved understand their relative roles in the combined response.
- Retains sufficient flexibility of option to suit local circumstances to enable the emergency services to interact effectively (Dealing with Disaster, 1994; 2001).

All the different agencies should use this structure to organise their own planning procedures, so that they interface effectively with each other. The three levels are operational, tactical and strategic (sometimes referred to as bronze, silver and gold). At each level, each of the agencies has its own commander for co-ordinating the response. At the strategic level, these commanders make up a senior co-ordinating group. The operational response is carried out by each agency, concentrating on their specific tasks within their areas of responsibility, e.g. the Fire Service fighting fires. The tactical response determines the priority in allocating resources. It also plans and co-ordinates the overall response, obtaining other resources as required, for example additional fire engines. The strategic co-ordinating group has to formulate the overall policy within which the response to a major incident will be made. At the strategic level, there is one person from each emergency service. Under the EMCRS, the management of the response to major emergencies will normally be undertaken at one or more of the three levels. The degree of management required will depend on the nature and scale of the emergency. The following is a representation of the EMCRS:

Strategic level	Senior co-ordinating group		
Tactical level	Fire Service	Police Service	Ambulance Service
Operational level	Fire Service	Police Service	Ambulance Service

There needs to be co-ordination at all levels of the EMCRS, so that the disaster situation is brought under control, as quickly and efficiently as possible. There needs to be co-ordination at each level within the hierarchy and between the levels. One of the main mechanisms by which the performance of any planning system is affected, is that of coordination. This mechanism is required, because each problem-solving agent only possesses a local view and incomplete information and, therefore, must co-ordinate with other agents to achieve globally coherent and efficient solutions. In emergency management, there is not only coordination between each problem solving agent within one group, but also co-ordination between each agency (which is made up of many single agents) on a horizontal level, and vertical co-ordination between the different command levels. As stated in the introduction earlier, co-ordination, or rather lack of co-ordination, has been identified as a major factor in the ineffective response of the emergency services to disasters (Auf de Heide, 1989).

The aim of this research is to attempt to diagnose these co-ordination problems with respect to the planning and control of the EMCRS. The emergency services' response to disasters has different phases. First, there is the initial response, when the situation is usually fairly chaotic. Second, the response some time later (which could be a few hours, maybe longer depending on the scale of the incident), when the situation is more stable. Last, the restoration of normality phase, when the actual incident has been brought under control, but the situation has not returned to normal. Within each of these phases, the emergency services will have different roles/tasks that they need to carry out. During the initial response phase, the tasks being carried out by the emergency services will be their primary tasks in response to the situation, e.g. Fire Service fighting fires, Ambulance Service treating casualties. Collaboration, coordination and communication are thus, vital at the initial response stage (Dealing with Disaster, 2001). Coordination problems, occurring between services in the initial response phase, will, therefore, have more of a detrimental effect on EMCRS performance than coordination problems occurring at other phases, when the tasks being carried out are not dealing with the initial effects of the situation. Data collected for use in the modelling of the EMCRS will thus need to include the initial phase as a priority. The level of description of the data is also important. At a major incident, there are potentially three levels of operation – operational, tactical and strategic. The operational level will have lots of personnel and their resources, who are physically responding to the disaster. Data at this level of description, will not be required to inform the modelling, partly because these data risk making the model too complex, and so difficult to apply, but mainly because the aim of the research is to identify planning and control co-ordination problems between the different services, not between the different personnel of each service, or within personnel of the same service. As each agency has it own roles/tasks that must be carried out in response to a disaster, it is suggested that this level will be the lowest description for the data. An example task, for the Fire Service, would be to fight fires. A description of the behaviours associated with this task would be given at the level of description of firemen and fire equipment – not Fireman 1 plus Fire Hose 1, Fireman 2 plus Fire Hose 2 etc.

The EMCRS is thus a complex system interacting with a complex dynamic situation. There are multiple agencies, with multiple personnel, at multiple levels of command, carrying out concurrent task activities. The HCI-PCMT has been chosen for modelling the EMCRS because: the framework is for modelling planning and control systems of which the EMCRS is an example; the work involves multiple tasks; there is a need to identify the tasks and behaviours of the worksystem in relationship to its work, better to identify coordination problems within the EMCRS; and the framework supports directly the diagnosis of design problems and so ineffective performance (and indirectly prescription of design solutions). Chapter 2 presents the HCI-PCMT framework in detail.

The following sections outline other models and frameworks from the HCI and Emergency Management literature that were not viewed as suitable for developing the EMCRS models.

1.4 Frameworks and models from HCI and other relevant literature

Frameworks and models are prevalent in the HCI literature (Long 1987; Whitefield 1990). However, most models of interaction are task based (Wright et al., 2000). Traditional task analysis methods such as GOMS (Card et al, 1983), Hierarchical Task Analysis (Shepherd, 1989), Task Knowledge Structures (Johnson, 1992), based on observable actions may not be appropriate for analysing complex work domains. (Moray et al,

1992). These methods of task analysis do not account for the variability of behaviour that is observed in complex systems. (Vicente, 1990). Other analysis techniques, such as protocol analysis, video analysis, discourse analysis, conversation analysis, interaction analysis, cognitive task analysis, and sequential data analysis, use naturally unfolding events as data. (Sanderson and Fischer 1994). However, the data collected from such techniques is qualitative. How to use these analysed data to produce design solutions is not made clear. Other more advanced techniques such as the Interaction Framework (Blandford, Harrison and Barnard, 1995), have been developed to aid the design of interactive systems involving two or more agents, and for evaluating such systems. The Interaction Framework will produce interactional requirements for a system. However any design solutions proposed, do not take considerations, other than interactional ones, into account (Blandford et al, 1995).
All of the frameworks, methods, or analysis techniques mentioned so far, do not use an ecological perspective, as an approach to HCI. The ecological perspective takes its name from an approach to psychology that was advanced by Brunswik (1956) and Gibson (1979). The approach viewed Psychology as the study of the interaction between the human organism and its environment. When applied to human factors, the ecological approach suggests that the fundamental unit of analysis is the human-machine system (Flach, 1989). Human and work environment are reciprocally coupled and cannot be studied independently of each other. As a result, an ecological approach to human factors begins by studying the constraints in the environment (i.e. the task or the work domain) that are relevant to the operator. (Vicente, 1990). This emphasis is different from the one used by the methods/frameworks that have been already mentioned, which often minimise or do not acknowledge the importance of the domain on behaviour. One of the areas that the ecological approach can inform is human performance modelling. In order to understand behaviour, it is necessary to have a separate, but commensurate, understanding of the context in which the behaviour takes place, and the mechanisms generating that behaviour (Vicente, 1990). Thus, when developing a model of human performance, it is important to have a functional description of the domain, in which behaviour is taking place.

In the case of the EMCRS, the importance of understanding the behaviour of the system, with respect to the dynamic nature of the disaster domain, is obvious. Analysing the behaviours of the EMCRS, without taking into account the effects those behaviours are having on the domain, and likewise not taking into account the effects the changing domain has on those behaviours, would provide an unrealistic analysis of the EMCRS, attributing the complexity of the EMCRS behaviours only to complex psychological mechanisms.

The HCI-PCMT framework has an ecological perspective, in as much as it includes a domain external to the system of concern. In addition, the framework models the interactive combination of the human and computer/device. There are, of course, other methods that have some type of ecological perspective. One area of HCI, that has been claimed by Woods (1998) to be ecological, is cognitive engineering. Woods (1998) states; 'It is about multidimensional, open worlds and not about the artificially bounded closed worlds typical of the laboratory or the engineers desktop. An example of the ecological perspective is the need to study humans solving problems with tools (i.e. support systems), as opposed to laboratory research, which continues, for the most part, to examine human performance stripped of any tools. Cognitive engineering is a *sine qua non* for this – how to put effective cognitive tools into the hands of practitioners.' There are therefore, ecological methods and models in the area of Cognitive Engineering. Mancini (1986), proposed the DYLAM methodology (where machine and human behaviour are modelled separately; but are also tightly coupled by the dynamic simulation of the studied sequences), as a technique for balancing and interfacing between the model of the human mental processes and mechanisms of decision making and the model of the machine affected by the human actions (Amendola et al 1988). However, this method is not appropriate in multiple task situations. Boy (1983) and Boy and Tessier (1983) created a model called MESSAGE, which includes a supervisor managing three types of processes called channels, i.e. receptors, effectors and cognition. MESSAGE includes the concepts of automatic and controlled processes. These automatic processes involve a particular knowledge, which is modelled by a situational representation – the term situation is used to characterise the instantaneous state of the environment or world, by a set of components called world facts. (Boy 1988). This methodology has been used in the development of knowledge-based systems (KBS), which have been used in the training of operators in complex environments.

Another area of research, where models and methods are relevant to the current research is distributed decision making. A system is characterized by distributed decision making to the extent that it lacks a centralised control agent, or decision maker. The need for distributed decision making or control arises because of the complexity of the problems facing the decision makers. Tasks are distributed, and this distribution leads to a need for coordination (Brehmer 1991). The EMCRS could, thus, be classified as distributed decision making. Classical decision making models have limited usefulness in modelling distributed decision making, as they normally only consider one decision maker, who may only have one goal, which can be stated in quantitative terms. The decision maker has a known number of solutions, and the models are normative – i.e. the decision making is considered as a logical process. (Koopman and Pool, 1991). Rasmussen (1991) has identified the need to take a Cognitive Engineering approach in developing modelling frameworks for distributed decision making. Separate representations of the work domain, the generic cognitive decision tasks, and the useful strategies for such decision tasks, together with the subjective criteria of choice, need to be identified to develop useful models. Teams in emergency management are often faced with ill-structured problems, uncertain and dynamic environments, shifting, ill-defined and sometimes competing goals, multiple eventfeedback loops, time constraints, high stakes, multiple players, and organisational norms and goals that must be balanced against the team member's personal choices. These factors have been identified by Orasanu and Connolly (1993) as typical for decision making in naturalistic environments (Schaafstal et al 2001). There has been much research in this area developing models and methods for analysing naturalistic decision settings (including emergency management), resulting in the Naturalistic Decision Making (NDM) paradigm (Klein, 1997). NDM emphasizes the role of situation awareness in decision making and the use of mental simulation to describe the mental processes of decision making. However, Doherty (1993) and Klein and Woods (1993), have identified clear limitations in the models and research of naturalistic decision making - the major problems being that none of the models or methods are easily testable. The statements tend to be about what goes on at a high level of description and there is little about how it goes on, at a lower level, i.e. in detail. A second weakness is that the research base is limited - many of the studies depend on ethnographic designs, which lack rigour. Application of these models has been used in the support of decision training. However, these models do not support diagnosis of co-ordination design problems, and thus, do not support design directly. The idea of socially distributed cognition refers to the fact that participants in collaborative work relationships are likely to vary in the knowledge they possess and must therefore engage each other in dialogues that allow them to pool resources and negotiate their differences to accomplish their tasks. Hutchins (1990) has identified important features to be accounted for in a distributed task, which ensure effectiveness:

- Shared task knowledge - each person understands enough about each others' work to co-ordinate effectively;
- Horizon of observation - which allows other team members to witness other performances; and
- Multiple perspectives, which allow for activities to be observed from different points of view.

The behaviour of each member of the team is contingent on the behaviour of all the other members of the team. An action by one member will trigger an action (reaction) by another member, until the task is complete. Each member of the group has knowledge of a specific part of the distributed task, the whole group is undertaking. The co-ordination among the actions of the members of the team is not achieved by following a master procedure, instead it emerges from the interactions among the members of the team. The procedure is used as a guide to organising actions. Distribution of tasks leads to a need for co-ordination. In extending the scope of the HCI-PCMT framework to accommodate the EMCRS, these features may need to be taken into account. For example, having shared task knowledge. Each of the emergency services needs to understand what each of the other services are doing, in order to co-ordinate their behaviours to produce effective performance.

There have been many methods, models and frameworks developed for analysis of Emergency Management. Specifically Rogalski and Samurcay (1993) have focused on communication between the services as a means of analysing distributed decision making. In one paper (Rogalski and Samurcay, 1993), they have analysed horizontal and vertical co-ordination through conversational analysis of the interactions between two groups of emergency decision groups, planning the resolution of two forest fires. The efficiency of the two groups is compared. The analysis allows an understanding of why one group is better than the other. The group that has a better flow of communication and distribution of roles is more efficient. Samurcay and Rogalski (1991) have also developed a Method for Tactical Reasoning (MTR) and applied it in emergency management. This method describes a decomposition of the overall task (for the class of emergency situations) into specific tasks (involved in analysis and planning), as prescribed tasks in the sense developed by Leplat (1988). The MTR provides a model of the cognitive tasks, involved in emergency management. This research allows for an understanding of emergency management behaviours, but does not relate it directly to the design of the emergency management system. Kaempf et al (1996) studied the decision making of experienced personnel in complex command and control environments, using the recognition-primed decision (RPD) model (Klein, 1993), which depicts how experienced people make decisions in natural settings. The results of the study suggested that decision makers use recognitional processes and that situation awareness is of primary concern. However, it is difficult to generalise from this study to other command and control domains, as the domain studied was very procedural in nature, and thus, other command and control settings may place different requirements on the decision makers. Other work, such as Blandford and Wong, (2004) and Blandford et al, (2002) has looked at the behaviours of individual services within emergency management, but does not relate these behaviours to the other services within emergency management, and does not develop systematic models that can be directly used for design of the emergency management system.

It is recognised that no specific reference has been made in this section to the planning literature. The relevant planning literature is presented in the following chapter as part of the background to the HCI-PCMT framework development.

1.5 HCI-PCMT Framework

A framework was earlier developed to model the management, that is, planning and control, of multiple task work (PCMT) in office administration. The Framework is the Planning and Control for Multiple Task Framework (HCI-PCMT) (Smith et al, 1992; 1997, Hill et al, 1995). The HCI-PCMT framework is based on a conception of HCI (Dowell and Long 1989 and 1998), and has an ecological perspective. The HCI-PCMT framework has taken the approach of developing a generic cognitive model for the worksystem as a whole, as opposed to the user alone, which is similar to the 'joint-cognition' approach of Woods and Hollnagel (1987). Hutchins (1987) has used the term 'distributed cognition' to refer to models of cognition supported by many agents working together, usually teams of individuals. Models derived from application of the framework will be similar inasmuch as the cognition of the worksystem is distributed across the physically separate user and devices. Chapter 2 will present the HCI-PCMT framework and background to its development.

1.6 Means-Ends Hierarchy versus HCI-PCMT

This chapter has described the many models and methods that abound in the HCI and emergency management literature, but which are not viewed as appropriate for the current modelling, for the reasons given. However, to further justify the use of the HCI-PCMT framework in the current research, rather than using another established framework, a comparison will now be made, at a high level, between the HCI-PCMT framework and the Means-Ends Abstraction Hierarchy of Rasmussen and Vicente (1989), which is also a framework for modelling complex work environments. Rasmussen and Vicente (1989) developed a framework for modelling complex work domains. This framework – the Means-Ends Abstraction Hierarchy similar to HCI-PCMT has an ecological approach to HCI in the

Gibsonian (Gibson, 1979) sense of the primary unit of analysis being the total ecosystem of users and environment, and not the users and environment as distinct categories. Rasmussen and Vicente mapped Gibson's affordances within the Means-Ends Hierarchy (Rasmussen, 1986). The results of this mapping indicated that affordances could be structured as a Means-Ends Hierarchy, and thereby function as a mechanism to cope with the complexity of the natural environment. The Means-Ends model has five levels, ranging from physical properties to high level goals and intentions. The interrelationships between the affordances and the five levels are articulated as 'what', 'how' and 'why'. These are fundamental questions that in Artificial Intelligence terms correspond to: declarative knowledge (what); procedural knowledge (how); and meta-knowledge (why) (Albrechtsen et al, 2001).

Adopting such a format to structuring the affordances of a system provides a mechanism for coping with complexity. However unlike the HCI-PCMT framework, which is based on the Dowell and Long (1989) conception of HCI which distinguishes the interactive worksystem, comprising users and computers or devices, from its domain of application constituting the work of the work system, the Means-Ends Abstraction Hierarchy does not make this distinction. The concept of domain is the world in which work is performed and is conceived as discrete objects. Objects may be both abstract as well as physical and are characterised by their attributes. Task goals express specific desired states of objects. The desired state expressed by a task goal is the ideal product of the task. Task quality thus describes the actual product of a task with respect to the desired product (expressed by the task goals). As task quality describes the product as a change effected by the task in the attribute state of an object (with respect to the desired change), quality enables all possible products of a task to be equated and evaluated. Also as task quality is separately expressed from the behaviours of the system, task quality supports the design of novel systems which cannot be simply specified by the behaviours of the old system. Thus, the HCI-PCMT framework supports the expression of task quality for the different tasks of the EMCRS, in terms of domain object attribute value changes. Expressing the EMCRS multiple tasks in this way allows for analysis of any co-ordination problems arising from behaviour conflicts where particular desired domain object attribute value changes cannot be carried out.

Within the Dowell and Long (1989) conception the concept of performance is expressed as the effectiveness with which the work of the worksystem is carried out as a function of the resource costs to the system (the effort etc. of performing that work well), and the task quality afforded by this work (how well it is performed). Overall performance, thus, expresses whether goals have been achieved and at what cost. A design problem is diagnosed, if actual performance (Pa) does not equal desired performance (Pd), where performance (P) is expressed as task quality (Tq), user costs (Uc) and computer (device) costs (Cc). A design solution is prescribed if Pa is equal to Pd. Without HCI-PCMT supporting this expression of performance, the current research would not be able to develop models of the EMCRS that diagnose design problems.

Last, the HCI-PCMT framework was developed for analysing planning and control for multiple task work systems, and has been shown in previous case-studies to diagnose planning and control design problems (Smith et al, 1997). Thus the HCI-PCMT framework has an, albeit minimalist architecture, to accommodate such planning and control systems. The Means-Ends Abstraction Hierarchy is a more general framework for analysing complex HCI systems, its purpose is not specifically for modelling planning and control in multiple task work situations, and therefore it does not have a planning and control architecture. Thus, although the Means-Ends Abstraction Hierarchy has its place in the development of HCI models for complex systems, in this instance, the HCI-PCMT framework has been chosen for the modelling for the following reasons:

1) The HCI-PCMT framework has the concept of a domain of application which allows for an expression of task quality that enables co-ordination problems to be identified.
2) The HCI-PCMT framework has an expression of performance that enables design problems to be diagnosed.
3) The HCI-PCMT framework has a specified planning and control architecture for modelling planning and control systems.

1.7 Data Acquisition and Analysis

Within qualitative research traditions there is a broad spectrum of methods – at one end almost formal methods and at the other end most informal methods. Where you locate yourself in this tradition depends on access and data acquisition. Access to data of the EMCRS response to an actual disaster was not possible due to the confidentiality of such data, and the requirements of the current research to publish in the public domain. Therefore, the data was acquired from training exercises. However, within the current research the constraints on data acquisition at the training exercises were at a maximum as no video or audio recording device could be used. The data recorded were the notes taken by the researcher during the exercises, and therefore the data collection is at its most informal.

The HCI-PCMT framework was applied to this data to produce diagnostic models of the EMCRS. No formal method is given within the current research for application of the HCI-PCMT framework to the data, but an informal untested method is given of how to construct models by HCI-PCMT framework application. However, the approach used is in the tradition of Grounded Theory (Strauss and Corbin, 1990) and is consistent with some aspects of this tradition. Grounded Theory is a social-science approach to theory building that combines systematic levels of abstraction into a framework about a phenomenon, which is verified and expanded throughout the study (Adams, 2002). Social science methodologies support design only implicitly and indirectly. Grounded Theory is therefore not directly applicable in the current research where the aim is to produce knowledge that is explicit and supports design directly in the form of diagnostic models. Therefore, within the current research an attempt is not made to apply Grounded Theory as such - the HCI-PCMT framework has different requirements (to produce diagnostic models), but there are similarities in the approach taken within the method for model construction to the Grounded Theory approach. These similarities are identified here to justify the current approach taken.

The basic idea of the Grounded Theory approach is to analyse data, in whatever form, and 'discover' or label variables, called categories concepts and properties and their interrelationships. Thus the data is analysed, conceptualised and then re-expressed with respect to these variables. To enable this conceptualisation to occur in a structured manner, there are three major coding stages – open, axial and selective, in the analysis procedure. The open coding stage identifies, names, categorises and describes phenomena and identifies the properties of these phenomena (categories). The axial coding stage then identifies the high level phenomena (e.g. central ideas, events) along with the conditions and participants strategies pertaining to those phenomena (e.g. causal conditions, intervening conditions, action/interaction strategies). Finally the selective coding stage is the process of choosing one category to be the core category, and relating all other categories to that category. This process is iterative, with continuous validation with the raw data to confirm or refute conclusions. The last stage of analysis is the integration of process effects which are factors that change over time, so that changing factors within the framework can be identified. The ability to perceive variables and relationships is termed 'theoretical sensitivity', which refers to the researcher's personal degree of sensitivity, depending upon previous readings and experience, relevant to the area of study.

The method for model construction (see Chapter 4 Section 4.3) like Grounded Theory requires theoretical sensitivity on the part of the researcher. The current researcher had experience and knowledge from previous applications of the HCI-PCMT framework in other domains (Hill et al, 1996); an understanding of the present domain of work of the EMCRS; and documented information describing the objectives of EMCRS behaviours. Also like Grounded Theory the data is analysed, conceptualised and re-expressed with respect to the variables categorised. The coding of these variables in the HCI-PCMT model construction relate directly to the HCI-PCMT framework representation, (where there are abstract and physical worksystem structures and an abstract and physical domain representation) and the HCI-PCMT framework axioms. Therefore, better than Grounded Theory the HCI-PCMT model construction separates the variables of the worksystem (user and devices) from the

variables of the domain (constituting the work of the worksystem). Also the HCI-PCMT framework axioms specify the relationships between the different variables. However, the coding from the data is similar in nature to the coding stages in Grounded Theory, although the stages are not carried out in the same order. For example, phase one of the method for model construction conceptualises the domain of work of EMCRS, which is the core category to which all the other domain categories relate, so this is similar in nature to the selective coding stage of Grounded Theory. Conceptualisation of the domain sub-objects and their attributes and values is carried out in a similar way to the open coding stage, as is identification of the abstract and physical worksystem structures. The model descriptions of the work of the worksystem with respect to the worksystem behaviours and the changes these behaviours effect in the domain, have similarities with the identification of action/interaction strategies and consequences of these strategies within the axial coding stage of Grounded Theory. However, the HCI-PCMT model descriptions provide an expression of the effectiveness or performance of the EMCRS by showing the quality of work in terms of domain changes, and the resource costs to the worksystem in carrying out these changes. The Grounded Theory methodology has no such specification of performance.
The above discussion has described the similarities between the Grounded Theory approach and the approach used in the current research (the method for model construction) to justify this approach. It has also been discussed as to why Grounded Theory itself was not deemed applicable within the current research.

1.6 Chapter Summary

This chapter has presented the background to the domain of study for the research (EMCRS), the background to the approach used (HCI), and the aims of the current research: to develop models of the EMCRS that support the specification of EMCRS co-ordination design problems and reasoning about solutions to such problems. A review of the literature of relevant research has also been presented. The framework chosen for modelling the HCI-PCMT framework has been briefly outlined - the following chapter will present the framework in full.

Chapter 2
HCI-PCMT Framework

Introduction

This chapter presents the HCI-PCMT framework that will be used for modelling the EMCRS. Section 1 presents the conceptual background to the framework. Section 2 provides the explicit description of the framework. Section 3 characterises the differences between the systems that have been modelled by the framework to date, and the EMCRS. How the current framework will need to be extended, to accommodate these differences, will be discussed.

2.1 Background to the HCI-PCMT framework

As described in Chapter 1, a framework was developed earlier to model the management, that is, planning and control, of multiple task work (PCMT) in office administration (Smith et al, 1992; 1997). To reiterate, the HCI-PCMT framework is based on a conception of HCI (Dowell and Long 1989 and 1998). The conception distinguishes the *interactive worksystem*, which comprises users and computers or, more generally devices/equipment, from its *domain of application*, constituting the work carried out by the worksystem. The effectiveness with which work is carried out, that is performance, is a function of the quality of the work (how well it is performed), and the resource costs to the worksystem (the effort etc. of performing the work that well). Overall performance, thus, expresses whether goals have been achieved, and at what cost. A design problem is diagnosed, if actual performance (Pa) does not equal desired performance (Pd), where performance (P) is expressed as task quality (Tq), user costs (Uc) and computer (device) costs (Cc). A design solution is prescribed if Pa is equal to Pd.

In the Dowell and Long conception, a domain of application (or work domain) is described in terms of **objects**, which may be abstract or physical. Objects are constituted of *attributes*, which have <u>values</u>. The attribute values of an object may be related to the attribute values of one or more other objects. An object, at any time, is determined by the values of its attributes. The worksystem performs work by changing the value of domain objects (i.e. by transforming their actual attribute values) to their desired values, as specified by the work goal. Attributes may be affordant or dispositional. Affordant attributes are transformed by the worksystem; their transformation constitutes the work performed. Dispositional attributes are relevant to the work (they need to be used by the worksystem), but are not changed by the worksystem.

The worksystem is conceptualised as a behavioural system comprising the interacting user behaviours (supported by user structures) and computer (device) behaviours (supported by device structures). Abstract structures comprise representations and processes. Abstract representation structures refer, for example, to the worksystem's knowledge, databases or information stores. Abstract process structures refer, for example, to the worksystem's procedures, methods or heuristics. Abstract structures support worksystem abstract behaviours, when abstract process structures, such as procedures, act on abstract representation structures, such as a database. Similarly, worksystem physical structures support worksystem physical behaviours. The HCI-PCMT framework specifies worksystem structures for the planning and control of multiple task work. These structures are expressed at both abstract and physical levels of description. Physical structures embody abstract structures and physical behaviours embody abstract behaviours. At the abstract level, the framework describes the worksystem's cognitive structures. These comprise four process structures (**planning**, **controlling**, **perceiving** and **executing**), and two representational structures (**plans** and **knowledge-of-tasks**). These structures support the planning and control behaviours of the worksystem and are distributed across the physical users and devices/equipment. The four processes support the behaviours of planning, control, perception and execution respectively. The physical structures support the physical behaviours, but are not differentiated further by the HCI-PCMT framework, as the framework's concern is primarily with abstract behaviours associated with planning and control.

The rationale for what to some might appear a 'minimalist' architecture is threefold. First, the general architecture of representations and processes is commonly assumed by Cognitive Psychology models in the information processing tradition. Second, the architecture was adequate to support the construction of the initial HCI-PCMT framework for the domain of secretarial office administration. Third, the architecture supported the construction of models, whose form and granularity were commensurate with solving user interface design problems. The full argument for this set of structures, can be found elsewhere (Smith, Hill, Long and Whitefield, 1997), but can be summarised as follows:

Influenced by Newell and Simon (1972), much planning research in Cognitive Science and Artificial Intelligence has tended to view plans as complete and fully-elaborated behaviour sequences, which ensure task goal achievement. This view has been undermined by research into planning in HCI. The behaviours of users, who are part of worksystems, it has been argued, cannot be regarded entirely as the output of executable plans (e.g., Suchman, 1987; Larkin, 1989; Payne, 1991) - rather they are often, at least partly, direct responses to the task environment. Within this perspective, plans need not be complete and fully-elaborated, but rather they may be partial (in the sense that they may specify only some of the behaviours to be implemented) and/or general (in the sense that some behaviours may be specified only generally and not at a level that is executable). Such plans might be more generally viewed as 'resources' for guiding behaviour (Suchman, 1987). Furthermore, if a plan is regarded as a resource to guide behaviour it is no longer necessary that it be limited to specifying behaviours. Rather it might, instead, specify required states of the task or conditions of the environment. Plans, which serve as resources for guiding behaviour, rather than as specifications of complete and fully-elaborated behaviour sequences, cannot ensure that goals will be achieved. This research also undermines the assumption that perception precedes planning, which precedes execution. Ambros-Ingerson (1986) argued that all planning can precede execution only when:

1. The task environment is *static* - relevant changes in the task environment do not occur after the plan is complete;
2. The task environment is *simple* enough to be practically modelled - the consequence of behaviours can be predicted sufficiently well to generate a complete and fully-elaborated behaviour sequence; and
3. The task environment is *known* - the planner's knowledge of the task environment can be complete before planning commences.

Most task environments studied by HCI researchers do not embody these assumptions (Young and Simon, 1987). In direct contrast, they are usually dynamic, complex, and partly unknown by the planner (e.g., Hollnagel, Mancini and Woods, 1988). *Execution* behaviours in worksystem task environments are required to commence before plans are complete and fully-elaborated and therefore the *perception, execution* and *planning* behaviours must be temporally inter-leaved - having no necessarily fixed order in which to be performed.

When performing a task, a system has to exercise control; that is, it has to select the next behaviour to be carried out at each moment (e.g. Hayes-Roth, 1985). For a system, which constructs complete and fully-elaborated plans, controlling is a simple process of selecting behaviours, according to the plan and initiating their execution. However, for worksystems, which employ plans as *resources* to guide behaviour, some more complex control behaviour is required to select execution behaviours over time - since the selection is constrained by, rather than specified by, the plan. Furthermore, if a worksystem inter-leaves execution behaviours with planning and perception behaviours, controlled sequencing of these behaviours is also required.

Consistent with the preceding arguments, the HCI-PCMT framework describes the worksystems' cognitive structures for planning and control as follows:

At the first (abstract) level of description, **Plans** are specifications of required transformations of domain objects and/or of required behaviours. They may be partial (in the sense that they may specify only some of the behaviours or transformations), and they may be general (in the sense that some behaviours or transformations may be specified only generally and not at a level that is directly executable). Planning behaviours, thus, specify the required domain object transformations and/or behaviours to support those transformations.

Perception and **execution** behaviours are, respectively, those whereby the worksystem acquires information about the domain objects and those whereby it carries out work, changing the value of the object attributes as desired. Information about domain objects from perception behaviours is expressed in the **knowledge-of-tasks** representation. **Control** behaviours entail deciding which behaviour to carry out next, both within and between tasks, but involve more than reading off the next behaviour from a complete and fully-elaborated plan.

The second level of description of planning and control structures is physical, wherein the framework describes the distribution of the abstract cognitive structures across the physically separate user and devices of particular worksystems. The framework, thus, allows the construction of alternative models of the distribution of cognitive structures across the user and devices, and so supports reasoning about allocation of function between users and devices, a major decision in design problem solutions. In the office administration domains studied for the development of the framework, the physical worksystem was the person plus devices, but not a computer. These domains were: secretarial office administration and medical reception. This notion of worksystem is somewhat wider than that used to illustrate Dowell and Long's (1989) conception, and is used here for the analysis of to-be-computerised systems.

The outline of the HCI-PCMT framework, including its domain of application, its worksystem and its performance, is now complete. How the framework supports the analysis of multiple task work will now be outlined.

Multiple task work requires a user, as part of the interactive worksystem, to perform distinct, but overlapping tasks. Each task potentially competes for worksystem behaviours. Multiple task work represents an important concern for system designers, as performing overlapping tasks is likely to have an effect on work performance. The term 'multiple task work', as characterized by the framework, refers to situations, in which more than one task is carried out concurrently over relatively long and overlapping periods of time. Characterising multiple task work requires a single task to be defined. In the framework, a task is considered to be part of the work carried out in the domain of the worksystem. A task is thus conceptually distinct from the worksystem itself and its behaviours. In one of the systems previously analysed by the framework, medical reception, (see Hill et al, 1995) a task was expressed as the support of a medical case object (i.e. patients consulting with medical practitioners). The medical reception domain is an instance of multiple task work, since support is provided concurrently for multiple ongoing and temporally overlapping medical cases (i.e. for many patients together).

The explicit description of the framework now follows.

2.2 HCI-PCMT Framework

This section gives a description of those aspects of the framework, that need to be exposed for current research purposes i.e. application of the framework to a domain other than office administration, where there are multiple users at multiple levels of command. Thus, there are some aspects that will not be applicable in such a domain, and they are, therefore, not presented here. The framework is expressed as a set of axioms, based on a partial and selective application of Dowell and Long's (1989) conception for HCI. The purpose of the HCI framework is to express design problems to aid a designer to reason about possible design solutions, in a specify-and-implement type of design practice. The axioms presented are direct extracts from Smith et al, (1997).

Axiom 2.1 HCI-PCMT design problems: HCI-PCMT design problems and their possible solutions, generated by specify-and-implement design practice, entail the specification of the implementable **planning** (**structures** and) **behaviours** and **control** (**structures** and) **behaviours** of the user and devices of the worksystem, such that when they interact with the **perception** (**structures** and) **behaviours** and **execution** (**structures** and) **behaviours** of the user and devices, they carry out multiple task work such that the actual level of performance falls within some desired level of performance.

Axiom 2.2. HCI-PCMT domain: multiple task work: Relationships between domain objects give rise to different *levels of description*. Abstract objects constitute higher level descriptions of physical objects, and some abstract objects may be higher level descriptions of other abstract objects.

Vertical relationships exist between the values of the attributes at different levels of description. Values of attributes at higher levels of description are determined by an *emergence* relationship to the

values of attributes at lower levels. *Horizontal relationships* exist between the values of attributes at the same level of description.
A *task* is the required state transformation of a single abstract object at the highest level of description, including all lower level transformations associated through object relationships.
Multiple task work is that domain work in which, at the highest level of description, there are typically two or more objects undergoing independent, but temporally overlapping work transformations.
A *sub-task* is some part of the state transformation, which constitutes a task. It is a sub-transformation.

Axiom 2.3. HCI-PCMT worksystem: planning and control behaviours and structures:
Four types of abstract behaviour are generic to the worksystem and undifferentiated between the users and devices. These behaviours are *planning, control, perception and execution.* The four types of abstract behaviour are supported by abstract structures, also undifferentiated between users and devices. These abstract structures comprise four types of process, corresponding to the four types of behaviour. That is, a planning process, a controlling process, a perceiving process, and an executing process. There are two types of representations: a plan representation and a knowledge-of-tasks representation. Figure 1 shows the abstract planning and control structures within the framework and their relationship.
Perception behaviours are those, whereby the worksystem detects and records the values of the domain object attributes. The states of domain objects form the contents of the knowledge-of-tasks representation. Perception behaviours update the contents of the

knowledge-of-tasks representation, based on their reading of the domain. Execution behaviours are those, which carry out the work of the worksystem directly by transforming the values of domain object attributes.

Planning behaviours are those, which specify what and/or how tasks will be accomplished in terms of required object state transformations and/or required worksystem behaviours. These specifications form the content of the plan representation. Planning behaviours update the contents of the plan representation, based on their reading of the contents of the knowledge-of-tasks representation and the existing contents of the plan representation.

Control behaviours select which behaviours are to be carried out next at any particular time. Control behaviours set the *parameters* of the planning, perceiving and executing processes. Thus, they configure the behaviours, supported by those processes, based on their reading of the contents of the knowledge-of-tasks representation and the contents of the plan representation.

Axiom 2.4 HCI-PCMT performance: Performance is some function of: (1) the task quality associated with the multiple task work carried out; and (2) the resource costs associated with the worksystem structures and behaviours of planning and control (incurred by the worksystem as a whole).

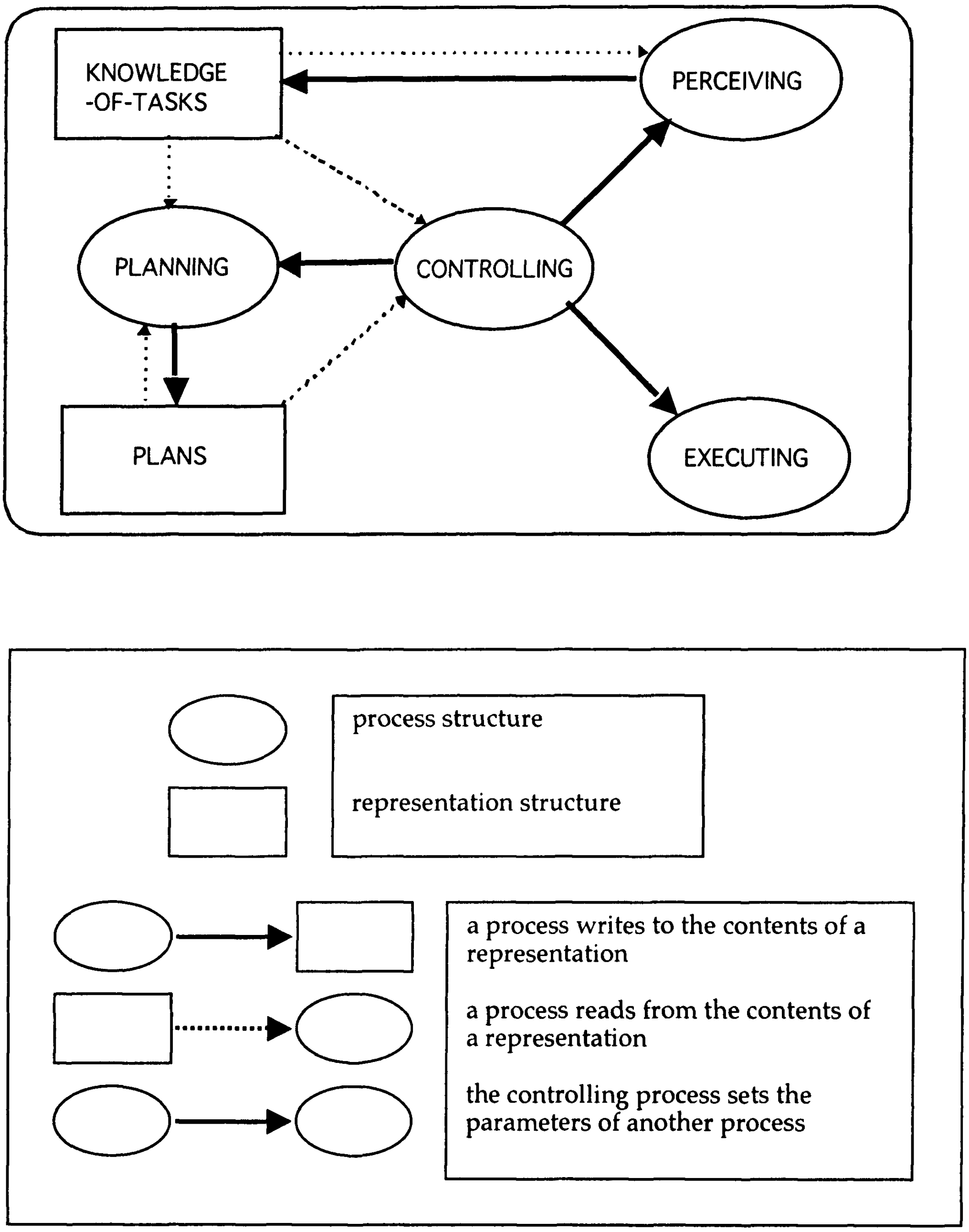


Figure 1 HCI-PCMT Abstract structures

These axioms are to be used in the application of the framework to the EMCRS. Section 3.2 below, characterises the differences between the EMCRS and the office administration domains, already modelled by the framework, to identify where the HCI-PCMT framework will need to be extended to accommodate such differences.

A diagrammatic representation of the generic HCI-PCMT framework is shown in Figure 2. This representation will be used to apply the framework to the EMCRS.

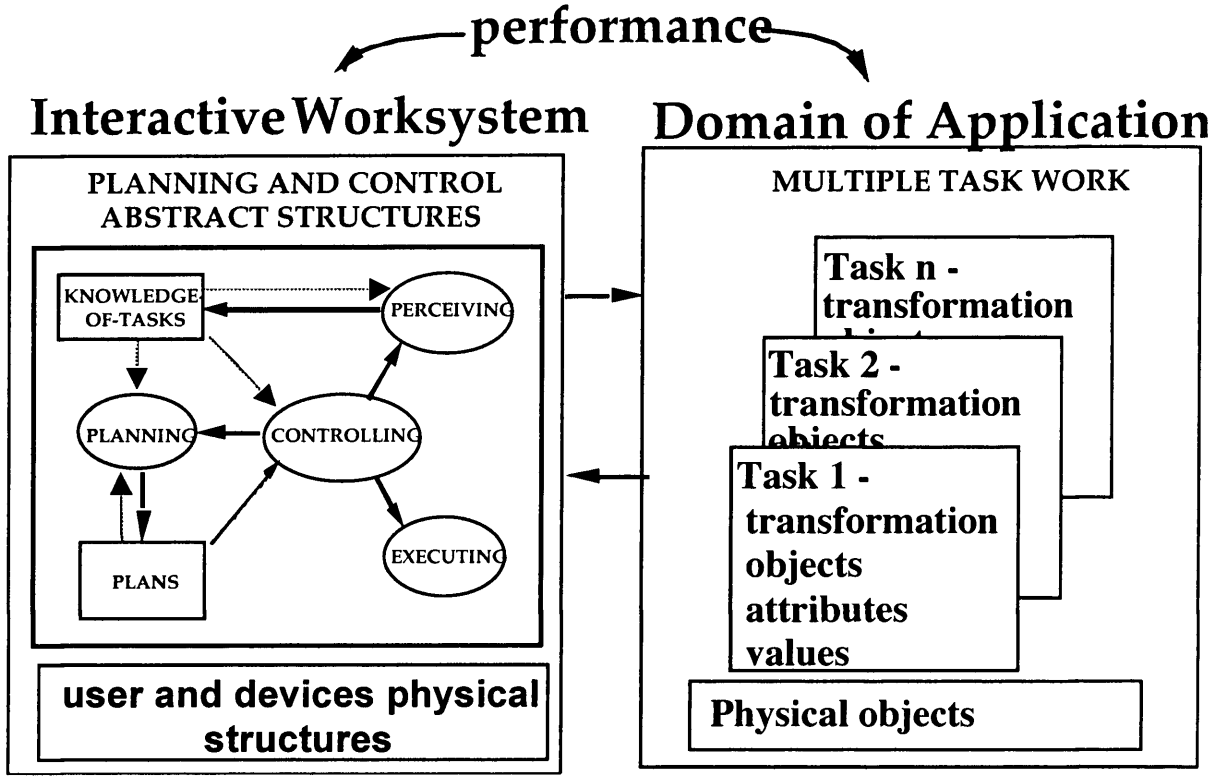


Figure 2 HCI-PCMT Framework

Thus, application of the framework allows for a description of the abstract and physical structures of the interactive worksystem and the abstract and physical objects of the domain of application (work). The framework defines the relationship between the abstract and physical structures of the worksystem, and the relationship between the abstract and physical objects of the domain. Performance is some function of the task quality, associated with the multiple task work carried out, and the resource costs, associated with worksystem structures and behaviours of planning and control. The framework will thus allow for a description of design problems, as described in Axiom 2.1 above.

2.3 Characterisation of the EMCRS

The characteristics of the EMCRS are believed to be generalisable to other similar complex planning and control systems. Thus, extension of the HCI-PCMT framework to accommodate the characteristics of the EMCRS, would extend the framework for modelling other complex planning and control systems, with similar characteristics.

The term 'multiple task work', as characterized by the framework, comprises situations in which more than one task is carried out concurrently over relatively long and overlapping periods of time. Characterising multiple task work requires a single task to be defined. The previous domains modelled by the HCI-PCMT framework were characterised by one user and their devices. The work of these systems was described as support for a functional abstract description of the job, which incorporates social and organisational factors. As mentioned earlier, the work of medical reception (Hill et al, 1995) was described as the support of medical cases, where a medical case is an abstract representation of patients consulting with medical practitioners. A single task is the support for a single medical case, i.e. a single patient consulting with a medical practitioner. The work is multiple task, since support is provided concurrently for multiple ongoing and temporally overlapping medical cases (i.e. for many patients together).

In the EMCRS, there are multiple agencies, who need to work together towards the goal of stabilising the disaster situation. Each of the agencies, involved within the EMCRS, has its own set of tasks that it must carry out in order to achieve the overall goal of stabilising the disaster. These tasks are carried out independently from the other agencies; but the behaviours, associated with each of these tasks, need to be co-ordinated with the other agencies, to maximise the effectiveness of the overall EMCRS response. The work of the EMCRS can be described as the support of a disaster. Unlike the previous systems analysed with the framework, there are obviously not multiple disasters, and thus a single task cannot be described as support for a single disaster. Rather, a single task would be each of the individual agency tasks in support of a disaster. Thus, the work of the EMCRS is multiple task, since support is provided concurrently for the multiple ongoing and temporally overlapping tasks carried out by the individual agencies in response to a disaster. This difference in the task description has implications for the application of the framework to the EMCRS, and will be one of the areas of extension for the framework, that modelling a multi-user planning system requires. These implications will be described in detail with respect to the framework axioms, once EMCRS data have been gathered for framework application (see Chapter 4). Extending the framework in this way would enable application of the framework to other complex systems, where there are multiple users or groups of users carrying out independent, but concurrent tasks, that need to be co-ordinated for effective performance. The EMCRS has more than one level of operation; in fact, potentially three, (operational, tactical and strategic), depending on the characterisation of the disaster to which response is made. The HCI-PCMT framework has so far only been applied to systems with one level of operation. The HCI-PCMT framework will need to be extended to accommodate this difference. The EMCRS, as well as having more than one level of operation, has interactions within and between the levels. Again, the HCI-PCMT framework will need to be extended to accommodate these interactions. These extensions would enable application of the framework to other complex systems, where there is more than one level of operation and interactions between the levels. Last, the EMCRS will change over time in response to the changing disaster situation. The HCI-PCMT framework will need to be extended to accommodate a changing worksystem. This last extension would enable application of the framework to other systems, which change over time in response to their domain. Each of these differences are identified as issues with the application of the current HCI-PCMT framework, to model the EMCRS. These issues are discussed in detail in Chapter 7. Solutions to these issues, and thus extensions to the framework, are presented in Chapter 8.

2.4 Chapter Summary

This chapter has presented the HCI-PCMT framework. The aim of this research is to use the HCI-PCMT framework to model the EMCRS. In so doing, the scope of the framework will be extended to accommodate the differences between the EMCRS and other domains previously modelled. Differences between the EMCRS and the other systems, already modelled by the framework, have been discussed. These differences constitute the areas in which the HCI-PCMT framework will need to be extended, to accommodate the EMCRS. These differences are seen as characteristics of distributed planning and control systems, comprising more than one user, or groups of users, whose activities must be co-ordinated for effective performance. Therefore, in extending the framework to accommodate the EMCRS, it is expected that the framework would be suitable for application to other distributed planning and control systems, with similar characteristics. The next chapter will present the background to the EMCRS data collection.

Chapter 3
EMCRS Data

Introduction

Application of the HCI-PCMT framework to model the EMCRS required data. Ideally, such data would be from response to an actual disaster. However, these data are confidential and the research was required to be published in the public domain. One of the main sources of data for the modelling was expected to be from public enquiry documents. Having read the documentation for the Kings Cross Fire (Fennell, 1988), Clapham Rail crash (Hidden, 1989) and Marchioness disaster (Marriott, 1991), and others, it became apparent that the information contained in the enquiry documents did not provide sufficient detail to inform the model. Obviously some valuable information was gleaned from these documents, but more detailed information was required, to carry out the modelling. As discussed in Chapter 1, the specific requirements for the data were: that they would include the EMCRS initial phase of disaster response; and that EMCRS data should not be at the lowest level of description (i.e. actual personnel and equipment at the operational level of command), but must include details about individual agency roles/tasks at the different levels of operation. A further requirement is that the data be recordable in some format for later analysis.

The last possibility for data gathering was thus training exercises. There are various different types of training exercise carried out by the emergency services, which are set-up to address different types of problem. In Section 1 the different types of exercises will be discussed, along with which type would be best suited for data gathering, based on the above requirements identified. Section 2 discusses the data gathering – what different exercises were attended and how data were collected. Section 3 summarises this chapter.

3.1 Type of exercise

Other than actual events, exercises are one way to assess the effectiveness of EMCRS in response to major incidents. Exercises bring together those who may be involved with responding to an incident and allow assessment of their responses under controlled conditions. They are useful management tools for giving confidence to those, who may be involved in a crisis. Bringing together people from different agencies, to work together as a team, enables an understanding of each others' strengths and weaknesses and can help identify problems that they each may have. There are basically three types of exercise, discussion-based and table-top, which are paper based, and live. Each of these may vary considerably. This section will discuss each type of exercise in turn and identify the merits of each for the present research.

3.1.1 Paper-based exercises

There are two types of paper-based exercise: discussion-based and table-top. Both of these types of exercise can be structured in a similar way with respect to the exercise directing team. According to Overy (1993), there are two types of table-top exercise, the liaison exercise and the team building exercise, which can be distinguished in terms of structure by the role of the exercise directing team. In the first type, the exercise directing team maintains direct personal contact with the players and interacts with them as a central or key part of the game. Players representing different agencies are usually encouraged to talk to each other. In the second type, the exercise directing team tries to stand outside and away from the players and most of the interaction is on paper or over the telephone. Under the rules of the game, players representing different agencies are often only permitted to talk to each other through the exercise directing team.

3.1.1.1 Discussion-based exercises

Discussion based exercises are generally low-cost activities, which are often a component of a seminar or other training activity. They are designed to inform participants about the organisation and the procedures, which would be used to respond to an incident. Discussion is usually centred on a given paper-based scenario. Participants representing different agencies are formed into groups, often called syndicates, to discuss their response/problems in relation to the scenario. These groups usually contain representatives from each of the different agencies attending the exercise. Participants explore the scenario, its developing circumstances and its consequences. The emphasis is on identifying problems and finding solutions rather than on decision making. There are often panel discussions for each participating group to discuss their findings with a wider audience. The exercise directing team encourage interaction between the differing agencies involved in the response. This type of exercise falls into what Overy (1993) calls a liaison exercise. Data gathered at this type of exercise would, therefore, give high level information about the emergency services' response to a disaster scenario, focusing on plans and procedures, used by the different emergency services, and the identification of potential problems in their disaster response. Recording such data may be difficult. The different syndicates will be separate from each other, so no recording device could be used, when the discussions are within the syndicates.

3.1.1.2 Table top exercises

These are a form of role-play exercise. They are viewed by the services as being a very cost-effective and efficient method of testing plans and procedures. They may involve participants role-playing agents within a scenario, or the participants may comprise members of the team, who would be activated in a real emergency. In the liaison exercise, there is usually a physical, scale model of a catastrophe, supported by a scenario description. Key personnel from each of the agencies involved in the emergency operation, sit around the table and describe their individual and collective responses. The team building or paper feed exercise uses the passing of text between the moderator and participants to simulate the communications and the time-course of events during an emergency. Thus, in a paper feed exercise the participants will be in one room, the moderator outside this room. The participants await paper feed information from the moderator regarding the emergency scenario, for example, a petrol station explosion in the centre of market town. Each paper feed will have a time stamp on it, i.e. the first feed in this example could be 9.00 am. The next feed will be in real-time i.e. it will be presented to the participants in real time and will have the scenario time stamp on it. For example: "9.05 am Police declare major incident". This paper feed would be presented to the participants five minutes after the first feed to correspond with the stamped time frame. After each feed, the participants who would need to respond to the paper feed information, have to write down their response on dockets with time information, and these responses are passed between the participants. Data gathered at this type of exercise would, therefore, give detailed real time information about the disaster response, from each of the agencies involved. As the responses are recorded on dockets with time stamps, the data gathered would be the actual recorded data from the exercise.

3.1.1.3 Live exercises

These range from a small scale single agency test of one component of their response, to a full-scale multi-agency test of the whole response to an incident. Live exercises provide the best means of confirming satisfactory operation of emergency communications. Live exercises involve the 'live reconstruction of an actual incident' with simulated 'live' casualties. They involve the actual mobilisation of equipment and personnel and involve extensive use of 'real buildings and real communications'. They allow the different agencies and their personnel to rehearse their roles, to assess their preparedness, and to identify co-ordination problems. Live exercises are very costly to mount and are therefore infrequent. Overy (1993) has also raised questions about the effectiveness of the learning experience for all participants. Live exercises will provide data that is realistic, i.e. the emergency services may be in a simulated disaster situation, but their responses must be as they would be for an actual disaster. Data would be at a low level of description, as there would be data for the response of every personnel member. However, how to analyse such data may be a problem. Each of the emergency services keep a detailed log of all actions in response to the disaster. Each service has a different way of logging actions. So collating this information across the different services would be difficult.

The different types of exercises and potential data types, that could be gathered from such exercises, have been discussed above. Based on the current research requirements, the merits of data from each of these types of exercise will now be discussed, so that a suitable type of exercise for data gathering can be selected. The requirements for the data, as set out in the introduction were: that it would include data on the EMCRS initial phase of disaster response, and that EMCRS data should not be at the lowest level of description (i.e. actual personnel and equipment at the operational level of command), but must include details about individual agency roles/ tasks at the different levels of operation. Also, the data should be recordable for later analysis.

- Discussion based exercises would potentially provide data from the EMCRS initial response phase. Data would not be at a low level of detail, although recording of such data may be difficult due to the set-up of the exercise.
- Table-top exercises would provide data from the EMCRS initial response phase; data would hopefully be at the desired level of description (but may be at too low a level); recording of data would be easy, as the exercise set-up requires data to be recorded by participants.
- Live exercises would provide the more realistic EMCRS data than discussion-based or table-top exercises. Initial response data would be present. Data would be at a very low level of description. Recording of data would not be a problem as each of the services must log their actions, but analysis may prove difficult. (Also, due to the expense in both time and money of live exercises, they happen very infrequently.)

The type of exercises best suited for the required data would, thus, as a first choice be a table-top exercise. Table-top exercises would seem to provide data that covers the EMCRS response phase required and at the appropriate level of detail. Also, recording of such data would be ideal. The next section will discuss the actual data gathering.

3.2 Data gathering

There are various specialist training centres in the UK for the emergency services. However, there is only one centre where multidisciplinary training is provided - The Cabinet Office Emergency Planning College at

Easingwold (formerly the Home Office Emergency Planning College). The aim of the college is to promote and sustain emergency preparedness within the United Kingdom through the concept of Integrated Emergency Management. Many different training exercises are run at the centre, that cover all aspects of emergency planning. These exercises differ in their focus – from planning for a rock concert for the local authority, to inter-agency response to a disaster. Some of the exercises are table-top and some discussion based. Given the requirements above, first, the exercise needed to focus on the EMCRS, and so an exercise which involves the emergency services and not just the local authority or other non-emergency agency, was required. Second, a table-top set-up for the training exercise was required. Given these requirements, the first exercise attended was the Emergency Services Seminar on Inter-Agency Response to Disaster. The information regarding the exercise made it clear that it was the most appropriate of all those run by the college, for gathering EMCRS data. Further, it was hoped that the set-up would be table-top. (The exercises at the college were embedded in seminars. Before and after each exercise, there would be presentations by experts, regarding various aspects of emergency planning.)

3.2.1 Emergency Services Seminar on Inter-Agency Response to Major Disaster

Each of the seminars run by the college had a particular remit, which was outlined in the college brochure (Emergency Planning College, 1996). For justification of this particular seminar as a first choice for data gathering, this brochure information is presented.

The information was as follows:

'Are you a senior officer responsible for disseminating good practice in emergency preparedness at the local level? If so, you should join this innovative seminar which will enable you to work with your counterparts from other uniformed services and the local authority in pre-selected, multi-disciplinary district, county or regional teams.

'Organised under the auspices of ACPO (Association of Chief Police Officers), CACFOA (Chief and Assistant Chief Fire Officers Association), ASA (The Ambulance Service Association) and SOLACE (Society of Local Authority Chief

Executives) to promote a greater understanding of integrated emergency management at an operational, tactical or strategic command level, this seminar sets out to help you:

- *develop consistent good practices across all 'blue light' services in your area of command;*
- *identify and resolve any inconsistencies in approach*
- *identify the common elements needed to mitigate any disaster*
- *become aware of the help available from other sources.*

Applications should be in team format, which should include, wherever possible, police, fire, ambulance and local authority emergency planning personnel. Where appropriate representatives from coastguard and health authorities may also be included as team members. This event is especially important for 'shadow' authorities and existing unitary authorities.'

From this information it seemed likely that this seminar would provide data on EMCRS response to a disaster, at an appropriate level of detail, and involving data on the initial response phase.

3.2.1.1 The Seminar

The aim of this seminar was to provide an opportunity for emergency services' personnel, who may have a role to play in the dissemination of best practice at the operational, tactical and strategic command areas, together with others, to study problems which might arise from major civil emergencies with particular reference to the need for a co-ordinated response. The objectives were:

- To develop consistency and good practice in locally based training in emergency procedures.
- To study the management of the response to a major civil emergency.
- To be aware of the roles and responsibilities of the emergency services and other organisations in responding to a major civil emergency.
- To understand the importance of liaison and co-operation between all services and other organisations in responding to a major civil emergency.
- To identify the elements which are common to the successful management of a major civil emergency.

• To be aware of government policy regarding emergency preparedness.

The set-up of the seminar was first to have presentations from experts regarding various aspects of inter-agency emergency management. The exercise was held on the second day of the seminar. The exercise was called Exercise Scorpio and the narrative was as follows:

Exercise Scorpio Narrative

Newford is a market town in the county of Crownshire. The main town centre is built around the main A338, which bisects the town in a north/south direction. In the centre of the town, a railway, carried on an embankment and bridge, runs directly across the town from east to west. From the railway bridge, in a northerly direction, the A338 is inclined and at the bottom of the incline is a canal with moorings for canal boats. This is a very busy holiday waterway and is a popular stopping point.

At approximately 0930 hours on a weekday during school term time, a tanker train en-route from a refinery to an airport fuel depot is derailed, whilst passing over a railway bridge.

The bridge, which is a steel Victorian structure, carries the railway over the A338, which provides the main access into the town centre. It is market day and there are numerous market stalls set up on the side of the roadway on either side of the bridge. The market and town are a popular destination for locals and visitors from out of the town area, including foreign citizens on sightseeing tours through the area. There are a number of housing developments, behind the shops in the High Street each side of the railway bridge, and a nursery school with 60 toddlers is sited approximately 400 metres away. A cottage Hospital with 30 beds is some 500 metres to the south east of the bridge and a primary school with 200 pupils some 800 metres to the south.

The train consists of a diesel electric locomotive and eight tank cars, each fully loaded with 100 tonnes of AVTUR Aviation Fuel (SIN 1863 with an emergency action code 3 (Y) E). During the derailment one of the tank cars is ruptured and aviation fuel flows down the sides of the embankment onto the roadway and into adjoining properties. Flammable vapours from the fuel have been ignited by an open gas burner from a catering caravan.

At the time the explosion occurred, a tourist bus was passing beneath the railway bridge. The bus is carrying 45 tourists of whom 25 are Japanese and German nationals.

The explosion has created severe structural damage to the railway bridge, premises adjacent to the bridge in an approximate 30 metre radius, and has created major leaks in two of the other tank cars. Structural damage of a moderate nature has occurred within an approximate 100 metre radius. At least 50 people have been killed, including some of the foreign tourists. Many people have received burns from the flashover of the explosion and numerous people are trapped and injured in properties beneath the bridge structure and in vehicles on the roadway. A number have also been contaminated by aviation fuel. There are numerous fires in the area.

The leaking fuel has run down the road incline to the north of the bridge and is entering the canal and watercourses at the bottom of the incline. The river flows from east to west but there is no particular flow on the canal. The wind is north westerly force 2 to 3. There are several barges, used for residential purposes, moored on the canal.

Early information from witnesses suggests youths have been seen running from the section of rail track where the derailment took place, and that vandalism may be responsible for the derailment.

3.2.1.2 Exercise Procedure

Once present at the seminar, it became apparent that the 'exercise' would be discussion-based. Although this was not the first choice for the type of exercise, where data could be gathered, the focus of the exercise was on the primary requirement for data, that of the EMCRS, so it was decided to gather data nevertheless. There were 60 emergency service senior personnel members attending the exercise. The emergency service personnel were brought together in multi-agency groups, called syndicates, to discuss the given disaster scenario. These syndicates, were pre-selected, i.e. the members had applied to attend the seminar as a group. The exercise directors did not choose the members of the groups. These syndicates were comprised of Police, Fire, Ambulance and local authority personnel from the same district, county or region. Each syndicate was given the scenario narrative and a detailed set of instructions to follow.

The instructions for participants were as follows:

Consideration 1: Organisations and their roles/responsibilities

As part of a multi-disciplinary group, you are asked to discuss the incident and identify:

the primary roles and responsibilities of the Police, Fire brigade, Ambulance service and the Local Authority during the response phase;

other organisations who could also have a role and how those organisations could assist the emergency services.

Following the syndicate discussion you should be prepared to discuss your findings with another syndicate.
Vufoils and flip charts are available if required.
The discussion should last for approximately 20 minutes.
A member of the Directing Staff will facilitate the discussion session.

Consideration 2: Likely problems to face organisations

As a single disciplinary group you are asked to discuss: - During the early stages of the response:

The likely problems which your organisation will face, including maintaining normal services;

The main problems facing the other emergency services and indicate how you could assist;

If your organisation's priorities are likely to conflict with others.

The group should nominate a spokesperson(s) who will be required to present (5-10 minutes) the group's findings during the central discussion session in the lecture theatre. Vufoils and flip charts are available if required.

(It is suggested that this nomination is made early in the exercise.)

Consideration 3: Co-ordination of response - 3 hours into the incident

In regard to this incident, and as part of a multi-disciplinary group, you are asked to consider:

The appropriate incident command structure employed by your own organisation and discuss how it aligns and communicates with others. If there are differences, how could the effectiveness of the response be impaired and if so, how would you improve it?

How would you AS A GROUP attain and maintain an effective co-ordinated response to the news media?

The group should consider the appropriate locations for the various functions, which would be employed in the response phase and to give reasons for those decisions. (Forward control point(s); incident control point(s); inner cordon(s); outer cordon(s); access/exit routes; marshalling area(s); rendezvous point(s); casualty receiving station(s); ambulance loading point(s); body holding area(s);evacuation assembly point(s); evacuee rest centre(s); survivor reception centre(s); friends and relatives reception centre).

The group should nominate a spokesperson(s) who will be required to present (5-10 minutes) the group's findings during the central discussion session in the lecture theatre. Vufoils and flip charts are available if required.
(It is suggested that this nomination is made early in the exercise.)

Consideration 4 was welfare and return to normality. However, as the initial response phase data was of primary import for modelling the ECMRS, data from this consideration were not necessary and will, therefore, not be considered here.

3.2.1.3 Data collection

As discussed above, data collection from discussion based exercises is difficult. As each syndicate was located separately, no recording device could be used. Therefore, during the syndicate discussions data were collected through note taking by the researcher. These notes were an aide-memoire for the researcher. General information from the presentations was recorded in bullet-point form on a printable white-board. These records were printed for the researcher. A further issue with data collection at this exercise was that the researcher was allocated to a particular syndicate by the exercise director, as the first consideration was being discussed. Unfortunately, this syndicate had other ideas and were planning their own 'live' exercise and so did not take part in these early discussions. As this was the first exercise that had been attended, and it was thought that data from a table-top exercise would be more suitable, as discussed above, the researcher did not regard this as a problem. However, once it became apparent that this syndicate would not be involved in any of the discussions, the researcher joined another syndicate and the presentations given by all the syndicates. Therefore, the data collected from this first exercise, only cover Considerations 2 and 3 of the exercise.

3.2.2 Metropolitan and Urban area authorities

The second seminar attended was that of the Metropolitan and Urban area authorities. From the information given in the emergency planning college brochure, it was clear that this was a table-top exercise, which would therefore provide data that fits the requirements for the EMCRS data collection. Also, it appeared to focus on a disaster and participants would be from the emergency services and other organisations, so it involved the EMCRS. However, once present at the exercise, it soon became clear that this exercise was set-up with a focus for Local Authority Emergency planners and not the emergency services. Therefore the focus of the data was not primarily on the EMCRS. The data were in fact, collected, as they were recorded on dockets, but were not analysed, as not being relevant to the present research.

3.2.3 Further data collection

Before attending any other seminar, potentially providing data fitting current requirements, further documentation was requested on each seminar. It then became clear, that the seminar, where data would fit the requirements best, was the Emergency services Seminar on Inter-agency

Response to Major Disasters, a type of seminar already attended. Therefore, it was decided to attend this type of seminar again to gather more data. Each running of this seminar involved different emergency service personnel, and so even though the seminar presentation was identical, the emergency service personnel responses would be different. Thus, the data would be complimentary to the first set, but not identical.

3.2.4 Emergency services Seminar on Inter-Agency Response to Major Disasters - 2

This type of seminar was attended again. The format of the seminar was exactly as that first attended. However, this time the researcher was attached to a syndicate that followed the whole exercise. Thus, data were recorded for all the considerations given in the exercise procedure. The data were recorded in the same way – by note taking, and receiving the print-outs from the whiteboards, after the presentations. There were again 60 emergency service personnel present with representatives from each of the emergency services, and local authority chief executives. The data gathered from both of these exercises will be presented in the successive chapters, along with the initial models produced from these data.

3.3 Chapter Summary

In summary, this chapter has discussed the different types of exercises used within emergency management training and identified the best type of exercise for gathering EMCRS data. The exercises attended for gathering data have been described. Although these exercises and their data collection techniques were not ideal, they did fit the requirements for the EMCRS data. The EMCRS initial response phase was included and data were at an appropriate level of detail. The raw data, gathered from the two exercises attended, along with an expansion or explanation of the data, are presented in Appendices 1 and 2. The successive chapters present the initial models developed through application of the HCI-PCMT framework to the data.

Chapter 4

EMCRS model development – cycle one

Introduction

This chapter presents the construction of the first EMCRS model, by application of the HCI-PCMT framework axioms and representation, to the first dataset. Section 1 gives a brief description of the EMCRS data gathered from the first attendance at Exercise Scorpio – Dataset 1 – the full data are in Appendix 1. Section 2 presents HCI-PCMT framework axioms for EMCRS. Section 3 presents the method for model construction, and uses the method to construct the EMCRS model. Section 4 presents the model for Dataset 1. Section 5 describes use of the model for diagnosing co-ordination design problems. Section 6 summarises the chapter.

4.1 Exercise Scorpio Data

Due to the limitations of the arrangements for the data collection, (no video/audio recording device could be used), the raw data were notes taken by the researcher. These notes constituted an aide-memoire for the researcher of the discussions amongst and presentations by the syndicates, during exercise Scorpio. After collection, the raw data were expanded to express as much information as possible, as discussed within the syndicates. The data are shown in tables in Appendix 1. The tables show the raw data on the left hand-side of the table and the more complete data on the right-hand side.

The data gathered were the responses given to considerations, posed by the exercise co-ordinators, which were presented in Chapter 3. In this first data collection, they are limited to responses to the second and third questions posed. This outcome was due to the researcher being involved in a syndicate who were not following the exercise fully. Also, for the Ambulance Service, only the data for their view of the problems that the Ambulance Service will face in response to the major incident are presented. This outcome is because data were not collected for the Ambulance Service on responses to the other questions, as the researcher could not be present when this data was offered.

The data presented in Appendix 1, is in two sections. The first section of data was collected from the syndicates which were set up as single disciplinary groups (e.g. Firemen). The second section of data was collected from the syndicates as multi-disciplinary groups.

To develop the EMCRS models the HCI-PCMT framework needed to be applied to the data. This application was twofold, involving application of the HCI-PCMT axioms, and application of the HCI-PCMT representation. These two applications were carried out together. The application of the HCI-PCMT axioms to EMCRS will extend the framework to accommodate the EMCRS. These axioms are now presented.

4.2 HCI-PCMT Axioms for EMCRS

The HCI-PCMT axioms presented in Chapter 2 are now expressed in terms of the EMCRS. The HCI-PCMT axioms are presented along with the HCI-PCMT EMCRS axioms for clarity.

Axiom 2.1 *HCI-PCMT EMCRS design problems*: HCI-PCMT EMCRS design problems and their possible solutions, generated by specify-and-implement design practice, entail the specification of the implementable **planning** (**structures** and*)* **behaviours** and **control** *(***structures** and*)* **behaviours** of the emergency service personnel and emergency service devices of the worksystem, such that when they interact with the **perception** (**structures** and*)* **behaviours** and **execution** (**structures** and*)* **behaviours** of the emergency service personnel and emergency service devices, they provide support for a disaster, such that the actual level of performance falls within some desired level of performance.

Axiom 2.2. HCI-PCMT domain: multiple task work:

Relationships between domain objects give rise to different levels of description. Abstract objects constitute higher level descriptions of physical objects, and some abstract objects may be higher level descriptions of other abstract objects. For the office administration domains there are three levels of description: Abstract level 2; Abstract level 1; and a Physical level.

EMCRS domain: Multiple task work:
The domain is described at both an abstract and a physical level. At the highest level of description (Abstract level 2) is the **Disaster** object. The sub-objects of the domain (**Lives** sub-object, **Disaster Character** sub-object. **Emergency Services** sub-object, **Disaster Scene** sub-object, **Property** sub-object, and **Environment** sub-object) are at a lower abstract level of description – Abstract level 1. At the physical level of description, the abstract sub-objects of the domain are realised as physical objects. Abstract level 1 objects have realisation attributes whose values specify the physical objects of their realisation. These three levels are the same as those for the office administration domains.

HCI-PCMT domain
Vertical relationships exist between the values of the attributes at different levels of description. Values of attributes at higher levels of description are determined by an emergence relationship from the values of attributes at lower levels. Horizontal relationships exist between the values of attributes at the same level of description.

EMCRS domain
Vertical relationships exist between the values of attributes at different levels of description. The realisation relationship between Abstract level 1 objects and Physical level objects is a many-to-one relationship. The value of physical object attributes, determine through emergence, the values of Abstract level 1 attributes. In turn, the values of attributes of the **Disaster** object (Abstract level 2) are determined by an emergence relationship from the values of attributes at Abstract level 1 - the sub-object attribute values. Horizontal relationships exist. There is a relationship between the values of the attributes at the same level of description. For example, at Abstract Level 1, the **Disaster Scene** sub-object attribute *scene containment* value contained will require the **Lives** sub-object *emergency services personnel safety* to have a value of equipped.

(The words in **bold** refer to worksystem structures and behaviours or domain objects; the words in *italics* refer to abstract domain object attributes; the <u>underlined</u> words refer to domain object attribute values. This notation will be used throughout the rest of this thesis.)

HCI-PCMT domain

A task is the required state transformation of a single abstract object at the highest level of description, including all lower level transformations, associated through object relationships.

EMCRS domain

A task is the required state transformation of the **Disaster** object, including all lower level transformations of the associated sub-objects.

HCI-PCMT domain

Multiple task work is that domain work in which, at the highest level of description, there are typically two or more objects undergoing independent, but temporally overlapping work transformations. In office administration systems, there are multiple objects at the highest level of description.

EMCRS domain

As there is only a single **Disaster** object, at the highest level of description, multiple task work is that domain work in which, at the highest level of description, the **Disaster** objects attributes are undergoing independent, but temporally overlapping transformations. This HCI-PCMT extension is to accommodate a multi user planning system. (The EMCRS domain thus contrasts with the office administration domain, where there are multiple objects at the highest level of description.)

HCI-PCMT domain

A sub-task is some part of the state transformation, which constitutes a task. It is a sub-transformation.

EMCRS domain

The overall task of the EMCRS is to transform the **Disaster** object to a desired level of stability and normality. The primary objectives for achieving the desired goal state of the disaster object are 'to save life, prevent escalation of the disaster, to relieve suffering, to facilitate investigation of the incident, safeguard the environment, protect property and restore normality' (Home Office, 1994). Associated with each of these objectives or goals, each of the Emergency Services, involved in the EMCRS, has specific tasks to fulfil. It is these tasks, which are described as the sub-tasks of the EMCRS. Each of these sub-tasks will have associated domain sub-object transformations – sub-transformations. The required transformation of the **Disaster** Object can be divided into a number of sub-transformations, concerning particular sub-objects and their attributes.

Axiom 2.3. HCI-PCMT worksystem: planning and control behaviours and structures:

Four types of abstract behaviour are generic to the worksystem and undifferentiated between users and devices. These behaviours are **planning, control, perception** and **execution,** supported by four processes and two representations (see Chapter 2, Section 2.1 for full description).

EMCRS worksystem: planning and control behaviours and structures:

Four types of abstract structures and behaviours are modelled, and two representations; these behaviours are described in detail with respect to the EMCRS in Phase 4 of model development below.

Axiom 2.4 HCI-PCMT performance:

Performance is some function of: the task quality associated with the multiple task work carried out; and the resource costs associated with the worksystem structures and behaviours of planning and control (incurred by the work). (Resource costs are not differentiated between the user and devices.)

EMCRS domain

Performance is some function of: the task quality associated with the multiple task work (for example, lives saved, fires contained) and the resource costs associated with the worksystem planning and control behaviours (for example, plans correct, firemen in place). (As above resource costs are not differentiated between the user and devices.)

All the HCI-PCMT axioms have now been re-expressed for the EMCRS. The next section presents the method for developing the EMCRS model by application of these axioms and the HCI-PCMT framework representation.

4.3 Method for model construction

This section describes the method used for constructing the model. This description is not a method per se but rather is an initial description of how the researcher constructed a model by application of the HCI-PCMT framework axioms and representation.

The EMCRS system and domain were modelled, together and iteratively, using the HCI-PCMT framework and the data collected from the training session. In addition, modelling used researcher experience and knowledge from earlier models (Hill et al, 1996); an understanding of the present domain of work - managing disasters; and documented information describing the objectives of EMCRS behaviours – see above. Physical domain objects, attributes and values were derived from the data. Abstract domain objects (attributes and values) were identified from the physical domain objects. EMCRS physical structures and behaviours, were derived from the data. The domain and the worksystem are then expressed using the HCI-PCMT representation.

(The data had offered up potential co-ordination problems within the EMCRS. These problems related to conflicts between particular sub-tasks being carried out by the different agencies of the EMCRS. Due to the complexities of modelling all the EMCRS data, which would involve modelling all the different sub-tasks with associated behaviours and domain transformations, it was decided that only those sub-tasks associated with the identified conflicts would be described by the model. Therefore, only structures and behaviours associated with these sub-tasks are defined for representation within the model worksystem, and only the sub-object attributes and values associated with these sub-tasks are conceptualised for representation within the model domain.)

4.3.1 Phase 1 – Abstract domain objects

The first phase of model construction was to conceptualise the domain of work for the EMCRS worksystem. As described in Chapter 2, and expressed in the EMCRS axioms above, the work of the EMCRS is the support of a single **Disaster** Object. This **Disaster** object is defined at Abstract level 2, the highest level. The attributes and values for the **Disaster** object were conceptualised as *stability* and *normality*, with values along a continuum. The performance of the EMCRS worksystem is expressed by the transformation of the **Disaster** object's attribute values. Each task carried out by the worksystem transforms the attribute values of the disaster object. These attribute values change by manipulation of the values of the attributes of the sub-objects of the domain. These sub-objects' attribute value changes are affected by the sub-tasks of the EMCRS, which are the individual agency tasks (also the multiple tasks in EMCRS). The attribute *normality* was conceptualised from the notion that at the beginning of the disaster scenario the 'disaster' is chaos, and the work of the EMCRS is ultimately to restore normality, i.e. to bring the disaster under control. Thus, the more desirable the level of normality the better the performance of the EMCRS. The second attribute – *stability* was conceptualised through an understanding of the expected overall performance of the EMCRS worksystem - that of stabilising the disaster (preventing further loss of life and containing fires and other hazards). Both of these attributes' values are changed by the transformation of the sub-object attribute values. The values for both of these attributes are along a continuum. It is not possible to be more explicit about the values as this system is so complex. There are multiple users, at multiple levels, carrying out multiple tasks. Explicitly identifying individual performance effects is therefore complex, and has not been attempted here. However, it is believed that being able to express performance through transformations on a continuum will be at a level of description appropriate for diagnosing co-ordination design problems.
The other abstract objects, which are sub-objects of the disaster object, were conceptualised from: the primary objectives of the EMCRS (see earlier); the primary roles/tasks for the emergency services described in Chapter 1; information from the exercise narrative; and the data. The sub-objects are the

Lives sub-object; **Disaster Character** sub-object; **Disaster Scene** sub-object; **Property** sub-object, **Environment** sub-object and **Emergency Service** sub-object. Each of these sub-objects was conceptualised as follows:
Lives sub-object – is an abstract representation of the people, subjected to the disaster. The reasons for conceptualisation are: the primary objective of the EMCRS is saving lives; the primary task identified by each of the emergency services is saving lives; from the narrative, there are foreign and other casualties, bodies, trapped people etc; and from the data, rescue and treatment of casualties is required (Data 1. 4g).

Disaster Character sub-object – is an abstract representation of information relating to the general characteristics of the disaster. One objective of the EMCRS is to prevent escalation of the disaster; one role of the Fire Service is to prevent escalation of the disaster; from the narrative there has been a goods train crash, with leaking aviation fuel; and from the data, the Fire Service need to fight fires (Data 1. 4j). Each of these requires the conceptualisation of this sub-object.

Disaster Scene sub-object – was conceptualised from the requirement to represent information, relating to the specific scene, or site of the disaster. An objective of the EMCRS is facilitating criminal investigation; one role of the Police Service is to preserve the site, one role for the Fire Service is to contain the scene; from the narrative, vandalism may be responsible for the derailment; and from the data, the inner cordon set-up by Fire Service (Data 1. 4q).
Property sub-object – was conceptualised from the requirement to represent information relating to the physical structures at the site. An objective of the EMCRS is protection of property; one role of the Fire Service is protecting property; from the narrative, structural damage to buildings and vehicles; and from the data, removal of damaged vehicles (Data 1.1w).

Emergency Services sub-object – was conceptualised from the requirement to represent the emergency services equipment that becomes part of the domain. An objective of the EMCRS is preventing escalation of the disaster; one role of the Fire Service is to fight fires; from the narrative, leaking fuels, fires, casualties etc.; and from the data, controlling resources and getting access to the scene (Data 1. 4e, Data 1. 3a).

Environment sub-object – this sub-object was conceptualised from the requirement to represent information relating to environmental issues. An objective of the EMCRS is safe-guarding the environment; one role of the Fire Service is dealing with chemicals and other hazards; from the narrative, leaking aviation fuel is entering the canal and river; from the data, there is floating fuel on the river (Data1. 4h).

4.3.2 Phase 2 - Physical domain objects

The second phase was to analyse the data to give the physical level of description for the model. The physical objects and attributes are shown in the tables below. The objects and attributes are split into groups that relate to the conceptualised sub-objects. Table 1 thus, gives the attributes of the 'people' at the incident, which relate directly to the **Lives** object. Where a node could not continue, due to lack of space, its attributes are represented in another table, for example, survivors. Each table will be explained in turn. Which data points each node corresponds to are given in brackets in each node. The data is shown in Appendices 1 and 2. Sometimes a node will not be directly traceable to the data but will be traceable to the narrative. The Exercise Scorpio narrative is by its very nature the emergency services representation of the domain of the disaster. Although the following physical domain objects are for model dataset 1, these physical objects are the same for model dataset 2. In Chapter 5 where model dataset 2 is described only those physical domain objects that are different from model dataset 1 are given. Therefore in the following tables reference is given to both datasets.

People	Foreign (narrative, Data 2.1p)	Dead (narrative, Data 2.1r)	Where located (Data 1.1x; Data 2.A16; Data 2.1m)	
		Survivors (narrative)		
	UK (narrative, Data 2.1g)	Dead (narrative)	Where located (Data 1.1x; Data 2.A16; Data 2.1m)	
		Survivors (narrative)		
		Evacuees (Data 2.8b; Data 1.1o; Data 2.C6)	Where located (Data 1.4k; Data 1.1o; Data 2.1g))	Mobility (Data 1.1o; Data 2.1g)
		ES personnel (Data 1.1i; Data 1.3g; Data 2.5a; Data 2.9a; Data 2.6c)		

Table 1 People object attributes and values (dispositional)

In Table 1, the physical object attributes and values are shown for the people in the incident. The attributes and values shown are dispositional, inasmuch as they are based on information that the worksystem needs to know about, or perceive, but that the work of the worksystem will not change, for example, where an evacuee is located. A distinction has been made between evacuees and survivors. Evacuees are those people who have not been directly affected by the incident, but live in the vicinity and so are at risk from the incident and will need to be evacuated. Survivors are those people who have been directly affected by the incident. The emergency service (ES) personnel are only present as a dispositional attribute, with respect to whether they have safety equipment or not.

Tables 2 and 3 show the physical attributes and values for the node survivors, and emergency services personnel respectively, from Table 1 above. These are again dispositional attributes. The affordant attributes for these nodes are shown in the following tables. The affordant and dispositional attributes and values are shown independently to enable a more accurate description of the work of the EMCRS. The work is complex, deciding on the relationships between the attributes and values is therefore complex, especially for the 'people' or 'lives.' Describing the attributes and values separately enables a more systematic analysis of the EMCRS domain.

Survivors (UK, Foreign)	Mobile	Injured (narrative; Data 1.3l; Data 1.1p)	Inaccessible (Data 1.4g)	Trapped (narrative)
				Not trapped
			Accessible	
		Uninjured	Inaccessible (Data 1.4g)	Trapped (narrative)
				Not trapped
			Accessible	
	Immobile	Injured (narrative; Data 1.3l; Data 1.1p)	Inaccessible (Data 1.4g)	Trapped (narrative)
				Not trapped
			Accessible	
		Uninjured	Inaccessible (Data 1.4g)	Trapped (narrative)
				Not trapped
			Accessible	

Table 2 Survivors physical attributes and values (dispositional)

<table>
<tr><td rowspan="2">Emergency Service (ES) Personnel</td><td>Safety equipped
(Data 1.1i; Data 1.3g; Data 2.5a; Data 2.6c; Data 2.9a)</td></tr>
<tr><td>Safety unequipped</td></tr>
</table>

Table 3 ES personnel physical attributes and values (dispositional)

<table>
<tr><td rowspan="5">Survivors</td><td>Not rescued
(Data 2.C7)</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Rescued
(Data 1.4g; Data 2.4i)</td><td>Not triaged
(Data 1.13a)</td><td></td><td></td></tr>
<tr><td rowspan="3">Triaged
(Data 2.A12)</td><td>Transported (not treated)
(Data 1.3l)</td><td>Information recorded at hospital</td></tr>
<tr><td rowspan="2">Treated (not transported)</td><td>Casualty bureau logged
(Data 1.3l; Data 2.1h; Data 2.8c)</td></tr>
<tr><td>Personal information recorded
(Data 1.1p; Data 1.10b; Data 2.1i; Data 2.7k)</td></tr>
</table>

Table 4 Survivors physical attributes and values (affordant)

<table>
<tr><td rowspan="2">Evacuees</td><td>Not rescued
(Data 2.1g; Data 1.1o)</td></tr>
<tr><td>Rescued
(Data 2.8b)</td></tr>
</table>

Table 5 Evacuees physical attributes and values (affordant)

Table 4 and 5 show the affordant attributes and values for the nodes survivor and evacuees. Affordant attributes are those attributes, whose value changes constitute the work of the worksystem. The distinction between affordant and dispositional attributes was described in Chapter 2, Section 2.1.

		Inaccessible site (narrative; Data 1.7b; Data 1.1b; Data 1.4q)		
		Market town location (narrative)		
	Site of disaster (Data 1.1b)	Restrict access to the site (Data 2.A4; Data 1.1c)	Contain site with outer cordon (Data 1.1c; Data 1.1v; Data 1.9b; Data 2.A2; Data 2.A4; Data 2.B2)	
Disaster area		Crime scene (Data 1.1b; Data 1.3j; Data 2.B3)	Preserve site for evidence (Data 1.1b; Data 2.1c; Data 2.3a)	
		Access points (Data 1.3a; Data 2.A4; Data 2.B3; Data 2.2a)	Location (Data 2.7i; Data 1.3a; Data 1.4q)	Suitable for Fire Service (Data 1.3a; Data 2.4n; Data 2.6b)
	Scene of disaster (Data 1.1b)	Contained by inner cordon (Data 1.3g; Data 1.9a; Data 1.4r; Data 2.C5; Data 2.A10)		

Table 6 Disaster area physical attributes and values

Table 6 shows the physical objects attributes and values that relate to the **Disaster Scene** sub-object. The attributes and values both, affordant and dispositional are shown. It is not required to separate the two types of attribute at this level of description for this object, as the distinction will be made at Abstract level 1, the attributes and values of the domain sub-objects. For all the remaining tables no distinction is made at this level of description between the different types of attributes.

<table>
<tr><td rowspan="4">Disaster classification</td><td rowspan="4">Goods train crash
(narrative)</td><td>Aviation fuel fires
(narrative)</td></tr>
<tr><td>Explosion
(narrative)</td></tr>
<tr><td>Aviation fuel fumes
(narrative)</td></tr>
<tr><td>Aviation fuel
(narrative)</td></tr>
</table>

Table 7 Disaster classification physical attributes and values

Table 7 shows the object attributes and values that relate to the **Disaster Character** sub-object.

<table>
<tr><td rowspan="4">Property</td><td></td><td>Severely damaged
(narrative; Data 2.A10))</td><td></td></tr>
<tr><td>Buildings
(narrative)</td><td>Damaged</td><td></td></tr>
<tr><td></td><td></td><td>Burning</td></tr>
<tr><td>Vehicles
(narrative)</td><td>Damaged
(Data 1.1w)</td><td>Not burning
(narrative)</td></tr>
</table>

Table 8 Property physical attributes and values

Table 8 shows the physical object attributes and values that relate to the **Property** sub-object of the domain.

Emergency services equipment	Available (Data 1.4d; Data 1.4e; Data 1.7e; Data 2.4j; Data 2.2b; Data 2.7b; Data 2.1b)	Usable (Data 1.1c; Data 1.3a; Data 1.4q; Data 1.12d; Data 2.4n; Data 2.6b; Data 2.7i; Data 2.B8)

Table 9 ES equipment physical attributes and values

Table 9 shows the physical object attributes and values that relate to the **Emergency services** sub-object. The emergency services equipment is only represented in the domain here with respect to making the equipment and available and usable which is part of the work of the EMCRS worksystem.

<table>
<tr><td rowspan="3">Environment</td><td rowspan="3">Waterways
(narrative)</td><td>Canal
(narrative)</td><td rowspan="3">Aviation fuel contamination possible
(Data 1.4h; Data 2.A9; Data 2.A17; Data 2.4h)</td></tr>
<tr><td>Sewers
(narrative)</td></tr>
<tr><td>River
(narrative)</td></tr>
</table>

Table 10 Environment physical attributes and values

Table 10 shows the physical object attributes and values that relate to the **Environment** sub-object of the domain.

4.3.3 Phase 3 abstract domain objects attributes and values

The third phase of model development was to conceptualise the attributes and values of the sub-objects. As stated above attributes can be affordant or dispositional. Dispositional attributes are relevant to the work (they need to be perceived by the worksystem), but their transformation does not itself constitute work. Affordant attribute value changes constitute the work of the EMCRS worksystem. As described in the EMCRS axioms above, the attributes and values for the sub-objects, at Abstract Level 1, are determined by an emergence relationship with the physical object attributes and values. The realisation relationship between Abstract Level 1 objects and Physical Level objects is a many-to-one relationship. For example, for the survivor attribute at the physical level there are many values – triaged, foreign, injured etc. The **Lives** sub-object does not have a survivor attribute with many values. Each identified value at the physical level has its own attribute representation at the abstract level, so there are survivor 'x' attributes with singular values (for example, for rescue, there is an attribute of *survivor rescue status*, with values of <u>rescued</u> or <u>not rescued</u>). Thus, for this object, there is a many-to-one emergence relationship between the attributes and values. The justification for this mapping is the knowledge of the work of the EMCRS, and how to represent this work so that design problems can be diagnosed. Thus, the work of the EMCRS has many sub-tasks carried out by the individual agencies of the EMCRS. The transformation of the attribute values of Abstract Level 1 comprises this work. To distinguish between the different sub-task transformations accurately, the attributes must be realised by this mapping, so that each individual value change can be demonstrated. These changes support an accurate description of the task quality of the work in reference to the worksystem behaviours, thus, expressing EMCRS performance and so design problems. All the sub-object attributes and values are shown in the tables below.

Dispositional attributes	Value
Victims location	X
Victims nationality	Y
Survivor mobility	Immobile/mobile
Survivor condition	Uninjured/injured
Survivor location	Inaccessible/accessible
Survivor nationality	Z
Evacuees location	X
Evacuee mobility	Mobile/immobile
Survivors entrapment	Not trapped/trapped
Emergency services Personnel safety	Unequipped/equipped

Table 11 Lives sub-object dispositional attributes and values

Affordant attributes	Value
Survivor personal information	Unrecorded/recorded
Survivor information	Casualty bureau un-logged/logged
Survivor/evacuee rescue status	Not rescued/rescued
Survivor treatment status	Not treated/treated
Survivor transport status	Not transported/transporte
Survivor triage status	Untriaged/triaged

Table 12 Lives sub-object affordant attributes and values

Dispositional attribute	Value
Scene/site accessibility	Easy/difficult
Location	Market town
Affordant attributes	Value
Scene containment	Uncontained/contained
Site preservation	Unpreserved/preserved
Site containment	Uncontained/contained
Access point position	Unlocated/located
Access point suitability	Unsuitable/suitable
Site status	No crime scene/crime scene

Table 13 Disaster Scene sub-object attributes and values

Dispositional attribute	Value
Type	Fire, hazardous material, explosion
Class	Transport
Affordant attributes	Value
Fire status	Uncontrolled/controlled
Hazardous materials status	Uncontrolled/controlled
Explosion status	Uncontrolled/controlled

Table 14 Disaster Character sub-object attributes and values

Dispositional attribute	Value
Type	Buildings and vehicles
Buildings condition	Undamaged/damaged
Vehicle condition	Undamaged/damaged
Affordant attributes	Value
Buildings status	Not at risk/ at risk
Vehicles status	Not at risk/ at risk

Table 15 Property sub-object attributes and values

Affordant attributes	Value
Equipment availability	Not available/available
Equipment condition	Non-utilizable/utilizable

Table 16 Emergency Services sub-object attributes and values

Dispositional attribute	Value
Type	Waterway
Affordant attributes	Value
Waterway status	Not at risk/ at risk

Table 17 Environment sub-object attributes and values

4.3.4 Phase 4 worksystem structures

Phase 4 of model construction was to describe the EMCRS abstract and physical worksystem. The EMCRS abstract worksystem is defined in terms of the abstract cognitive structures, identified within the HCI-PCMT framework. The physical worksystem structures were identified from

analysis of the data, from information about EMCRS structures, and information about the required personnel and resources for particular worksystem behaviours (specified in the roles/tasks of the different services). Thus, from information on the EMCRS, we have commanders at the tactical and operational levels of control. From information on roles/tasks for the emergency services, and from the data (Data1. 1a), one role of the Police Service is the preservation of the scene for evidence and enquiries. Preserving the scene will require Police personnel to manage the scene. All the physical structures required for model diagnosis of design problems from the identified conflicts are represented in the model. These abstract and physical structures are shown in the model below.
The behaviours associated with these structures are as follows: **Perception** behaviours are those, whereby the worksystem acquires information about **Property, Lives** and other domain objects, such as their risk status, and records these values. The states of the domain objects form the contents of the **Knowledge-of-tasks** representation. **Perception** behaviours update the contents of the **Knowledge-of-tasks** representation, based on the reading of the domain; for example that there are properties at risk. **Execution** behaviours are those which carry out the work of the worksystem by transforming the values of the domain object attributes values directly; for example, treating injured survivors at the scene transforms the **Lives** sub-object attribute *survivor status* from untreated to treated. These **execution** behaviours will in turn transform the **Disaster** object to a more desired level of *stability* along its continuum. **Planning** behaviours are those that specify what and/or how tasks will be accomplished in terms of required object state transformations and/or required worksystem behaviours, for example, that the site should be declared a crime scene, which requires Police personnel to patrol it. **Control** behaviours select which behaviours should be carried out next, based on the contents of the **plan** and **Knowledge-of-tasks** representation. A **plan** representation structure embodies the plans used in the combined response. These structures are distributed across the different levels of the worksystem, i.e. strategic, tactical and operational.

4.4 Model for Dataset 1

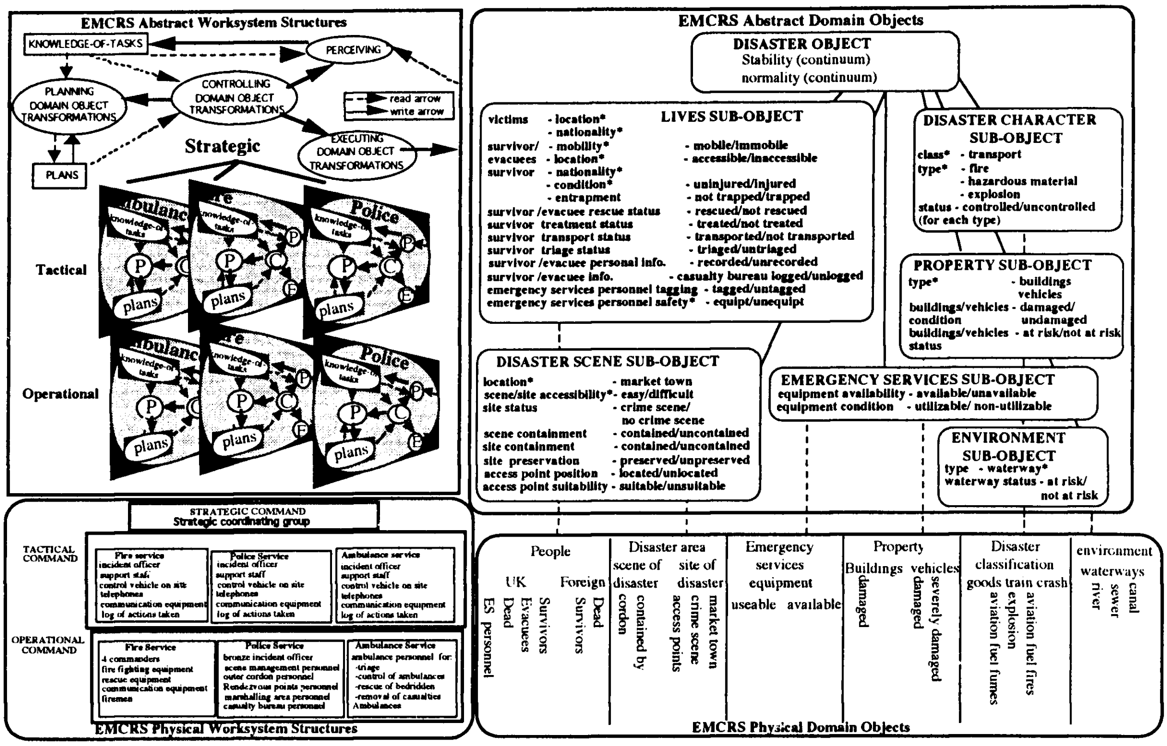


Figure 1 Model for Dataset 1

Figure 1 shows the Model for Dataset 1. The model shows the abstract and physical structures of the worksystem on the left hand-side of the diagram. At the abstract level, the three tier structure of the EMCRS, operational, tactical and strategic, is depicted (but interactions within and between levels are not shown). These abstract structures are distributed across the physical worksystem structures. This distribution is not shown here, due to the limitations of the representation, but is described in detail in the model behaviour conflict descriptions in Chapter 6. The abstract structures representation is the same as that shown in Chapter 2. That is, an oval depicts a process structure, a rectangle depicts a representation structure, a read arrow depicts a process reading from the contents of a representation, and a write arrow depicts a process writing to the contents of a representation. The physical level shows all those structures that have been identified as necessary to inform the abstract structures of the worksystem for the conflicts, identified within the data. On the right-hand side, the domain objects, attributes and values are shown, both abstract and physical. The physical level objects' attributes and values are not shown in full, as they have already been described in full in Section 4.3 above. The links between the abstract sub-objects and the physical objects, shown with a dotted line, define the abstract to physical realisation relationship. The full lines between the **Disaster** object and the other sub-objects define a part-of relationship. The attributes with a star (*) are dispositional. There are issues with the model representation, which relate to the EMCRS characteristics, identified in Chapter 2. Thus, the model does not represent a changing worksystem, or interactions within and between the different horizontal and vertical layers of the system. These issues are addressed fully in Chapter 7.

Once constructed, the model can then be used to describe the work of the worksystem with respect to the planning, controlling, perceiving and executing behaviours and the transformations these behaviours effect in the domain. These model descriptions will provide an expression of the effectiveness or performance of the EMCRS by showing how well the work is performed (the quality of work) in terms of domain transformations, and the resource costs to the worksystem for carrying out these transformations. Model descriptions have been produced for each EMCRS sub-task, where there is a potential co-ordination design issue, as identified from the data. These descriptions are given in full in Chapter 6.

4.5 Co-ordination design problems

The EMCRS model has been used to describe tasks carried out by the EMCRS, in terms of the **planning, control, perception** and **execution** behaviours and the transformations these behaviours effect on the domain. However, sometimes, behaviours that perform these different tasks conflict. These 'conflict' behaviours are used to identify potential planning and control co-ordination design problems between agencies. For example, in the training exercise, the Fire Service set-up an inner cordon for safety at the scene and require safety equipment to be worn by anyone entering the cordon. The Ambulance Service want to locate casualties at the scene, but for safety reasons (they are not wearing the correct equipment), they are not allowed access to the cordon by the Fire

Service. This between service behaviour 'conflict' may signal a potential co-ordination design problem, expressed as overall EMCRS ineffectiveness. Performance may be reduced by either hindering goal achievement, for example, by reducing life-saving behaviours, and/or by rendering system resource costs unacceptable, for example, requiring excessive personnel effort. Thus, 'conflict' behaviours have been used to diagnose EMCRS co-ordination design problems. An explicit EMCRS axiom expression of a behaviour conflict is now given to support co-ordination design problem diagnosis through behaviour conflict identification.

A behaviour conflict is described by the model at the second level of description (Abstract Level 1), in two cases: either, two or more sub-objects are undergoing independent, but temporally overlapping transformations, which conflict, for example, the transformation of the **Disaster Scene** sub-object when a crime scene is declared (by the Police Service), and the transformation of the **Disaster Character** sub-object whilst preventing escalation of the disaster (by the Fire Service); or, two or more attributes of a sub-object are undergoing independent, but temporally overlapping transformations, which conflict, for example, the transformation of the **Lives** sub-object, when witness information is being recorded (by the Police Service), and transformation of the **Lives** sub-object, when survivors are being transported to hospital (by the Ambulance Service). In both of these types of conflict, one of the sub-objects will not be transformed as desired. A task in EMCRS as described above is, the required state transformation of the Disaster object, including all lower level transformations of the associated sub-objects. These state transformations are realised by the sub-transformations of the sub-objects. If a sub-object is not transformed as desired, then the **Disaster** object will not be transformed as desired. Task quality is expressed by desired state transformations of the **Disaster** object. This expression of a behaviour conflict, therefore, identifies a the conflict as reducing task quality. The model, in addition, allows identification of the worksystem structures and behaviours, associated with the behaviour conflict and so allows an expression of the resource costs. Performance of the EMCRS is expressed as a function of task quality and resource costs. A behaviour conflict is, thus, diagnosed by the model as causing ineffective performance of the EMCRS. Thus, a behaviour conflict is diagnosed as a design problem, as actual performance does not equal desired performance. The design problem diagnosed is a planning and control co-ordination design problem. The EMCRS model is an HCI-PCMT model, and thus diagnoses planning and control design problems.

How to explicitly diagnose co-ordination design problems from the identified conflict behaviours will be described in Chapter 6. Four behaviour conflicts were identified in Dataset 1. These were: trampling/scene preservation; cordon restrictions; witness reporting; and access of fire appliances. Each of these is described by the model in chapter 6.

4.6 Chapter Summary

This chapter has presented the first cycle of model development. The first set of data has been discussed, and application of the HCI-PCMT framework axioms, and representation, to this data have been described. The first model – Model Dataset 1 has been presented. How this model can be used to diagnose co-ordination design problems of the EMCRS through behaviour conflict identification, has been described. Issues with the current model representation have been identified. The following chapter will present the next cycle of model development.

Chapter 5

EMCRS model development – cycle two

Introduction

This chapter presents the second cycle of model construction, using data gathered at the second observation of exercise Scorpio – Dataset 2. The method for model construction, presented in Chapter 4, is then applied to model these data. Resulting changes in the domain and worksystem representations for EMCRS, at both an abstract and physical level with respect to Dataset 2, are presented, in Section 2. The model for Dataset 2 is presented in Section 3, along with details of behaviour conflicts identified by the model.

5.1 Dataset 2

The second seminar attended was identical in format to the first. However, this time the researcher was attached to a syndicate that followed the complete exercise. Thus, data were recorded for all the considerations given in the exercise procedure. The data were recorded in the same way – by note taking, and receiving the print-outs from the whiteboards after the presentations. There were again 60 emergency service personnel present with representatives from each of the emergency services, and local authority chief executives. The raw data were expanded as in Dataset 1. The raw data and more complete data are presented in a tabular form, in Appendix 2.

To develop the EMCRS models, the HCI-PCMT framework was applied to the data. This application was twofold, involving the HCI-PCMT axioms, and representation. These two stages were carried out together and iteratively. The EMCRS framework axioms have already been presented in Chapter 4. These axioms remain the same for Dataset 2. The next section describes the construction of the EMCRS model this dataset.

5.2 Model construction

The model was constructed using the method for model construction described in the previous chapter. Due to the data being collected at a second running of the same exercise, exercise Scorpio, the model constructed has few differences to the model for Dataset 1. Thus, Dataset 2 supports the model constructed from Dataset 1, and suggests it is typical.

5.2.1 Phase 1 – abstract domain objects

The domain of work for the EMCRS was conceptualised, as for Dataset 1, as the support of a single **Disaster** Object. The attributes and values for the Disaster object were also the same, *normality* and *stability* with values along a continuum.

The other abstract objects, which are sub-objects of the disaster object, were also conceptualised as the same as Dataset 1, i.e. **Lives** sub-object: **Disaster Character** sub-object; **Disaster Scene** sub-object; **Property** sub-object; **Environment** sub-object and **Emergency Services** sub-object. Dataset 2 served to reinforce the conceptualisation of these sub-objects. Each sub-object is listed below with selected data points from Dataset 2 to illustrate this reinforcement.

Lives sub-object: Data 2. C6, Data 2. C7, Data 2.1p, Data 2.4i, Data 2.8b refer to people or lives in the domain.

Disaster Character sub-object: Data 2. C1 and Data 2. C8 refer to the aviation fuel. Data 2. A7 refers to the fires.

Disaster Scene sub-object: Data 2. A6 and Data 2. B1 refer to Police cordons, Data 2. A.10 and Data 2. C5 refer to Fire cordons, Data 2. 2a and Data 2.4n refer to access.

Property sub-object: Data 2. 1g and Data 2. 4b refer to the structural damage at the site.

Environment sub-object: Data 2.4h, Data 2. A9, and Data 2. 4s all refer to the aviation fuel contamination of the river and canal.

Emergency Services sub-object: Data 2. 2b and Data 2.7b refer to emergency service resources.

Once the sub-objects of the domain had been defined, the next phase of model construction was to define the physical level of description for the domain.

5.2.2 Phase 2 - physical domain objects

The second phase was to analyse the data to give the physical level of description for the model. Most of these physical level object descriptions were the same as for Dataset 1. The one conflict that had not been identified in Dataset 1 was that of decontamination. The addition of physical attributes for contamination are shown in the tables below. Also, in Dataset 1 witness reporting was identified as a conflict but Dataset 2 did not reflect this conflict. Only those tables, where this addition and subtraction require changes are shown. All the other tables for physical object attributes and values shown in Chapter 4, for Dataset 1, are the same for Dataset 2, and so are not shown here. Table 1 shows the changes to the physical object dispositional attributes and values for the 'people', with the addition of information on contamination.

People	Contaminated (Data 2.6g)	Foreign	Dead (narrative, Data 2.1r)	Where located (Data 1.1x; Data 2.A16; Data 2.1m)	
			Survivors (narrative)		
		UK	Dead (narrative)	Where located (Data 1.1x; Data 2.A16; Data 2.1m)	
			Survivors (narrative)		
			Evacuees (Data 2.8b; Data 1.1o; Data 2.C6)	Where located (Data 1.4k; Data 1.1o; Data 2.1g))	Mobility (Data 1.1o; Data 2.1g)
			ES personnel (Data 1.1i; Data 1.3g; Data 2.5a; Data 2.9a; Data 2.6c)		
	Uncontaminated	UK	Dead (narrative)	Where located (Data 1.1x; Data 2.A16; Data 2.1m)	
			Survivors (narrative)		
			Evacuees (Data 2.8b; Data 1.1o; Data 2.C6)	Where located (Data 1.4k; Data 1.1o; Data 2.1g))	Mobility (Data 1.1o; Data 2.1g)
			ES personnel (Data 1.1i; Data 1.3g; Data 2.5a; Data 2.9a; Data 2.6c)		
		Foreign	Dead (narrative, Data 2.1r)	Where located (Data 1.1x; Data 2.A16; Data 2.1m)	
			Survivors (narrative)		

Table 1 People physical attributes and values (dispositional)

<table>
<tr><td rowspan="5">Survivors</td><td rowspan="5">Contaminated</td><td>Not rescued (Data 2.C7)</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Rescued (Data 2.4i)</td><td rowspan="4">Triaged (Data 2.A12)</td><td rowspan="2">Treated</td><td>De-contaminated (Data 2.9b; Data 2.7h)</td><td rowspan="2">Personal information recorded (Data 2.7k; Data 2.1i; Data 1.10b; Data 1.1p)</td></tr>
<tr><td>Not de-contaminated (Data 2.6g)</td></tr>
<tr><td rowspan="2">Not treated</td><td>De-contaminated (Data 2.9b; Data 2.7h)</td><td rowspan="2">Transported</td></tr>
<tr><td>Not de-contaminated (Data 2.6g)</td></tr>
</table>

Table 2 Survivors physical attributes and values (affordant)

<table>
<tr><td rowspan="2">Emergency services personnel</td><td>Uncontaminated</td><td></td></tr>
<tr><td>Contaminated</td><td>Decontaminated (Data 2.4u)</td></tr>
</table>

Table 3 ES personnel physical attributes and values (affordant)

Evacuees	Contaminated	Not rescued (Data 2.1g)	
		Rescued (Data 2.8b)	De-contaminated (Data 2.9b)
			Not de-contaminated

Table 4 Evacuees physical attributes and values (affordant)

Tables 2, 3 and 4 show the changes to the affordant attributes and values for the nodes survivor, evacuees and emergency service personnel, with the addition of contamination information.

Emergency services equipment	Available (Data 1.4d; Data 1.4e; Data 1.7e; Data 2.4j; Data 2.2b; Data 2.7b; Data 2.1b)	Usable (Data 1.1c; Data 1.3a; Data 1.4q; Data 1.12d; Data 2.4n; Data 2.6b; Data 2.7i; Data 2.B8)	Uncontaminated	
			Contaminated	Decontaminated (Data 2.9b)

Table 5 ES equipment physical attributes and values (affordant)

Table 5 shows the changes to the physical object attributes and values for the emergency services equipment object, with the addition of contamination information.

These changes to the physical object representation will realise changes in the abstract sub-object representations. These changes are discussed in the next section.

5.2.3 Phase 3 - abstract domain objects attributes and values

The third phase of model development was to conceptualise the attributes and values of the sub-objects. For Dataset 2 ,the abstract domain sub-objects attributes and values are as for Dataset 1 except for: those which have been realised from the physical object attribute changes relating to contamination; and those which are not reflected in these data, relating to witness reporting.

Dispositional attributes	Value
Emergency services Personnel status	Uncontaminated/contaminated
Survivor/evacuee contamination status	Uncontaminated/contaminated

Table 6 Lives sub-object dispositional attributes and values

Affordant attributes	Value
Survivor/evacuee contamination status	Contaminated/decontaminated
Emergency services Personnel contamination status	Contaminated/decontaminated

Table 7 Lives sub-object affordant attributes and values

Dispositional attribute	Value
Equipment status	Uncontaminated/contaminated
Affordant attributes	Value
Equipment contamination status	Contaminated/decontaminated

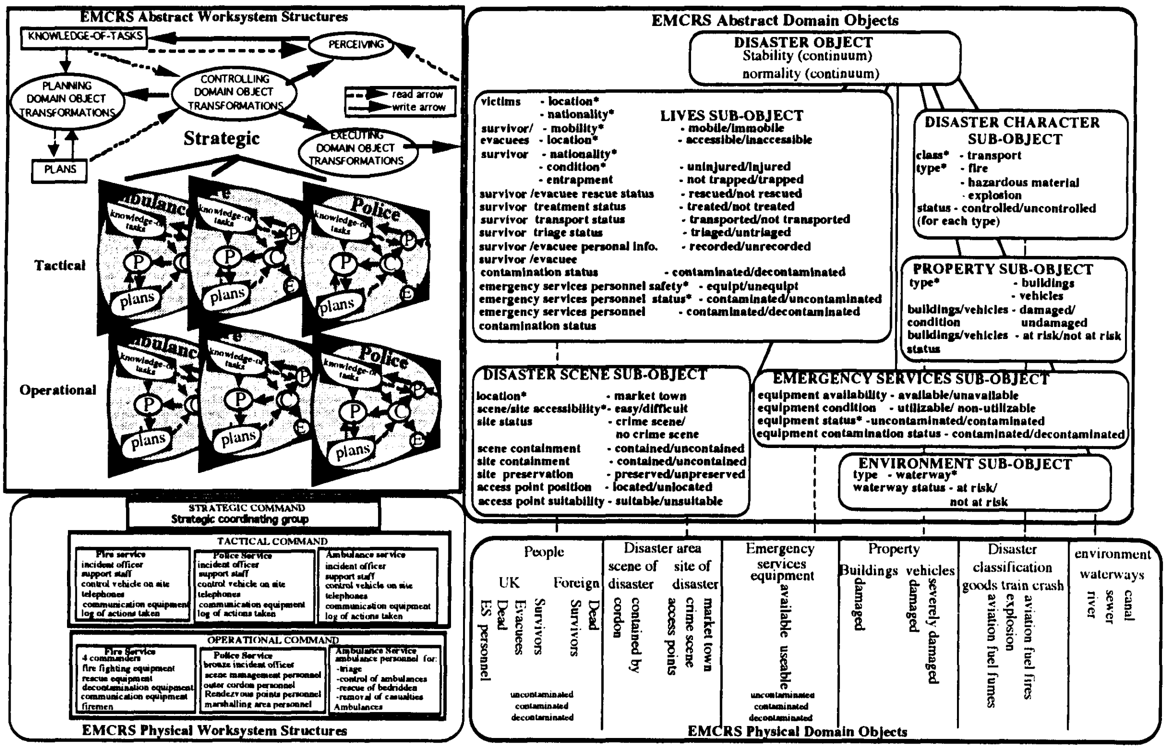
Table 8 Emergency Services sub-object attributes and values

Once the domain sub-objects attributes and values are defined, the next phase of model construction is to define the worksystem.

5.2.4 Phase 4 - worksystem structures

Phase 4 of model construction was to describe the EMCRS abstract and physical worksystem. The EMCRS abstract worksystem is defined in terms of the abstract cognitive structures identified by the HCI-PCMT framework. The physical worksystem structures were identified from analysis of the data, information about EMCRS structures, and information about the required personnel and resources for particular worksystem behaviours (specified in the roles/tasks of the different services). The changes to the physical worksystem representation through Dataset 2 are shown in Model-Dataset 2, and reflect the data. That is, there are additions to the worksystem physical structures with respect to contamination as identified above. The additions to the physical worksystem structures resulting from this information are reflected in the model representation below.

5.3 Model from dataset 2



EMCRS model for dataset 2

The model for Dataset 2 is very similar to the model for Dataset 1. The model shows the abstract and physical worksystem on the left hand-side of the diagram. At the abstract level, the three tier structure of the EMCRS, operational, tactical and strategic is depicted (but interactions within and

between levels are not shown). These abstract structures are distributed across the physical worksystem structures. This distribution is not shown here, due to the limitations of the representation, but is described in detail in the model behaviour conflict descriptions in Chapter 6. The abstract structures representation is the same as that shown in Chapter 2 and as reiterated in Chapter 4, in the description of the model for Dataset 1. The physical level shows all those structures, that have been identified as necessary to inform the abstract structures of the worksystem, for the conflicts identified by the data, and include here a structure for decontamination. On the right-hand side, the domain objects, attributes and values are shown, both abstract and physical. The physical level objects attributes and values are not shown in full, as this representation is unable to support them. However, they have already been described with respect to Dataset 2 in Section 5.2 above. The physical objects attribute value changes identified in Section 5.2 are, however, shown – those that relate to contamination. The changes they realise in the abstract domain objects attributes and values are also shown. The other change to the abstract domain objects attributes and values is with respect to Dataset 2 not reflecting Dataset 1 as concerns witness reporting. Thus, all references to this are removed in model Dataset 2. The links between the abstract sub-objects and the physical objects, shown with a dotted line, define the abstract to physical realisation relationship. The full lines between the **Disaster** object and the other sub-objects define a part-of relationship. As for model Dataset 1, the starred (*) attributes are dispositional.
There are issues with the model representation, as for Dataset 1, which relate to the EMCRS characteristics, identified in Chapter 2. Thus, the model does not represent a changing worksystem, or interactions within and between the different horizontal and vertical layers of the system. These issues are addressed fully in Chapter 7.
Once constructed, the model can then be used to describe the work of the worksystem with respect to the planning, control, perception and execution behaviours and the transformations these behaviours effect in the domain. These model descriptions will provide an expression of the effectiveness, or performance, of the EMCRS, by showing how well the work is performed (the quality of work) in terms of domain

transformations, and the resource costs to the worksystem for carrying out these transformations. Four behaviour 'conflicts' which are potential co-ordination design problems were identified with the model: trampling/scene preservation; access of fire appliances; cordon restrictions; decontamination. These conflicts are therefore the same as identified with Dataset 1, with the addition of decontamination and the subtraction of witness reporting (Dataset 2 does not identify witness reporting as a behaviour conflict). The model identifies these behaviour conflicts as co-ordination design problems, as expressed in Section 4.5. How explicitly to diagnose co-ordination design problems from the identified behaviour conflicts is described in Chapter 6

5.4 Chapter Summary

This chapter has presented the second cycle of model development. The set of data collected from the second running of exercise Scorpio has been discussed. The method for model construction has been applied to these data to produce model – Dataset 2. This model reflects the differences in the two datasets. Four behaviour conflicts have been identified with this model, which will be explicitly described in Chapter 6. Issues with the current model representation were identified as the same as for model Dataset 1, these issues will be addressed in Chapter 7. The following chapter will present Model 1, the combined model from the two datasets, the method for diagnosing co-ordination design problems and use of the method to diagnose each of the different behaviour conflicts, identified by the data, as co-ordination design problems.

Chapter 6

EMCRS design problem diagnosis

Introduction

This chapter presents EMCRS Model 1 the combined model from both datasets and uses it to diagnose EMCRS coordination design problems, by means of behaviour conflict identification. Section 1 presents EMCRS Model 1. Section 2 presents the diagnosis method for identifying co-ordination design problems from the behaviour conflicts. This method for diagnosis is then applied. Section 3 presents each stage of the application of the method and, thus, diagnoses EMCRS co-ordination design problems. Finally, Section 4 discusses appropriate performance expression with EMCRS Model 1.

6.1 EMCRS Model 1 - Combined Datasets 1 and 2

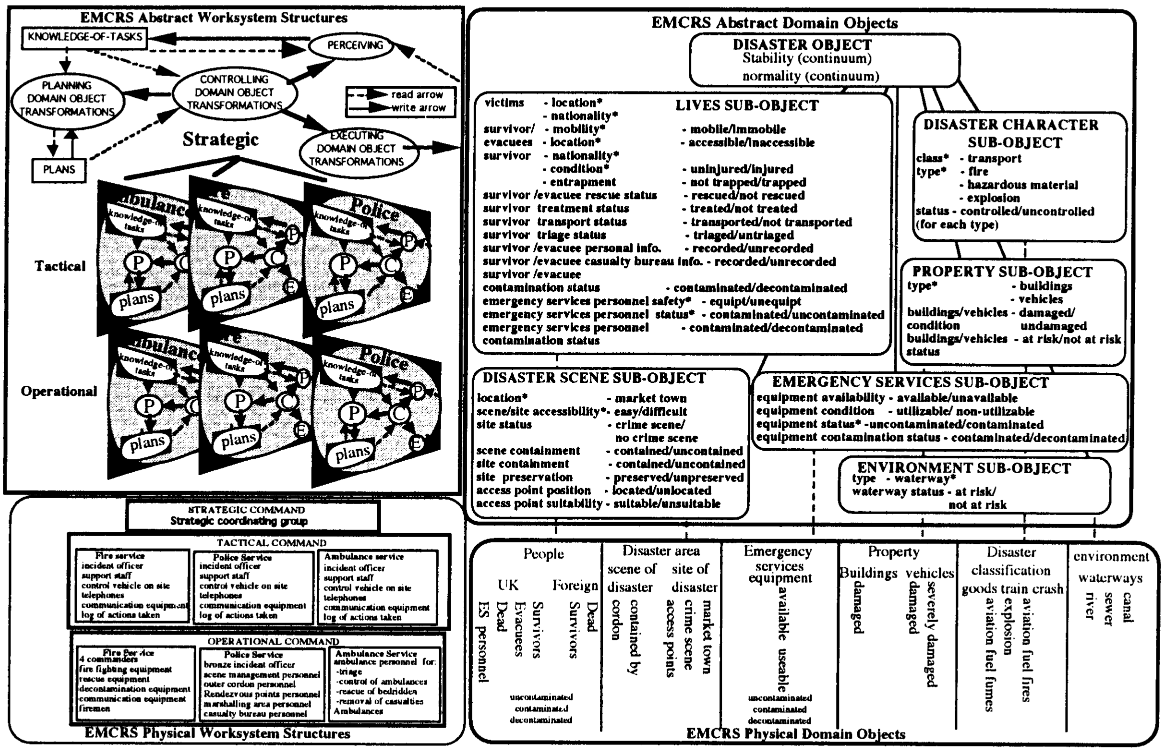


Figure 1 EMCRS Model 1

Figure 1 shows EMCRS Model 1, the model constructed by application of the HCI-PCMT framework to the combined Datasets 1 and 2. EMCRS Model 1 shows all the abstract and physical structures of the worksystem identified from both datasets, on the left hand-side of the diagram. At the abstract level, the three tier structure of the EMCRS, operational, tactical and strategic is depicted (but interactions within and between levels are not shown). These abstract structures are distributed across the physical worksystem structures. This distribution is not shown here, due to the limitations of the representation, but is described in detail in the model behaviour conflict descriptions in Section 2 below. The abstract structures representation is the same as that shown in Chapter 2, Figure 1. That is: an oval depicts a process structure; a rectangle depicts a representation structure; a read arrow depicts a process reading from the contents of a representation; and a write arrow depicts a process writing to the contents of a representation. The physical level shows all those structures that have been identified as necessary to inform the abstract structures of the worksystem for the conflicts identified within both Datasets. On the right-hand side, the domain objects, attributes and values are shown, from both datasets, both abstract and physical. The physical level objects attributes and values are not shown in full, as this representation cannot support this depiction. They have already been described in detail in Chapter 4, Section 4.3 and Chapter 5, Section 5.2. The links, between the abstract sub-objects and the physical objects, shown with a dotted line define the abstract to physical realisation relationship. The realisation relationship has a many-to-one mapping, as described in the method for model construction phase three (Chapter 4, Section 4.3). The full lines between the **Disaster** object and the other sub-objects define a part-of relationship. The attributes with a star (*) are dispositional, that is they need to be perceived by the worksystem, but are not changed by it.

Although a strategic level of command is represented in Model 1, (and in the models shown in Chapters 4 and 5), this is for completeness of the EMCRS representation. The structures of the strategic level are not referred to in the model descriptions presented in Section 6.3. The reason is because, although a strategic level of command was set up in the exercise and so is, thus, included in the representation, this command level is not activated in the initial response phase to the exercise. The data for the modelling are only from the initial response phase, and therefore do not refer to the strategic command level. It is often the case that a strategic level of command is not activated in major incidents, until later in the response, or sometimes not at all, if it is decided that it is not required. There are issues with the model representation, which relate to the EMCRS characteristics identified in Chapter 2. Thus, the model does not represent a changing worksystem, or interactions within and between the different horizontal and vertical layers of the system. These issues are addressed fully in Chapter 7

Once constructed, Model 1 is used to diagnose EMCRS co-ordination design problems, through application of the method for diagnosis. These Model 1 diagnoses are given in Section 6.3. The next Section describes the method for co-ordination design problem diagnosis.

6.2 The method for co-ordination design problem diagnosis

Table 1 presents the method for co-ordination design problem diagnosis.

Method stages	Action	Example for clarification
1	From data, identify tasks carried out by each agency in response to the scenario, where there are potential conflicts	Set-up of inner cordon by the Fire Service; access to casualties for triage without regulation safety equipment by the Ambulance Service.
2	Use Model 1 to describe the behaviours associated with each task and the corresponding desired domain sub-object transformations.	Desired domain sub-object transformations are those transformations that would be carried out, if an agency's behaviours are not hindered. For the above example, one desired domain sub-object transformation for the Ambulance Service would be: **Lives** sub-object attribute *survivor triage status* from untriaged to triaged
3	Identify behaviour conflicts i.e. which domain sub-object transformations will hinder other domain sub-object transformations	From the above example, the Fire Service behaviours of transforming the **Disaster Scene** sub-object attribute *scene containment* from uncontained to contained has hindered the Ambulance Service behaviours and corresponding domain sub-object transformations
4	Use Model 1 to identify whether other domain sub-object transformations that will be hindered as a 'knock on effect' from the initial conflict behaviour	For example, the Ambulance Service not being able to transform the **Lives** sub-object attribute *survivor triage status* from untriaged to triaged will mean that the **Lives** sub-object attribute *survivor treatment status* cannot be transformed from not treated to treated. Also, as the Ambulance Service cannot access the casualties, the Fire Service will have to move the casualties to the edge of the cordon to enable triage to take place. In so doing, the Fire Service will reduce their fire fighting and property protection behaviours, as personnel will need to be taken away from these tasks to carry out rescue behaviours and will therefore not be able to transform the **Disaster Character** sub object attribute *fire status* from uncontrolled to controlled, and the **Property** sub-object attributes of *buildings/vehicles status* from at risk to not at risk.
5	Identify the performance effect of the hindered domain sub-object transformations by referring to the overall common objectives and priorities of the EMCRS (i.e. to save life, to prevent escalation of the disaster etc.). The primary priority for all services is to save life. Therefore, hindering any domain sub-object transformation that reduces life saving by the EMCRS will have the greatest impact on performance	In the current example, hindering triage and subsequent treatment transformations by the Ambulance Service of the **Lives** sub-object, will greatly affect the performance of the EMCRS with respect to the primary priority of saving life. Reducing the fire fighting and property protection behaviours by the Fire Service will have an effect on the secondary priority of preventing escalation of the disaster. Thus, Model 1 gives a performance expression of actual performance being less than planned/desired performance, as a performance deficit, is shown for both agencies.

Table 1 Method for Co-ordination Design Problem Diagnosis

This method is now applied and the diagnoses from this application are described in the following sections.

6.2.1 Method Stage 1 - Identifying potential conflicts

The training scenario questions included one on inter-agency conflicts. From the data recorded in responses to this question, five sets of conflicts were identified. Each of these conflicts is now described as identified in the data.

- **Conflict 1:** Trampling/scene preservation – Due to information in the Exercise Scorpio narrative, i.e. that is vandalism is suspected, the Police Service declare the site as a crime scene (Data 1. 1b, Data 2. B2). Thus, the Fire Service are required not to trample the site, as any evidence of a crime must be preserved (Data 1. 4o, Data 2. 6a). Avoiding trampling of the site slows the rescue of casualties and hinders prevention of escalation of the fires by the Fire Service. (Data 1. 4o, Data 1. 5a). The Police Service behaviours of preserving the site, conflict, with the Fire Service behaviours of casualty rescue, and fire containment.
- **Conflict 2:** Cordon restrictions – Due to information in the Exercise Scorpio narrative, regarding structural damage to buildings and a number of fires at the scene, the Fire Service set up an inner cordon to contain the scene (Data 1. 3g, Data 1. 4r, Data 2. C5). The Fire Service are responsible for the safety of all personnel within the cordon (Data 1. 4b, Data 2. 4d, Data 2. 4o). Access is restricted to those with regulation safety equipment (Data 1. 6a, Data 1. 3g, Data 2. 6c). The Ambulance Service need access to locate casualties and either treat them at the scene, or transport them to hospital. The Ambulance Service do not have regulation safety equipment and are not allowed access to the casualties (Data 2. 5a, Data 2. 9a). The Fire Service task of containing the scene conflicts with the Ambulance Service task of locating and treating casualties.
- **Conflict 3:** Decontamination – Due to information in the Exercise Scorpio narrative, regarding contamination of casualties, there is a need for decontamination. The Fire Service have the decontamination equipment (Data 2. 4u) and should therefore be responsible for decontamination. The Ambulance Service require all contaminated personnel, casualties, and ambulances to be decontaminated at the site,

before the casualties can be transported (Data 2. 7h). The Fire Service reject their responsibility for decontamination (Data 2. 6g), as they are too busy preventing escalation of the disaster. However, any contaminated ambulance or casualty arriving at a hospital will shut down that hospital for the rest of the emergency (Data 2. 9b). The Fire Service task of preventing escalation of the disaster, conflicts with the Ambulance Service task of decontaminating casualties, and other contaminated personnel and equipment.

- **Conflict 4:** Witness reporting - Due to information in the Exercise Scorpio narrative, where vandalism is suspected as being the cause of the incident, the incident is declared a crime scene. Therefore, there is a need to treat all at the scene as witnesses (Data 2. B3). The witnesses may be casualties, and as such may be taken away to hospital. The Police Service want to be able to record witness information, before they leave the scene (Data 1 3.l, Data 1. 1p). The Police Service set up a casualty bureau, through which all casualties should be cleared, before being transported elsewhere (Data 2. 1h). The Ambulance Service personnel attempt to record the personal details of casualties, for possible later interview, before they are transported, but the most serious cases will be immediately sent to hospital. (Data 2. 7k). The Police Service task of witness reporting, conflicts, with the Ambulance Service task of transporting casualties.
- **Conflict 5:** Access of fire appliances – Information from the Exercise Scorpio narrative, states that there is aviation fuel flowing down the sides of the embankment on to the roadway, and there are numerous fires in the area. The Fire Service need to stem the flow of aviation fuel (Data 2 C1), and need to fight fires and prevent escalation of the disaster (Data 1. 4d) and will, therefore, need access for their fire appliances. The Police Service decide where the access points to the site will be, taking into account access and egress for all the agencies (Data 1. 1i, Data 2. A4, Data 2. B2). These access points may not be suitably located for the Fire Service, (Data 1.3a, Data 2. 2a, Data 2. 4n), such that, they cannot utilise their equipment and therefore cannot carry out their tasks. The Police Service task of setting up access points conflicts with the Fire Service task of accessing the scene for fire fighting and prevention of escalation of the disaster.

Stage one of method application is now complete, and has thus identified five conflicts. The next stages of the diagnosis method are now applied to each identified conflict, to diagnose co-ordination design problems. Co-ordination design problems are diagnosed, if actual performance does not equal desired performance.

6.4 Method application to identified conflicts

6.4.1 Conflict 1 - Trampling/scene preservation

Method Stage 2

The conflict arose as follows: the Police Service operational commander (physical structure) carries out **perception** behaviours that update his **knowledge-of-tasks** representation with the information that youths have been seen running from the scene. He then carries out **control** behaviours that direct him to consult his major incident **plan**. The **plan** specifies that, if there is evidence of vandalism, then the site should be declared a crime scene and that the scene should not be trampled to preserve the evidence. Based on this **plan** and the **knowledge-of-tasks** (about the vandalism), the operational commander then carries out **control** behaviours that direct him to consult the operational **plan** for preserving the site as a crime scene. The operational commander then carries out **control** behaviours that direct him to carry out **planning** behaviours, based on the operational **plan** and the **knowledge-of-tasks**. The **planning** behaviour specifies how the site should be declared a crime scene and how the site should be preserved. The operational commander then carries out **control** behaviours that direct him to carry out an **execution** behaviour of declaring the site a crime scene and specifying its preservation. This **execution** behaviour is carried out by the Police Service operational scene management personnel, informing the Fire and Ambulance Service operational personnel, that the site is now a crime scene, and specifying that only minimal trampling is now allowed, by all emergency service personnel in order to preserve the site. These physical object manipulations transform the abstract **Disaster Scene** sub-object's attribute *site status* from <u>no crime scene</u> to <u>crime scene</u>, and *site preservation* from <u>un-</u>

preserved to preserved, thus transforming the **Disaster** object's attribute *normality* to a more desired level along its continuum.

At the same time, the Fire Service operational commander (physical structure) carries out **perception** behaviours that update his **knowledge-of-tasks** with the information that there are a number of casualties at the scene and a number of fires. He then carries out **control** behaviours that direct him to consult his major incident **plan**. According to his **plan,** lives must be saved and prevention of escalation of the disaster must be carried out. He then carries out **control** behaviours that direct him to carry out **planning** behaviours to specify in the operational **plan** how escalation of the disaster should be prevented and how lives should be saved. Based on this **plan** and the **knowledge-of-tasks,** he then carries out **control** behaviours that direct the **execution** behaviours of preventing escalation of the disaster by controlling the fires, and saving lives by rescuing the casualties. These **execution** behaviours are carried out by the Fire Service operational personnel, i.e. the firemen and their fire fighting equipment, fighting the fires, and the firemen and their rescue equipment rescuing casualties. It is the manipulation of the physical casualties that transforms the abstract **Lives** sub-object attribute *survivor rescue status* from not rescued to rescued, and the manipulation of the physical fire that transforms the **Disaster Character** sub-object attribute *fire status* from uncontrolled to controlled. Both these manipulations in turn affect the **Disaster** object's desired level of stability.

Method Stage 3

However, as the Police Service have declared the site a crime scene, the Fire Service are only allowed to carry out minimal trampling, so that the site is preserved for evidence gathering. Therefore, the Fire Service operational personnel, when attempting to carry out their **execution** behaviours of rescuing the casualties, are only allowed to carry out minimal trampling, which slows rescue of casualties. Slowing rescue of casualties means that the Fire Service cannot transform the abstract **Lives** sub-object attribute *survivor rescue status* from not rescued to rescued and thus, cannot transform the **Disaster** object to a more desired level of *stability*. Likewise, slowing control of the fire by attempting not to trample the site, means that the **Disaster Character** object's attribute *fire status* cannot be transformed from uncontrolled to controlled, and therefore, the **Disaster** objects' *stability* cannot be transformed to a more desired level. A behaviour conflict has, thus, been identified.

Method Stage 4

No specific 'knock on effect' identified for this behaviour conflict.

Method Stage 5

The Police Service behaviours of preserving the scene have conflicted with the Fire Service behaviours of rescue and fire containment and have been identified as a behaviour conflict by Model 1. This conflict results in a co-ordination design problem, which may relate here to reduced overall EMCRS performance, either through hindered goal achievement (e.g. the site not being preserved or the survivors not being rescued) or through unacceptable system resource costs (e.g. Police working too hard, Fire Service trying not to trample). The model diagnoses an EMCRS co-ordination design problem as actual overall performance being less than desired performance with respect to the EMCRS common objectives. This co-ordination design problem relates to the common EMCRS objectives, i.e. to save life (casualties not rescued); to prevent escalation of disaster; (fire not contained); and to facilitate criminal investigation (vandals not caught). For this design problem, the model describes a performance deficit, related to hindered goal achievement and unacceptable resource costs for the Police and Fire Services. Trampling by the Fire Service reduces the chances of the vandals being caught by the Police Service. The Police Service will have to work harder to gather evidence if the site has been trampled. Carrying out minimal trampling reduces rescue of casualties, and containing of the fire by the Fire Service. The Fire Service will have to work harder when trying not to trample.

EMCRS Model 1 is a design-oriented model intended to constitute HCI substantive design knowledge to support the diagnosis of EMCRS design problems. An EMCRS design problem is diagnosed as actual performance not being equal to desired performance. Design knowledge supports design practice as the diagnosis of design problems and the prescription of design solutions. Prescription of design solutions is outside the remit of the current research, but potential design solutions will be suggested to clarify the nature of the design problem diagnoses. Design-oriented models should enable designers to reason about potential design solutions to the diagnosed design problems. One design problem diagnosis by the EMCRS model, has just been described. The EMCRS model will support reasoning about potential design solutions to this problem, as the model allows identification of the cognitive structures within the system, which may be causing the design problems, i.e. planning, control, perception, execution, plans and knowledge-of-tasks. Thus, for the current design problem, reasoning about a potential design solution is as follows: The execution behaviours of the Police Service (declaring the site a crime scene and insisting on minimal trampling to preserve the scene) have been identified as part of the cause of the identified design problem. How these behaviours came about can be identified by the EMCRS model. It was the planning and control behaviours of the operational commander that instigated these execution behaviours. Thus, the design problem might be related to EMCRS planning or control - the data do not make this clear. However, a potential solution to this problem is the re-design of planning and control, as expressed by the EMCRS model, for the operational commanders, as supported by devices/equipment/training etc. that results in desired performance.

Below are tabular representations of the domain object attribute value changes for each of the tasks involved in the behaviour conflict. The desired changes are those that would be carried out, if there was no behaviour conflict identified. The actual changes are those which occur as a consequence of the behaviour conflict. These tabular descriptions of the object attribute transformations are presented as an aid to the reader in understanding the behaviour conflict identification, in method Stage 3. Attributes that are starred with '* ' are dispositional, and are not changed by the EMCRS; but need to be perceived by it. Within the tables (desired) refers to desired performance, and (actual) to actual performance. Where it is not specified whether a transformation is desired or actual, is when actual performance equals desired performance. (Tabular descriptions are given for the tasks in each behaviour conflict. The information specified here, relating to these descriptions is the same for all the tabular descriptions given in the following sections.)

Police Service task of preserving the site as a crime scene

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Normality	Abnormal	---------->(desired)	Less abnormal
Normality	Abnormal	---------->(actual)	Abnormal

Disaster Character sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Cause *	Not known		Non-accidental

Disaster Scene sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Site status	No crime scene	---------->	Crime scene
Site preservation	Unpreserved	---------->(desired)	Preserved
Site preservation	Unpreserved	---------->(actual)	Unpreserved

Fire Service task of saving lives

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	----------> (desired)	Less unstable
Stability	Unstable	---------->(actual)	Unstable

Lives sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Survivor condition *	Not known		Injured
Survivor rescue status	Not rescued	---------->(desired)	Rescued
Survivor rescue status	Not rescued	---------->(actual)	Not rescued

Fire Service task of preventing escalation of the disaster

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	----------> (desired)	Less unstable
Stability	Unstable	---------->(actual)	Unstable

Disaster Character sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Type	Unknown		Fire
Fire status	Uncontrolled	---------->(desired)	Controlled
Fire status	Uncontrolled	---------->(actual)	Uncontrolled

6.4.2 Conflict 2 - Cordon restrictions

Method Stage 2

The behaviour conflict arose as follows: The Fire Service operational commander (physical structure) carries out **perception** behaviours that update his **knowledge-of-tasks** with the information that there are structurally damaged buildings, fires and leaking hazardous fuels. He then carries out **control** behaviours that direct him to consult the major incident **plan**. The **plan** specifies that the Fire Service is responsible for setting up an inner safety cordon, when there are hazards and dangers at the scene, and maintaining the safety of all those within the scene. Based on this **plan**, and the **knowledge-of-tasks** (about the fires etc.), the operational commander carries out **control** behaviours that direct him to consult the operational **plan** for setting up of a cordon. The operational **plan** gives guidance for cordon set-up and regulations. The operational commander then carries out **control** behaviours that direct him to carry out **planning** behaviours, based on the operational **plan** and the **knowledge-of-tasks**. The **planning** behaviour specifies how the inner cordon should be set-up and what the regulations are for entering it. The operational commander then carries out **control** behaviours that direct him to carry out an **execution** behaviour of setting up the cordon. This **execution** behaviour is carried out by the operational personnel (firemen) setting up the cordon and maintaining specified safety regulations. This physical object manipulation transforms the abstract **Disaster Scene** sub-object's attribute *scene containment* from <u>un-contained</u> to <u>contained</u>, thus transforming the **Disaster** object attribute of *stability* to a more desired level along its continuum. (At the same time, other operational firemen and their fire equipment are controlling the fire and stabilising buildings, transforming the attributes of the **Property** and **Disaster Character** sub-objects, which are again transforming the **Disaster** objects *stability* attribute towards its desired level.)

The operational commander then carries out **control** behaviours that direct him to inform the tactical incident officer of the inner cordon set-up. (Some kind of internal communication behaviour is carried out to inform the incident officer about the cordon set-up.) The tactical incident officer (and his communication equipment) then carries out **perception** behaviours, which update his **knowledge-of-tasks** about the inner cordon set-up. The tactical incident officer then carries out **control** behaviours that direct him to consult his **plan** to assess the resources required for the set-up. He then carries out **planning** behaviours to specify the resources required for this task.

At the same time, the operational Ambulance Senior officer (tactical level), (with his communication equipment) is carrying out **perception** behaviours that update his **knowledge-of-tasks** with the information that there are a number of casualties at the scene. He then carries out **control** behaviours that direct him to consult his major incident **plan**. According to the plan, casualties must be triaged and then either treated at the scene and/or transported to hospital. He then carries out **control** behaviours that direct him to carry out **planning** behaviours to specify in the operational **plan** which personnel are required to triage, treat and/or transport the casualties. Based on this **plan** and the **knowledge-of-tasks,** he then carries out **control** behaviours to direct the **execution** behaviours of triaging, treating and/or transporting casualties. These execution behaviours are carried out by the Ambulance Service operational personnel for triage and treatment with their ambulances for transport. It is the manipulation of the physical casualties, which transforms the abstract **Lives** sub-object attributes *survivor triage status* from <u>untriaged</u> to <u>triaged</u>, *survivor treatment status* from <u>not treated</u> to <u>treated</u> and *survivor* *transport status* from not transported to transported. In turn these sub-object transformations, change the **Disaster** object's desired level of *stability*.

Method Stage 3

However, the Ambulance Service operational senior officer (tactical level, and his communication equipment) has not carried out **perception** behaviours that update his **knowledge-of-tasks,** that the scene is now contained, and regulation safety equipment is required to enter it. Therefore, when the Ambulance Service personnel attempt to carry out their **execution** behaviours, they do not fulfil the proper safety requirements, which would allow them to enter the inner cordon. Therefore, the **execution** behaviours of triaging, treating and/or transporting casualties cannot be carried out. Thus, they cannot transform the abstract **Lives** sub-object attributes and so cannot transform the **Disaster** object to a more desired level of stability. Thus, a behaviour conflict has been identified.

Method Stage 4

The primary objective of EMCRS is to save life. In order to try to increase the desired level of stability of the **Disaster** object, the **Lives** object attribute values must be changed. Therefore, the Fire Service must carry out rescue **execution** behaviours to move the survivors to the edge of the inner cordon, so that the Ambulance Service can carry out their **execution** behaviours and, thus, increase the stability of the disaster object. However, the Fire Service carrying out rescue **execution** behaviours will decrease the resources available for performing the **execution** behaviours of controlling the hazard, thus decreasing the effectiveness of the response to the secondary objective of preventing escalation of disaster. The outcome is that the performance of the EMCRS is reduced even further.

Method Stage 5

The Fire Service behaviours of containing the scene have conflicted with the Ambulance Service behaviours of triaging, treating and/or transporting casualties, and result in a behaviour conflict. This behaviour conflict results in a co-ordination design problem, which may relate to reduced overall EMCRS performance, either through hindered goal achievement (e.g. lives not saved) or through unacceptable system resource costs (e.g. excessive fire-fighter workload). The model diagnoses an EMCRS co-ordination design problem as actual overall performance being less than desired performance with respect to the EMCRS common objectives. This co-ordination design problem relates to the common EMCRS objectives, i.e. to save life (casualties not rescued); to prevent escalation of disaster (fire not contained). Model 1 describes a performance deficit, related to hindered goal achievement and unacceptable resource costs for the Ambulance and Fire Services. Containment of the scene with safety requirements by the Fire Service reduces casualty triage and treatment (life saving) by the Ambulance Service. The Ambulance Service having to wait to treat casualties will increase their treatment workload. The Fire Service scene entrance safety requirements excluding the Ambulance Service, reduces Fire Service fire containment, as they have to rescue casualties to the edge of the scene. The Fire Service workload will thus increase.

A design problem diagnosis by the EMCRS model has been described. To authenticate this design problem diagnosis, a potential design solution to this problem will now be suggested. The execution behaviours of the Fire Service (setting up an inner cordon and maintaining specified safety regulations) have been identified as part of the cause of the identified design problem. How these execution behaviours came about can be identified by the model. These execution behaviours were instigated by the planning and control behaviours of the Fire Service operational commander. Thus, the design problem might be related to planning or control - the data do not make this clear. However, a potential solution to this problem is the re-design of planning and control, as expressed in the EMCRS model, for the operational commanders, as supported by devices/equipment/training etc. that results in desired performance

Below are tabular representations of the domain object attribute value changes for each of the tasks involved in the behaviour conflict. The descriptions have the same format as described above for Conflict 1.

Fire Service task of set-up of inner safety cordon

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	----------> (desired)	Less unstable
Stability	Unstable	---------->(actual)	Unstable

Property sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Type *	Unknown		Buildings
Buildings condition *	Unknown		Damaged
Buildings status	At risk	---------->(desired)	Not at risk
Buildings status	At risk	---------->(actual)	At risk

Disaster Scene sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Scene containment	Uncontained	---------->	Contained

Disaster Character sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Type *	Unknown		Fire
Type *	Unknown		Hazardous materials
Fire status	Uncontrolled	---------->(desired)	Controlled
Fire status	Uncontrolled	---------->(actual)	Uncontrolled
Hazardous materials status	Uncontrolled	---------->(desired)	Controlled
Hazardous materials status	Uncontrolled	---------->(actual)	Uncontrolled

Lives sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Survivor rescue status	Not rescued	---------->	Rescued

Ambulance Service task of treating and transporting casualties

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	---------->(desired)	Less unstable
Stability	Unstable	---------->(actual)	Unstable

Lives sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Survivor condition *	Not known		Injured
Emergency services personnel safety *	Unequipped		Unequipped
Survivor triage status	Untriaged	---------->(desired)	Triaged
Survivor triage status	Untriaged	---------->(actual)	Untriaged
Survivor treatment status	Not treated	---------->(desired)	Treated
Survivor treatment status	Not treated	---------->(actual)	Not treated
Survivor transport status	Not transported	---------->(desired)	Transported
Survivor transport status	Not transported	---------->(actual)	Not transported

6.4.3 Conflict 3 - Decontamination

Method Stage 2

The Fire Service operational commander (physical structure), carries out **perception** behaviours that update his **knowledge-of-tasks** representation with the information that there are a number of aviation fuel fires and a number of structurally damaged buildings. He then carries out **control**

behaviours that direct him to consult his major incident **plan**. The **plan** specifies that the Fire Service are responsible for protecting property and containing the fire. Based on this **plan** and the **knowledge-of-tasks** (regarding the fires, structurally damaged buildings), he then carries out **control** behaviours that direct him to carry out **planning** behaviours to specify in the operational **plan**, how property should be protected and how the fire should be contained. He then carries out **control** behaviours that direct him to carry out **execution** behaviours of protecting property and containing the fire. These **execution** behaviours are carried out by the Fire Service operational personnel i.e. the firemen and their equipment. These physical object manipulations transform the abstract **Property** sub-object attribute *buildings status* from at risk to not at risk, and the **Disaster Character** sub-object attribute *fire status* from uncontrolled to controlled. The **Disaster Character** sub-object attribute transformations will in turn transform the **Disaster** object attribute *stability* to a more desired level, and the **Property** sub-object attribute transformation will transform the attribute **Disaster** object attribute *normality* to a more desired level.
At the same time, the Ambulance Service operational safety officer (physical structure), carries out **perception** behaviours that update his **knowledge-of-tasks** representation with the information that a number of casualties have been contaminated with aviation fuel. He then carries out control behaviours that direct him to consult his major incident **plan**. The **plan** specifies that the Ambulance Service need to determine priority of decontamination in conjunction with the Fire Service. Based on this **plan** and the **knowledge-of-tasks** (the contamination of casualties), the operational safety officer then carries out **control** behaviours that direct him to consult the operational **plan**. The **plan** specifies that the Ambulance Service operational personnel must liaise with the Fire Service with regards to decontamination of casualties. The **plan** also specifies that any operational personnel who handle a contaminated casualty, must be decontaminated, as must any equipment that comes into contact with contamination. Based on this **plan** and the **knowledge-of-tasks,** the operational safety officer then carries out **control** behaviours that direct him to carry out **planning** behaviours to specify how the operational personnel should deal with decontamination in conjunction with the Fire

Service. The operational safety officer then carries out **control** behaviours that direct him to carry out an **execution** behaviour of decontaminating the casualties. This **execution** behaviour is carried out by the operational Ambulance Service personnel liaising with the Fire Service for decontaminating the casualties. This physical object manipulation transforms the abstract **Lives** sub-object attribute *survivor contamination status* from contaminated to decontaminated, which will in turn increase the **Disaster** object's attribute *stability*.

Method Stage 3

However, when the Ambulance Service operational personnel attempt to carry out the **execution** behaviour of decontamination of casualties they are unable to. Although the Fire Service have decontamination equipment, in their current operational plan, decontamination of casualties is not specified. The Fire Service operational personnel are busy carrying out their **execution** behaviours, as specified in their operational plan. The Fire Service would have to reduce resources, available for containing the fire and protecting property, in order to carry out decontamination. Therefore, the Ambulance Service operational personnel cannot carry out their **execution** behaviours of decontamination of casualties and cannot therefore transform the **Lives** sub-object attribute *survivor contamination status* from contaminated to decontaminated and thus, cannot in turn transform the **Disaster** object to a more desired level of *stability*. Thus, a behaviour conflict has been identified.

Method Stage 4

Not executing decontamination of casualty behaviours has a severe knock-on effect for **Disaster** stability. This outcome arises because any emergency service personnel, handling contaminated casualties, also become contaminated, as does any emergency service equipment (for example, placing a contaminated casualty in an ambulance contaminates that ambulance). Not being able to transform the **Lives** sub-object attribute *survivor contamination status* from contaminated to decontaminated has a negative effect on other sub-object attribute values. The **Lives** sub-object attribute *emergency services personnel status* will change from uncontaminated to contaminated, and the **Emergency Services** sub-object *equipment status* attribute from uncontaminated to contaminated. These are dispositional attributes – their changes are not brought about by the work of the worksystem, but the changes need to be perceived by the worksystem as they will effect the work. Any contaminated piece of emergency service equipment, for example, an ambulance, leaving the scene will be out of action for the rest of the disaster, as will any hospital that receives a contaminated ambulance/casualty. The overall effect of non-decontamination, therefore, has an important effect on EMCRS performance with respect to **Disaster** stability.

Method Stage 5

The Fire Service behaviours of protecting property and fire containment have conflicted with the Ambulance Service behaviours of decontamination of casualties and result in a behaviour conflict. This behaviour conflict results in a co-ordination design problem, which relates to reduced overall EMCRS performance, either through hindered goal achievement (casualties not decontaminated) or through unacceptable system resource costs (e.g. emergency service equipment and personnel out of action). The model diagnoses an EMCRS co-ordination design problem as actual overall performance being less than desired performance with respect to the EMCRS common objectives. This co-ordination design problem relates to the common EMCRS objectives, i.e. to save life (contaminated casualties not transported); to prevent escalation of disaster (fire not contained, property not protected). For this design problem, the model describes a performance deficit, related to hindered goal achievement and unacceptable resource costs for the Ambulance Services. Fire containment and property protection by the Fire Service have not enabled decontamination by the Ambulance Service. Ambulance Service resource costs will increase as contaminated Ambulance Service personnel and equipment will be put out of action.

A design problem diagnosis by the EMCRS model has, thus, been described. To support this design problem diagnosis, a potential design solution to this problem will now be suggested. The execution behaviours of the Ambulance Service (decontaminating casualties in conjunction with the fire service) have been identified as part of the cause of the identified design problem. How these execution behaviours arose can be identified by the model. These execution behaviours were prompted by the planning and control behaviours of the Ambulance Service operational safety officer. Thus, the design problem might be related to planning or control - the data do not make this clear. However, a potential solution to this problem is the re-design of planning and control, as expressed in the EMCRS model, for the operational safety officers, as supported by devices/equipment/training etc. that results in desired performance. Below are tabular representations of the domain object attribute value changes for each of the tasks involved in the behaviour conflict. The format for the tables is as described above, for Conflict 1.

Fire Service task fire containment

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	----------->	Less unstable

Disaster Character object

Attribute	*Initial value*	*Transform*	*Final value*
Type(*)	Not known		Fire/hazardous material
Fire status	Uncontrolled	---------->	Controlled

Fire Service task protecting property

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Normality	Abnormal	---------->	Less abnormal

Property sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Type(*)	Not known		Buildings
Buildings status	At risk	---------->	Not at risk

Ambulance Service task of decontamination

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	---------->(desired)	Less unstable
Stability	Unstable	----------->(actual)	Unstable

Lives sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Survivor contamination status	Contaminated	-------->(desired)	Decontaminated
Survivor contamination status	Contaminated	---------->(actual)	Contaminated
Emergency services personnel status (*)	Uncontaminated		Contaminated

Emergency Services sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Equipment status (*)	Uncontaminated		Contaminated

6.4.4 Conflict 4 – Witness reporting

Method Stage 2

The Police incident officer (tactical level with communication equipment), carries out **perception** behaviours that update his **knowledge-of-tasks** with the information that youths have been seen running from the scene. He then carries out **control** behaviours that direct him to consult his major incident **plan**. The **plan** specifies that, if there is evidence of vandalism, then the site is declared a crime scene and anyone present within the scene at the time of the accident should be classed as a witness. Based on this **plan** and the **knowledge-of-tasks** (about the vandalism), the incident officer then carries out **control** behaviours that direct him to consult the operational **plan** for witness reporting. The operational **plan** specifies that all witnesses' names and addresses should be recorded through a casualty bureau. Based on this **plan** and the **knowledge-of-tasks**, the incident officer then carries out **control** behaviours that direct him to carry out **planning** behaviours, to specify in the operational **plan** that a casualty bureau should be set-up and all witnesses should be logged through it. The incident officer then carries out **control** behaviours that direct him to carry out an **execution** behaviour of logging all witnesses. (The incident officer then carries out some kind of internal communication behaviour to inform the operational officers to set up the casualty bureau.) This **execution** behaviour is carried out by casualty bureau operational personnel logging all witnesses before they leave the scene. This physical object manipulation transforms the **Lives** sub-object attribute *survivor information* from casualty bureau unlogged to casualty bureau logged. In turn, this transformation changes the **Disaster** object attribute of *normality* to a more desired value along its continuum.

At the same time, the Ambulance Service incident officer (tactical level with communication equipment), carries out **perception** behaviours, that update his **knowledge-of-tasks** with the information that there are a number of casualties at the scene. He then carries out **control** behaviours that direct him to consult his major incident **plan**. The **plan** specifies that casualties should be triaged at the scene and then be either treated at the scene or transported to hospital. Based on this **plan** and the **knowledge-of-tasks** (about the casualties), the incident officer then carries out **control** behaviours that direct him to carry out **planning** behaviours to specify in the operational **plan,** what personnel and equipment are required for treating and transporting casualties. Based on this **plan** and the **knowledge-of-tasks,** he then carries out control behaviours that direct him to carry out the **execution** behaviours of triaging casualties and either treating them at the scene or transporting them to hospital. (The incident officer then carries out some kind of internal communication behaviour to inform the operational officers to triage, and/or to treat, or to transport casualties.) These **execution** behaviours are carried out by operational Ambulance Service personnel for triage, treatment and transportation, and their equipment. It is the manipulation of the physical objects that transforms the abstract **Lives** sub-object attribute *survivor triage status* from untriaged to triaged, the attribute *survivor treatment status* from either untreated to treated and/or *survivor transport status* from not transported to transported depending on the triage results. These transformations will in turn change the attribute *stability* of the **Disaster** object to a more desired level.

Method Stage 3

However, the Ambulance Service operational personnel carry out triage execution behaviours, that prioritise treatment and need for transportation to hospital. The most serious cases, triaged as priority, will be immediately transported to hospital. These casualties will not necessarily be logged by the Police casualty bureau. Therefore, the Police Service operational personnel cannot carry out their **execution** behaviours of logging all witnesses at the casualty bureau, and thus, cannot transform the **Disaster** object attribute *normality* to a more desired level. However, delaying transportation of the most serious casualties to hospital by waiting for them to be casualty bureau logged, will delay the **execution** behaviours of transporting casualties, thus, not transforming the **Lives** sub-object attribute *survivor transport status* from not transported to transported, and therefore, not enabling transformation of the **Disaster** object attribute *stability* to a more desired level. Thus, a behaviour conflict has been identified.

Method Stage 4

Not carrying out transport **execution** behaviours has a knock-on effect, as this would not enable the treatment of the casualties at the hospital. Also, the ambulances for transportation will become unavailable, as they are tied up at the scene, thus transforming the **Emergency Services** sub-object attribute *equipment availability* from available to unavailable, further reducing the performance of the EMCRS in, again, not transforming the **Disaster** object to a more desired level of *stability*.

Method Stage 5

Therefore, triage and transportation behaviours by the Ambulance Service have conflicted with the Police Service behaviours of logging witnesses and result in a behaviour conflict. This behaviour conflict results in a co-ordination design problem, which relates to reduced overall EMCRS performance, either through hindered goal achievement (e.g. witnesses not logged), or through unacceptable system resource costs (e.g. more Police manpower required). The model diagnoses an EMCRS co-ordination design problem as actual overall performance being less than desired performance with respect to the EMCRS common objectives. This co-ordination design problem relates to the common EMCRS objectives, i.e. to save life (casualties not transported and treated); and to facilitate criminal investigation (cause of incident unidentified). For this design problem, the model describes a performance deficit, related to hindered goal achievement and unacceptable resource costs for the Police Service. Not logging the casualties for witness reporting, by the Police Service, would reduce the success of the Police Service enquiry into the cause of the disaster. Delay in transporting casualties to hospital would reduce lives saved by the Ambulance Service. The Police Service workload will increase as they will have to chase up witness information.

A design problem diagnosis by the EMCRS model has, thus, been described. To support this design problem diagnosis, a possible design solution to this problem will now be suggested. The execution behaviours of the Police Service (logging all witnesses) have been identified as part of the cause of the identified design problem. How these execution behaviours came about can be identified by the model. These execution behaviours were prompted by the planning and control behaviours of the Police Service incident officer. Thus, the design problem might be related to planning or control - the data do not make this clear. However, a potential solution to this problem is the re-design of planning and control, as expressed in the EMCRS model, for the incident officers, as supported by devices/equipment/training etc. that results in desired performance.

Below are tabular representations of the domain object attribute value changes for each of the tasks involved in the behaviour conflict. The format of these tables is as described for Conflict 1 above.

Police Service task logging all witnesses

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Normality	Abnormal	---------->(desired)	Less abnormal
Normality	Abnormal	----------->(actual)	Abnormal

Disaster Character sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Cause (*)	Non-accidental		Non-accidental

Lives sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Survivor information	Casualty bureau unlogged	---------->(desired)	Casualty bureau logged
Survivor information	Casualty bureau unlogged	----------->(actual)	Casualty bureau unlogged

Ambulance Service task of triaging and treating/transporting casualties

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	---------->actual	Less unstable

Lives sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Survivor condition (*)	Injured		Injured
Survivor triage status	Untriaged	----------->	Triaged
Survivor treatment status	Not treated	----------->	Treated
Survivor transport status	Not transported	----------->	Transported

6.4.5 Conflict 5 – Access of Fire appliances

Method Stage 2

The Police Service incident officer (tactical level with communication equipment) carries out **perception** behaviours that update his **knowledge-of-tasks** with the information that there has been a train crash on a bridge over a road, which is the main thoroughfare for the town. He then carries out **control** behaviours, that direct him to consult his major incident **plan**. The **plan** specifies that the Police Service are responsible for managing the site of disaster including locating access points for all the emergency services. Based on this **plan** and his **knowledge-of-tasks** (about the disaster site location), he then carries out **control** behaviours that direct him to carry out **planning** behaviours to specify in the operational **plan,** where the access points for the emergency services should be positioned. Based on this **plan,** he then carries out **control** behaviours that direct him to carry out an **execution** behaviour of setting up the access points. (He then carries out some type of internal communication behaviour to inform the operational personnel to set-up the access points). This **execution** behaviour is carried out by the Police Service operational personnel, setting up the access points. This physical object manipulation transforms the **Disaster Scene** sub-object attribute *access point position* from <u>unlocated</u> to <u>located</u>. This outcome in turn will transform the **Disaster** object attribute *stability* to a more desired level.

At the same time, the Fire Service incident officer (tactical level with communication equipment), carries out **perception** behaviours that update his **knowledge-of-tasks** with the information that there are aviation fuel fires, structurally damaged buildings and trapped people at the site of the disaster. He then carries out **control** behaviours that direct him to consult his major incident **plan**. The **plan** states that the Fire Service are responsible for containing the fire, protecting property and rescuing trapped casualties. Based on this **plan** and the **knowledge-of-tasks** (about the situation), the Fire Service incident officer then carries out **control** behaviours, that direct him to carry out **planning** behaviours to specify in the operational **plan** what Fire Service equipment is required for the Fire Service response. Based on this **plan** and the **knowledge-of-tasks,** he then carries out **control** behaviours that direct him to carry out

execution behaviours of making available the required equipment. (The incident officer will carry out some kind of internal communication behaviour to inform the operational personnel about making the equipment available). This physical object manipulation transforms the **Emergency Service** sub-object attribute *equipment availability* from unavailable to available. The Fire Service incident officer then carries out **perception** behaviours that update his **knowledge-of-tasks** with the information that the appliances are available. He then carries out **control** behaviours, that direct him to carry out **perception** behaviours to update his **knowledge-of-tasks** with the information of whether the access points have been located for the available appliances. He then carries out **control** behaviour that directs him to carry out **planning** behaviour to specify in the operational **plan** of how the appliances can locate the access points. Based on this **plan** and this **knowledge-of-tasks** (about the location of access points), he then carries out **control** behaviours that direct him to carry out an **execution** behaviour of moving the fire appliances to the access points in readiness for fighting the fire, protecting property, and rescuing the trapped casualties. (The incident officer will carry out some kind of internal communication behaviour to inform the operational personnel to move the fire appliances to the access points). This execution behaviour is carried out by the operational Fire Service personnel, moving the fire appliances to the access points. Manipulation of the physical fire appliances will transform the **Emergency Services** sub-object attribute *equipment condition* from non-utilizable to utilizable.

Method Stage 3

However, when the Fire Service operational personnel attempt to carry out their execution behaviours of making the equipment ready for fire containment, rescue and property protection execution behaviours, they find that the access points for their appliances are unsuitable and therefore, they cannot transform the **Emergency Service** sub-object attribute *equipment condition* from non-utilizable to utilizable, and in turn they cannot transform the **Disaster** object to a more desired level of *stability*. Thus, a behaviour conflict is identified.

Method Stage 4

As a knock-on effect the Fire Service cannot manipulate the physical casualties or fight the fires and therefore, cannot transform the abstract Disaster Character sub-object attribute *fire status* from uncontrolled to controlled; or the Property sub-object attribute *building status* from at risk to not at risk, or the Lives sub-object attribute *survivor rescue status* from not rescued to rescued. In turn, they cannot transform the Disaster object to a more desired level of *stability* and *normality*.

Method Stage 5

The Police Service behaviours of locating the access point, have conflicted with the Fire Service behaviours of making the fire appliances utilisable for rescue, property protection and fire containment and so result in a behaviour conflict. This behaviour conflict results in a co-ordination design problem, which relates to reduced overall EMCRS performance, either through hindering goal achievement (e.g. lives not saved) by the Fire Service, or through unacceptable resource costs (excessive fire-fighter workload) for the Fire Service. The model diagnoses an EMCRS co-ordination design problem as actual overall performance being less than desired performance with respect to the EMCRS common objectives. This co-ordination design problem relates to the common EMCRS objectives, i.e. to save life (survivors not rescued); to prevent escalation of the disaster (fire not contained); to protect property (property not protected); and to prevent escalation of the disaster (appliances not usable due to unsuitable access points). For this design problem, the model describes a performance deficit, related to hindered goal achievement and unacceptable resource costs for the Police Service. The Police Service having unsuitable access points for appliances will reduce the Fire Services' behaviours of rescue, property protection and fire containment, increasing resource costs to the Fire Service to an unacceptable level.

This ineffective performance relates to the common EMCRS objectives, i.e. a design problem diagnosis by the EMCRS model has been described. To support this design problem diagnosis, a possible design solution to this problem will now be suggested. The execution behaviours of the Police

Service (locating access points) have been identified as part of the cause of the identified design problem. How these execution behaviours came about can be identified by the model. These execution behaviours were instigated by the planning and control behaviours of the Police Service incident officer. Thus, the design problem might be related to planning or control - the data do not make this clear. However, a potential solution to this problem is the re-design of planning and control, as expressed in the EMCRS model, for the incident officers, as supported by devices/equipment/training etc. that result in desired performance.

Below are tabular representations of the domain object attribute value changes for each of the tasks involved in the behaviour conflict. The format of the descriptions is as given for Conflict 1 above.

Police Service task setting up access points

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	----------->	Less unstable

Disaster Scene sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Location (*)	Market town		Market town
Scene/site accessibility (*)	Difficult		Difficult
Access point position	Unlocated	----------->	Located

Fire Service task fire containment

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	---------->(desired)	Less unstable
Stability	Unstable	----------->(actual)	Unstable

Emergency Services sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Equipment availability	Unavailable	----------->	Available
Equipment condition	Non-utilizable	----------->(desired)	Non-utilizable
Equipment condition	Non-utilizable	----------->(actual)	Utilizable

Disaster Scene sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Access point position	Unknown		Located
Access point suitability (*)	Not known		Unsuitable

Disaster Character sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Type(*)	Not known		Fire/hazardous material
Fire status	Uncontrolled	---------->(desired)	Controlled
Fire status	Uncontrolled	----------->(actual)	Uncontrolled

Fire Service task protecting property

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Normality	Abnormal	---------->(desired)	Less abnormal
Normality	Abnormal	----------->(actual)	Abnormal

Emergency Services sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Equipment availability	Unavailable	----------->	Available
Equipment condition	Non-utilizable	----------->(desired)	Non-utilizable
Equipment condition	Non-utilizable	----------->(actual)	Utilizable

Property sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Type(*)	Not known		Buildings
Buildings status	At risk	---------->(desired)	Not at risk
Buildings status	At risk	----------->(actual)	At risk

Fire Service task of rescuing casualties

Disaster object

Attribute	*Initial value*	*Transform*	*Final value*
Stability	Unstable	---------->(desired)	Less unstable
Stability	Unstable	----------->(actual)	Unstable

Emergency Services sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Equipment availability	Unavailable	----------->	Available
Equipment condition	Non-utilizable	----------->(desired)	Non-utilizable
Equipment condition	Non-utilizable	----------->(actual)	Utilizable

Lives sub-object

Attribute	*Initial value*	*Transform*	*Final value*
Survivor rescue status	Not rescued	---------->(desired)	Rescued
Survivor rescue status	Not rescued	----------->(actual)	Not rescued

6.5 Performance expression

Each of the behaviour conflicts identified has now been described by the model, so diagnosing potential co-ordination design problems. However, defining effective performance of the EMCRS has proved complex, due to trade-offs between the individual agencies' performances. The model describes the actual overall combined agency performance with respect to EMCRS common objectives, and their priorities. This expression of performance does not take into account the individual agencies' priorities for these objectives, as specified in their own individual plans. For example, from Behaviour Conflict 1, the Police Service wish to preserve the disaster site as a 'crime scene' (vandalism is suspected), and to catch the criminals, and so require the Fire Service not to trample the site. The Fire Service, will slow the rescue of casualties, and make them less effective in fire prevention, if they do not trample the site. Model 1 describes the 'actual' overall combined agency performance with respect to EMCRS common objectives. The co-ordination problems identified, thus, do not take account of the performance trade-offs between agencies. For this behaviour conflict Model 1 describes an overall EMCRS performance deficit which derives from the Police and Fire Services. Trampling by the Fire Service reduces the chances of the vandals being caught. Carrying out minimal trampling reduces rescue of casualties and control of the fire. These overall deficits derive from the common objectives, i.e. to save life (casualties not rescued); prevent escalation of disaster; (fire not controlled); and facilitate criminal investigation (vandals not caught).

However, each agency has its own disaster plan. These plans describe agency functions/tasks and their priorities. To accurately express overall

EMCRS performance, account must be taken of these plans. For example, the Fire Service plan states: 'Investigation work will not take precedence over the necessity to rescue casualties, fight fires, or the protection of lives and property from fire or further deterioration. Every effort must be made by the Fire and Rescue Commander to preserve the scene intact.' (Chief and Assistant Chief Fire Officers' Association, 1994). Thus, the Fire Service should keep their trampling to a minimum, to preserve other Fire Service behaviours. Thus, for this co-ordination problem, there is no Fire Service performance deficit, as the actual performance effected by minimal trampling, is equal to the planned performance, which allows effects of minimal trampling. Thus, although there is still a Police Service performance deficit (minimal trampling still reduces vandal apprehension), the overall EMCRS performance deficit is less than was identified by Model 1 – the Combined Agency Model.

There is a need, therefore, to decompose the EMCRS into its parts and for each agency to be modelled individually with respect to its plans. These single agency (SA) models describe planned individual agency performance with respect to the combined agency actual performance, that is, overall EMCRS actual performance. Model 1 can then be re-interpreted with the help of the SA models, to diagnose more effectively overall EMCRS performance, as concerns planning and control co-ordination problems. These single agency models will be presented in Chapter 7.

6.5 Chapter Summary

This chapter has presented Model 1 the combined model from both datasets, and used it to diagnose EMCRS coordination design problems, by means of behaviour conflict identification. A diagnosis method for identifying co-ordination design problems has been presented and its application demonstrated. Five EMCRS co-ordination design problems have been diagnosed. However, accurately expressing performance of these co-ordination design problems has been identified as a problem. Single Agency (SA) models have been proposed as a solution to this problem. These models will be presented in Chapter 7, along with solutions to the other issues identified, in Section 6.1 above, with regards to the model representation.

Chapter 7
Model Issues

Introduction

Chapter 6 presented EMCRS Model 1, the model derived from combining Dataset 1 and Dataset 2. All the conflicts, within the data, were identified with the method for diagnosis, as EMCRS co-ordination design problems. However, there are issues with the model, both with respect to its representation and with respect to the model expression of EMCRS performance. The representation issues have been briefly outlined in Chapters 2, 4, 5 and 6. The performance expression issue was outlined in Chapter 6. This chapter will now address each of these issues in turn and offer solutions. These solutions are to be implemented in EMCRS Model 2, which is presented in Chapter 8. The issues are how to represent: (i) a changing worksystem; (ii) a system with more than one level of operation, and with interactions between the levels; and (iii) system performance with trade-offs between different parts of the system. These issues are considered common to modelling such complex systems. Each of these issues will be discussed and solutions offered. In Chapter 9, these issues will be generalised.

7.1 Issue 1: how to represent a changing worksystem

The first issue relates to the model representation. The configuration of the EMCRS changes over time. At the beginning of the disaster, there were fewer emergency personnel and devices/equipment, than after the major incident was declared, when many more personnel and devices/equipment were required. Also as time moves on, the EMCRS will continue to change in response to the domain, for example, a trapped person may require specialist equipment to rescue them, which will need to be brought to the scene. The models shown in earlier chapters fail to represent this changing worksystem. One solution to this issue is to represent the changing worksystem by using a time-line and '+' for the additional structures. Thus, 'snapshots' of the worksystem structures could be taken within specified time periods, which relate to specific tasks being carried out. This representation would be an extension to the HCI-PCMT framework representation to accommodate a changing worksystem. The time-sliced periods need to be specified carefully with respect to the domain, so the actual worksystem structures, required for particular tasks, are represented. For example, when the Fire Service set up the inner cordon, with safety requirements for entry, Fire Service personnel are required to be in charge of the cordon, so that no emergency personnel can enter the cordon without regulation safety equipment. Model 2 will be shown in Chapter 8, which will include the time-line, and '+' for additional structures as a solution to this issue. The behaviours of the worksystem are supported by the worksystem structures. Representation of worksystem structures over time will, therefore, enable specification of worksystem behaviours over time.

7.2 Issue 2: how to represent a system with more than one level of operation and interactions between the levels

The second issue, like the first, relates to the model representation. The EMCRS comprises multiple agents within a complex three-tier command structure. The HCI-PCMT framework has so far only modelled domains with a single level of operation. Thus, interactions between the different horizontal and vertical layers of the system are not presumed by the present framework. Thus, HCI-PCMT needed to be further developed to accommodate these additional interactions. To represent the interactions between the levels of this system, the different structures of the levels also need to be taken into account. That is, for example, the tactical level does not carry out execution behaviours directly, execution behaviours being carried out by the operational level. The tactical level only 'perceives' by means of the operational level. The tactical level is not in direct contact with the disaster, the operational level perceives information and passes it to the tactical level. Thus, the structures of the tactical level would not require an executing process as such. They would, however, require some form of output communication to the operational level to guide execution and some form of input communication, in order to perceive information from the operational level. These input and output communication structures would also be required for interaction between the horizontal levels of the worksystem, to allow for communication between the different agencies. These input and output communications and the differing structures for each command level will be shown in Model 2 in Chapter 8. This representation is an extension to the HCI-PCMT framework to accommodate systems with more than one level of operation and interactions between the levels.

7.3 Issue 3: accuracy of EMCRS performance expression

The third issue concerns the accuracy of specifying EMCRS performance. Conflict behaviours have been described by means of EMCRS Model 1 as co-ordination design problems. However, understanding what effect these co-ordination design problems have on overall EMCRS performance is complex, because there are trade-offs between different parts of the system. EMCRS Model 1 describes the actual overall combined agency (CA) performance with respect to EMCRS common objectives, and their priorities. This expression of performance does not take into account the individual agencies' priorities for these objectives, as specified in their own individual plans. For example, it may be more important for the Fire Service to put out fires than to rescue people, and the resource costs for their behaviours are acceptable. In the EMCRS model description of Behaviour Conflict 2 (inner cordon restrictions see Section 6.4.2), the Fire Service stop fighting fires to rescue casualties, increasing their workload, which can be interpreted as ineffective performance, as not fighting fires will not enable the domain sub object attribute value changes (**Disaster Character** sub-object attribute *fire status* from <u>uncontrolled</u> to <u>controlled</u>), and so will not enable the transformation of the **Disaster** object attribute *stability* to a more desired level. However, this performance may not be ineffective. Each agency has its own responsibilities with weightings for each task, some of which are specified in their plans. It may be that the Fire Service interpret rescue behaviours as primary within this situation, as the Fire Service objective of saving life needs to be maintained, as well as ensuring that none of the Ambulance Service are injured, by excluding them from the scene, and that resource costs for these behaviours are acceptable. As a result, the level of stability of the **Disaster** object is not decreased with respect to loss of life. In this case, then, some conflict or interaction of behaviours may not lead to ineffective performance. Some expression of individual agency desired performance is required, to moderate, and so to express more accurately, EMCRS performance. There is a need, therefore, to model each agency individually with respect to its own plans. These Single Agency models would describe individual agency performance with respect to overall EMCRS actual performance. EMCRS Model 1 could then be re-interpreted with the help of the single agency models, to diagnose more accurately overall EMCRS performance. Development of Single Agency models will become part of the EMCRS model diagnoses of co-ordination design problems. Therefore, additions need to be made to the method for co-ordination design problem diagnosis presented in Chapter 6. These additions will be Stages 6 and 7 of the method. Stage 6 is presented in Table 1 below, as it is applied in this chapter, and as it relates to Single Agency model development. Stage 7 relates to re-expressing EMCRS combined agency performance with respect to the Single Agency models. This stage is applied and presented in Chapter 8.

Method stages	Action	Example for clarification
6	Produce Single Agency models, which describe the planned performance for each agency with respect to the identified co-ordination problems. These models are text-based and use the individual agencies' contingency plans for response to major incidents as the reference for planned behaviours.	Extracts from the Ambulance service model: The Ambulance safety officer liaises closely with safety officers of the other agencies, particularly the Fire safety officer The Ambulance safety officer assumes responsibility for: Ensuring that the correct level of protective clothing is worn. Extracts from the Fire Service model: Non-fire service personnel entering the Fire Service cordon must be made aware of, and conform to, Fire Service safety procedures Second only to the prevention of further catastrophe, priority should be given to the treatment and recovery of casualties from the site

Table 1 Method for Co-ordination Design Problem Diagnosis Stage 6

The Single Agency models for each agency are now presented. The models were developed using method Stage 6 above. These models are not a model representation as such, but are more descriptive models. They are models, in as much as they represent the planned individual agency behaviours in a structured way with respect to the identified behaviour conflicts. These structured model descriptions were suitable for the current purposes of identifying planned performance for individual agencies. They describe only those behaviours, associated with the behaviour conflicts/co-ordination design, problems identified by EMCRS Model 1. They describe the behaviours of each agency with respect to their planned performance. The plans used were the generic emergency procedures manuals, produced by the individual agencies, as a guide for each local authority to specify their own more detailed and local, plans. These plans were used, and not the more detailed plans of each local authority for the following reasons. First, the data used for the model were gathered at an emergency management training scenario, where the trainees were representatives from the UK. Therefore, no specific local authority plan was used in response to the training scenario (an individual officer may have knowledge of their local plan, but this knowledge was not specifically taken into account). Also, during the exercise, the trainees only had access to the generic plans. Second, according to information provided by the Home Office Emergency Planning Department, local authority plans differ importantly with respect to their usefulness – some local authorities are much better at local planning than others. Therefore, to have used a specific local authority plan could have biased the Single Agency models with respect to either 'good or bad planning'. Third, the data gathered are analysed with respect to the roles/tasks that each agency needs to carry out in response to a disaster. Thus, the data have not been analysed at a lower level of description, for example, how the Fire Service should access fire hydrants for controlling the fire. This lower level of description was absent from the data. The local authority plans for individual agencies would contain information at this lower level of description, but which could not be accessed or used here.

The plans used were: for the Police Service, the Emergency Procedures Manual (Association of Chief Police Officers (ACPO), 1997); for the Fire

Service, the Fire Service Major Incident Emergency Procedures Manual (Chief and Assistant Chief Fire Officers Association (CACFOA), 1994); and for the Ambulance Service, Ambulance Service Operational Arrangements for Civil Emergencies (The National Health Service Ambulance Service, 1994).

The following sections present the Single Agency models for the Police, Fire and Ambulance Services. In Chapter 8, these Single Agency models will be cross-referenced to the EMCRS combined agency Models 1 and 2, to express more accurately EMCRS performance.

7.4 Single Agency Models

7.4.1 Police Service Single Agency Model

Three different behaviour conflicts have been identified by the training scenario data, which involve the Police Service, and which have then been diagnosed by the model as co-ordination design problems. The Single Agency model describes only those behaviours, associated with the behaviour conflicts with other agencies. In this section, each of the behaviour conflicts, in which the Police Service is implicated, is first reiterated for clarification. Then, information regarding each of these conflicts, taken from the Police Service plans, will be presented. Last, the planned performance for the Police Service for each conflict is presented.

Police Service conflict with other agencies

Police and Fire Services
The Police Service are trying to preserve the scene - the Fire Service are containing the hazard, rescuing casualties and trampling the area.
The Fire Service need good access for their appliances - the Police Service decide where access should be, which is not necessarily where the Fire Service want it.

Police and Ambulance Services
The Police Service need to be able to talk to the witnesses. The witnesses may be casualties, and as such may be taken away to hospital. The Police Service set up a casualty bureau, through which all casualties should be

cleared, before being transported anywhere. It is important that the Ambulance Service make sure the Police Service receive the information about the casualties that need hospital treatment, for possible interview later.

Extracts from the general Police Service plan:

(All extracts are in italics.)

Behaviour Conflict 1: Trampling/scene preservation

- *Police (P) P. 1.1) Section 1 5.4 When it becomes apparent that no further life can be saved, other considerations take precedence: preservation of the scene; protection of property; investigation.*

- *P. 1.2) Section 2.1.2 Inner cordon - to provide immediate security of the incident site (which must be treated as a 'scene of crime' and preserved as such).*

- *P. 1.3) Section 7.1.3. The disaster scene must always be treated as a 'scene of crime' and its protection is vital to preserve evidence. This treatment must not, however, take precedence over the rescue of survivors and consequently some initial disturbance will always take place.*

- *P. 1.4) Section 7.2.1 Once the rescue and victim recovery phases of the operation are complete, an extensive search of the scene must be undertaken to recover items for evidential or identification purposes and to identify and position wreckage etc.*

Police planned performance

The planned performance for the Police Service is to attempt to preserve the scene, but not to let scene preservation behaviours take precedence over life saving behaviours.

Behaviour Conflict 4: Witness reporting

- *P. 4.1) Section 3.3.1 Once rescued the removal of the injured to designated hospitals requires close liaison with the Ambulance Service and the Medical Officer in charge at the scene.*

- *P. 4.2) Section 3.3.3 To co-ordinate removal of the injured, the Ambulance Service, after consultation with the other emergency services as to location, routing and signing, will set up: a casualty clearing station; ambulance loading points; ambulance parking point; and ambulance control point.*
- *P. 4.3) Section 3.3.5 Police will liaise with the medical and ambulance incident officers to maintain a count of all persons processed through the casualty clearing station with details of the hospitals to which they have been taken.*
- *P. 4.4) Section 5.3.5.1 Casualty information*

  This information is forwarded to the Bureau from hospitals and, where the individual may have a minor injury not requiring hospitalisation, from the scene and survivor/evacuee reception centres, by police documentation teams. The information may be passed by telephone, fax, computer link etc., or by completed records, being delivered to the bureau. Good practice is for a Casualty Bureau operator to be dedicated to liaise with a particular hospital or reception centre.

Individual officers responsibilities (Appendix D)

- *P. 4.5) Casualty receiving station officer*

i) Responsible to the Incident Officer

ii) Liaise with the medical or ambulance officer in charge and request resources as required.

iii) Liaise with the ambulance officer and log numbers of casualties processed and to which hospitals they have been sent.

- *P. 4.6) Incident control post co-coordinator*

i) Establish and maintain close liaison with other on-site emergency and support services. Monitor the response of those other services, anticipating the needs of the Police Incident Officer.

- *P. 4.7) Ambulance Loading point officer*

i) Liaise with ambulance staff.

ii) Ensure unrestricted access and egress for ambulances.

Police planned performance

The planned performance for the Police Service is to attempt to log details of all casualties in the casualty bureau but not to delay casualties and to obtain the information at the hospitals as required.

Behaviour Conflict 5: Access of fire appliances

- *P. 5.1) Section 1.6.7 Incident control post responsible for controlling access to the scene, ensuring that only authorised personnel and vehicles are present and, where appropriate, have been logged in.*
- *P. 5.2) Section 2.6 Traffic Control*

i) Immediate action must be taken to ensure free passage of emergency traffic to and from the site and to prevent congestion at the scene and in the surrounding area.

ii) Wherever possible a 'one way' system, with defined access and exit routes for essential services, should be implemented to ensure the rapid attendance of emergency vehicles at the scene and to facilitate the unimpeded removal of casualties to hospital. If there is only one access route, 'turning areas' must be identified and supervised to avoid congestion.

Individual officers responsibilities (Appendix D)

- *P. 5.3) First officer at the scene*

i) Access - best routes for emergency vehicles, parking, turning points, routes blocked, and suitable rendezvous points

- *P. 5.4) Police incident officer*

i) Ensure that action has been taken to organise: priority traffic routes for essential services; and parking for essential service vehicles.

- *P. 5.5) Incident control post co-coordinator*

i) Control Access to the scene and issue passes.

- *P. 5.6) Traffic manager*

i) Ensure that the following have been designated, if required, and inform all relevant services of: rendezvous points; marshalling areas; access and exit routes for essential services; emergency routes to hospitals; diversions for non-essential traffic; and turning areas.

Police planned performance

The planned performance for the Police Service is to set-up the access points, if possible in sites, where emergency vehicles can have rapid attendance at the scene, and control these access points.

7.4.2 Fire Service Single Agency Model

The Single Agency model for the Fire Service describes its behaviours with respect to its planned performance. The model describes only those behaviours, associated with the identified behaviour conflicts with other agencies. Four behaviour conflicts have been identified from the training scenario, involving the Fire Service. Each of these behaviour conflicts will be described here, as for the Police Service. Then, extracts from the Fire Service plan relating to these conflicts is provided. Last, the planned performance for the Fire Service for each conflict is presented.

Fire Service conflicts with other agencies

Police and Fire Services
The Police Service are trying to preserve the scene - the Fire Service are containing the hazard, rescuing casualties and trampling the area. The Fire Service know that the scene needs to be preserved, but during their containment of the hazards and rescue behaviours, they know that they will trample the site, which will not help the Police Service in evidence gathering.

The Fire Service need access for their appliances. The Police Service decide where the access points will be, taking into account access and egress for all the agencies (these access points may not be as desired for the Fire Service).

Fire and Ambulance Services
The Fire Service set up an inner cordon and are responsible for safety of all personnel within the cordon - the Ambulance Service do not have regulation safety equipment and are not allowed access to the casualties. The Fire Service have decontamination equipment. Therefore, it is their responsibility to decontaminate any casualties, emergency service personnel and ambulances, before they leave the scene. However, the Fire Service do not necessarily see decontamination as their responsibility, as they are busy containing the incident. The Ambulance Service require all contaminated personnel, casualties and ambulances to be decontaminated at the site, before the casualties can be transported.

Extracts from the Fire Service plan

Behaviour Conflict 1: Trampling/scene preservation

- *Fire (F) F. 1.1) Section 6.6.1.2 The scene will be treated as a 'scene of crime', until it is found to be otherwise by the Police. The protection of the scene and the preservation of evidence are therefore vital.*

- F. 1.2) *Section 6.6.1.5 Investigation work will not take precedence over the necessity to rescue casualties, fight fires, or the protection of lives and property from fire or further deterioration. Every effort must be made by the Fire and Rescue Commander to preserve the scene intact. In the case of known, or suspected terrorist action, the necessity to fight fires and rescue casualties, etc. must be considered in liaison with the Police Incident Officer, having particular regard for the safety of personnel and the need to preserve evidence.*

Fire Service planned performance

The planned performance is to try to keep trampling to a minimum, but not to allow non-trampling behaviours to take precedence over fire fighting or rescue of casualties.

Behaviour Conflict 5: Access of Fire appliances

- *F. 5.1) Section 3.3.7 Rendezvous points*
  Initially, all fire appliances will be directed to the immediate scene of the incident. However, as soon as practical, rendezvous points should be established to assist in controlling the responding assistance. The identification and management of a rendezvous point is a police responsibility with a single site being the preferred option. Its location should be determined by consultation between the emergency services.

- *F. 5.2) Section 3.3.8 Marshalling Area*
  At many incidents, a marshalling area will be established, in liaison with the Police, to which resources arriving will be directed, pending their deployment.
- *F. 5.3) Section 4.4.5 Outside the inner cordon, the Police will be co-ordinating operations, particularly to control access to the incident site.*

Fire Service planned performance

The planned performance for the Fire Service is first to direct their appliances to the immediate scene, and then to rendezvous points set-up by the Police Service. These rendezvous points are not access points. The Police Service have control over access.

Behaviour Conflict 3: Decontamination

No mention of decontamination in the general Fire Service plan.

Fire Service planned performance

There is no planned performance for the Fire Service for decontamination.

Behaviour Conflict 2: Cordon restrictions

- *F. 2.1) Section 4.4.4 If there is a fire, the possibility of fire, a chemical or explosive hazard, or a situation exists, where access to the immediate scene is likely to lead to an escalation of the incident, the Police, in liaison with the Fire Service, will provide an inner cordon around the incident to enable the Fire Service to exercise control of fire fighting and rescue operations.*
- *F. 2.2) Section 4.4.5 The Fire Service have responsibility for the safety of all persons working within the inner cordon, and will liaise with the Police regarding, who should be allowed access.*
- *F. 2.3) Section 4.4.6 In exceptional circumstances, the Police inner cordon may be unsuitable for the control of Fire Service operations. This unsuitability may be due to it being too extensive an area, or for the need for other agencies to work within it, independently of the Fire Service. If this is the case, the Fire and Rescue Commander may establish a Fire Service cordon, to control those areas, where Fire Service personnel are working to restrict access to them. This action should be progressed in consultation with the Police and Ambulance Incident Officers.*
- *F. 2.4) Section 4.4.7 Non-Fire Service personnel entering the Fire Service cordon must be made aware of, and conform to, Fire Service safety procedures.*
- *F. 2.5) Section 4.4.13 Second only to the prevention of further catastrophe (e.g. gas or other explosion), priority should be given to the treatment and recovery of casualties from the site.*

- *F. 2.6) Section 4.5.3 Incident Control Post - maintaining close liaison with other emergency services and support services.*
- *F. 2.7) Section 8.5.1 It is essential that all personnel working within the inner cordon (or Fire Service cordon) are suitably protected against the hazards that may be encountered at a major incident.*

It should be noted that during Exercise Scorpio no distinction is made between the inner cordon and the Fire Service cordon, i.e. they are both referred to as inner cordons. It is the Fire Service 'inner' cordon, to which the Ambulance Service are not allowed access without the regulation protective clothing. There is an outer cordon at the road junction, and an inner cordon at the canal 600m from the site, and another inner cordon 100m, around the site under fire service control.

Fire Service planned performance
The planned performance is to set-up the cordon in consultation with the Ambulance Service, and, if necessary, recover casualties.

7.4.3 Ambulance Service Single Agency Model

The Single Agency model for the Ambulance Service describes the behaviours of this agency with respect to its planned performance. The Single Agency model describes only those behaviours, associated with the identified behaviour conflicts with other agencies. Three different behaviour conflicts have been identified from the training scenario, which cause co-ordination problems, for the Ambulance Service. Each of these behaviour conflicts will be described here, as for the other Single Agency models for clarification. Then extracts from the Ambulance Service plan, relating to these conflicts will be cited. Last, the planned performance for the Ambulance Service for each conflict is presented.

Ambulance conflicts with other services
Fire and Ambulance Services
The Fire Service set up an inner cordon and are responsible for safety of all personnel within the cordon - the Ambulance Service do not have regulation safety equipment and are not allowed access to the casualties. The Ambulance Service require sensible restrictions (laid down by the Fire

Service) in the inner cordon, so that their personnel can have access to casualties.

Any ambulance, Ambulance Service personnel or casualties, which have come into contact with a hazardous substance, will need to be decontaminated, before leaving the scene. If not, then an ambulance can be out of operation for the whole of the incident, and if a contaminated ambulance arrives at a hospital, then that hospital will be out of action for the whole of the incident too. Decontamination should be carried out by the Fire Service, as they have the equipment, but the Fire Service do not like taking responsibility for decontamination, as they have other priorities, such as, preventing escalation of the incident.

Police and Ambulance Services

The Police Service need to be able to talk to the witnesses. The witnesses may be casualties, and as such may be taken away to hospital. The Police Service set up a casualty bureau, through which all casualties should be cleared, before they are transported anywhere. It is important that the Ambulance Service make sure that the police receive the information about the casualties, that need hospital treatment, for possible later interview.

Extracts from the Ambulance Service Plan:

Behaviour Conflict 2: Cordon restrictions

- *Ambulance (A) A. 2.1) Section 8 The primary areas of Ambulance responsibility are:*

i) The saving of life, in conjunction with the other emergency services.

ii) The treatment and care of those injured at the scene, either directly or in conjunction with medical personnel.

Individual officers responsibilities

- *A. 2.2) The Ambulance safety officer*

i) Role 3 assumes responsibility for ensuring that the correct level of protective clothing is worn.

ii) Role 4 liaises closely with safety officers of the other agencies, particularly the Fire safety officer

- *A. 2.3) The Ambulance incident officer decides, whether additional Ambulance Service equipment is required*

- *A. 2.4) Forward incident officer maintains a high profile liaison with the other agencies on site.*

Ambulance Service planned performance

The planned performance for the Ambulance Service is to liaise with the other agencies, specifically with the Fire Service in this instance, so that the regulation safety equipment required is known and acted upon. Planned performance would ensure that the Ambulance Service officers arrive at the inner cordon set-up with the required level of safety equipment. Then, the officers can enter the cordon to treat the injured.

Behaviour Conflict 3: Decontamination

Individual officers' responsibilities

- *A. 3.1) The Ambulance safety officer*

Role 6 seeks appropriate advice for the Ambulance Incident Officer and/or Forward Incident officer of the correct treatment and procedures in cases of contamination of casualties, personnel, and vehicles/equipment.

Ambulance Service planned performance

The planned performance is to find out treatment and procedures for contaminated personnel, casualties and equipment, but the plan does not specify where the appropriate advice should come from, or who should act on the advice, once it is obtained.

Behaviour Conflict 4: Witness reporting

- *A. 4.1) Section Casualty documentation: 1 Ambulances should not be delayed at the scene in order to obtain personal details of individual casualties, which will be obtained by the police at the receiving hospitals.*

Ambulance Service planned performance

The planned performance for the Ambulance Service is to send the casualties to hospital as required, not worrying about recording details.

All the Single Agency models have now been presented. These models will be cross referenced with the EMCRS combined agency Models 1 and 2 in the following chapter.

7.5 Chapter Summary

This chapter has described all the issues identified during the development of Model 1. Each issue has been described in turn and solutions have been proposed. These will be implemented in EMCRS Model 2 presented in the following chapter. A solution to one issue, to enable accurate performance expression through the EMCRS models, is Single Agency models. These Single Agency models have been presented above. In Chapter 8, the Single Agency models will be used to re-describe the performance effects of the identified co-ordination design problems. Cross referencing between the Single Agency and Combined Agency Models will produce more accurate performance expressions, presented in Chapter 8.

Chapter 8
EMCRS Model 2

Introduction

This chapter presents EMCRS Model 2, in Section 1. EMCRS Model 2 is the combined agency model for the same data, used for EMCRS Model 1, but with all the issues, identified in Chapter 7, addressed. That is, EMCRS Model 2 has representations for: a changing worksystem, and a system where there is more than one level of control, and interactions between the levels. The other issue discussed in Chapter 7 was that of accurately expressing performance with EMCRS Combined Agency (CA) Models. Single Agency models for each of the emergency services were presented in Chapter 7, as a means of identifying more clearly individual agency performance with respect to their own contingency plans. The performance effects of the co-ordination design problems, identified by the CA Models (EMCRS Models 1 and 2), can now be re-expressed, taking into account Single Agency performance, as described by the Single Agency models. These performance expressions are presented in Section 2. For each of the co-ordination design problems, the following performance expressions will be given: the actual performance as expressed by the CA models; the planned performance as expressed by the Single Agency Models, and the re-expressed performance, identified by relating the differing model expressions.

8.1 EMCRS Model 2

Figure 1 presents EMCRS Model 2. It shows all the abstract and physical structures of the worksystem on the left side of the diagram. The abstract structures representation is the same as that shown in Chapter 2, Figure 1, and as used for the previous EMCRS models (see Chapters 4, 5 and 6). That is, an oval depicts a process structure, a rectangle depicts a representation structure, a read arrow depicts a process reads from the contents of a representation, and a write arrow depicts a process writes to the contents of a representation. The links between the abstract sub-objects and the physical objects, shown with a dotted line, define the abstract to physical realisation relationship. The relationship has a many-to-one mapping, as described in the method for model construction Phase 3 (Chapter 4, Section 4.3). On the right side, the model shows the EMCRS domain. The abstract domain objects, their attributes and values are the same as for EMCRS Model 1. The physical domain is represented over time corresponding to the EMCRS physical worksystem. Due to difficulties with representing the whole model in one diagram, some of the wording may be difficult to read. Therefore, each part of the model is presented in turn with its representation to aid understanding.

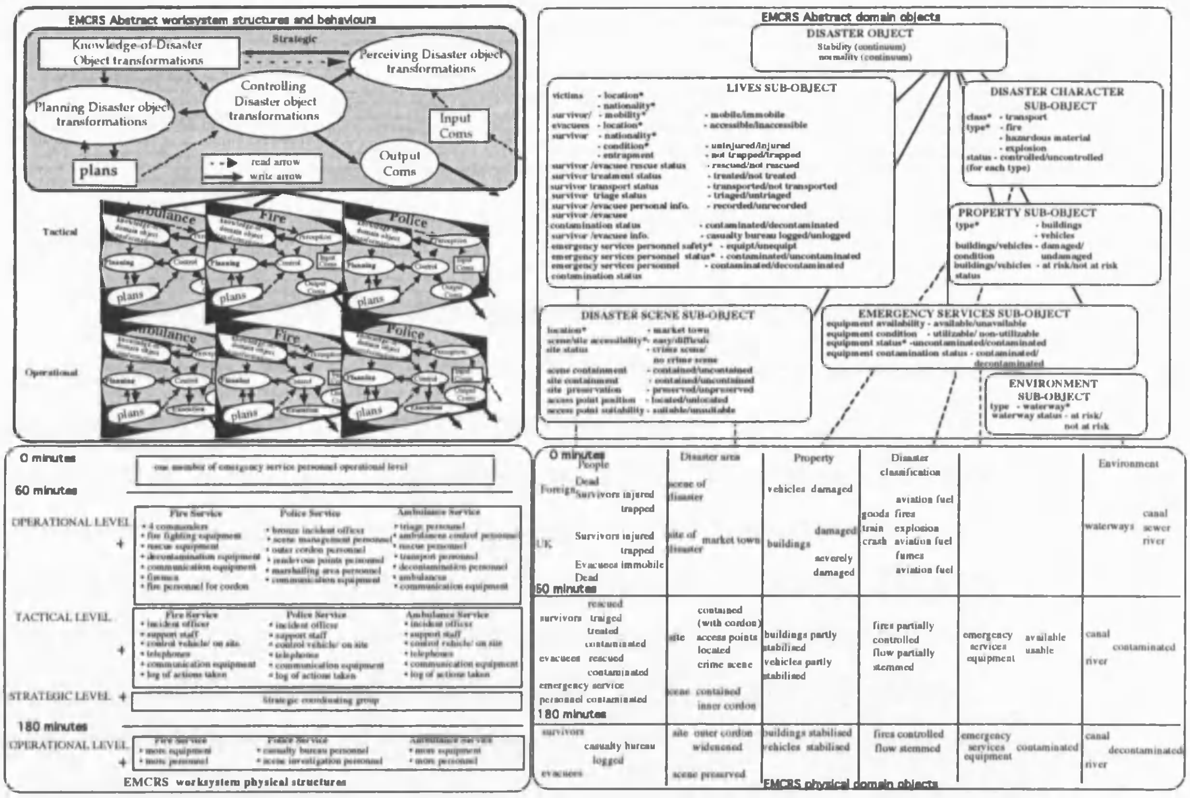


Figure 1 EMCRS Model 2

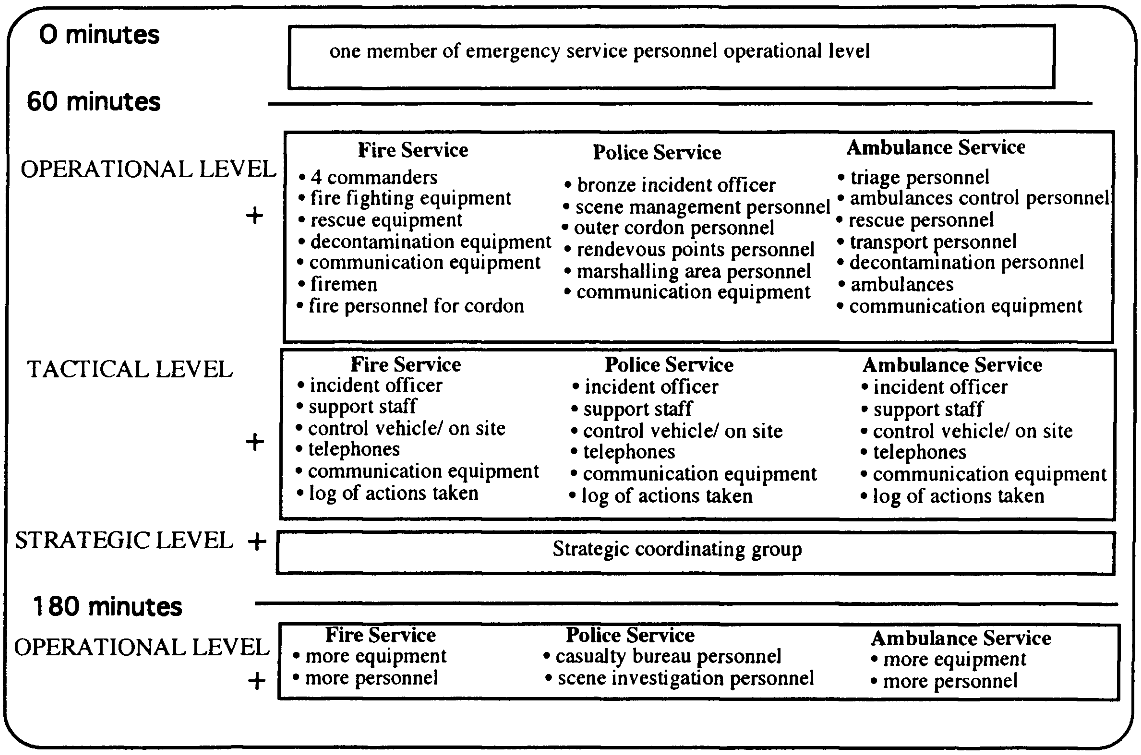


Figure 2 EMCRS Worksystem physical structures

Figure 2 shows the EMCRS Model 2 worksystem physical structures. The three tier structure of the EMCRS is represented for each agency. To represent the changing EMCRS worksystem, the physical worksystem is represented over time, with timelines and '+' for additional structures. The first timeline is 0 minutes, i.e. at the start of the incident. The only structure in the physical worksystem at 0 minutes is one member of the emergency services at an operational level. At the beginning of any incident, the first person of the emergency services to arrive, must assess the situation and report back to base. This person will be an operational personnel member. The second timeline is 60 minutes. A major incident is declared after 15 minutes, which is when the EMCRS is activated. One hour into the incident, the EMCRS is fully operational. The additional structures, represented in the physical worksystem after 60 minutes, are those structures that support the behaviours of the worksystem at this time. Thus, the physical structures of the worksystem relate directly to the physical domain. For example, firemen and fire-fighting equipment controlling the aviation fuel fires. All the physical structures, that could be inferred from the data, are represented. The last timeline is 180 minutes. The EMCRS is 'stood down', i.e. it is no longer required for the management of the incident, at 4 hours. Therefore, at 180 minutes the EMCRS structures support behaviours that are bringing the incident under control. There will be additional personnel for each agency along with more equipment, and specialist personnel to support behaviours, such as crime scene investigation by the Police. These timelines could be changed for other domains. The timelines correspond directly with the timelines used for the physical domain objects. This representation is an extension to the HCI-PCMT framework to accommodate changing worksystems.

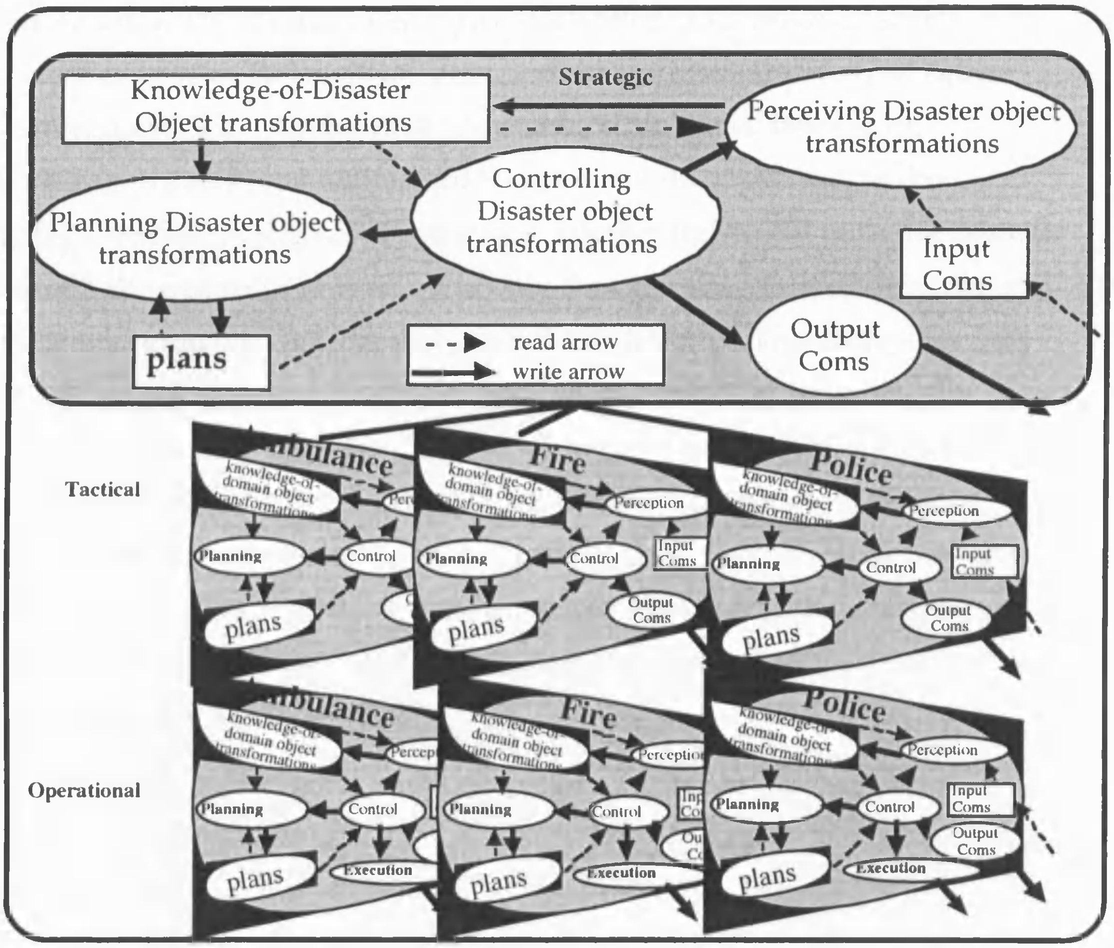


Figure 3 EMCRS Abstract worksystem structures and behaviours

Figure 3 shows the EMCRS abstract worksystem structures and behaviours for Model 2. The abstract structures are representations and processes that support the behaviours of the worksystem. In Figure 3, an oval depicts a process structure, a rectangle depicts a representation structure, a read arrow depicts a process reads from the contents of a representation, and a write arrow depicts a process writes to the contents of a representation. Shown at the strategic level, the process structures are: **planning**; **controlling**; and **perceiving**, and the representation structures are: **plans** and **knowledge-of-disaster object transformations** (**knowledge-of-tasks**). At the tactical and operational levels, the behaviours of the worksystem are shown i.e. planning, control, perception, and execution (only at the operational level, to be discussed below). Thus, Figure 3 represents the abstract structures and the abstract behaviours these structures support. The multiple agency, three tier nature of the EMCRS is represented, showing the distribution of the HCI-PCMT framework abstract structures across each level, and between levels. The interactions between levels are represented by **input** and **output coms**. (communications). At the strategic and tactical levels, there is no executing process represented, just output communications, as the strategic and tactical level of command interact indirectly with the domain through the operational level. It is only the operational level of command that transforms the EMCRS abstract objects directly. Therefore, it is only the operational level of command that has an executing process. The strategic level does not have separate structures and behaviours for each of the agencies, as at the strategic level, there is a senior co-ordinating group, with one representative from each agency, working together as a single group. This representation is an extension to the HCI-PCMT framework to accommodate systems, in which there is more than one level with interactions between them.

0 minutes People	Disaster area	Property	Disaster classification		Environment
Foreign: Dead Survivors injured trapped UK: Survivors injured trapped Evacuees immobile Dead	scene of disaster site of disaster: market town	vehicles damaged buildings: damaged severely damaged	goods train crash: aviation fuel fires explosion aviation fuel fumes aviation fuel		waterways: canal sewer river
60 minutes					
survivors: rescued traiged treated contaminated evacuees: rescued contaminated emergency service personnel contaminated	site: contained (with cordon) access points located crime scene scene: contained inner cordon	buildings partly stabilised vehicles partly stabilised	fires partially controlled flow partially stemmed	emergency services equipment: available usable	canal river: contaminated
180 minutes					
survivors: casualty bureau logged evacuees	site: outer cordon widenened scene preserved	buildings stabilised vehicles stabilised	fires controlled flow stemmed	emergency services equipment: contaminated	canal river: decontaminated

Figure 4 EMCRS Physical domain objects

Figure 4 shows the EMCRS physical domain objects attributes and values for Model 2. These physical objects are the same as those conceptualised for Model 1. The physical domain objects are represented over time. The timelines correspond directly with the timelines in the EMCRS physical worksystem for EMCRS model 2. Thus, the objects and attributes shown in Figure 4 correspond to the EMCRS worksystem behaviours at those times. For example, at 0 minutes the behaviours of the EMCRS are to **perceive** the domain and update the **knowledge-of-tasks** about the situation. At 0 minutes the physical domain, represents information about the disaster scenario (a representation of information in the Exercise Scorpio narrative). At 60 minutes, the physical domain reflects the behaviours of the worksystem, for example triage and treatment of casualties, containment of the scene with a cordon, and partial control of the fires. Emergency service personnel are now represented as part of the domain, but only if they are contaminated. Emergency service personnel are obviously part of the EMCRS worksystem. Contaminated personnel will become part of the domain as it will be the work of the EMCRS to decontaminate the personnel. Also, at 60 minutes, emergency service equipment become part of the domain. The reason is because making equipment available and usable is part of the work of the EMCRS. Last, at 180 minutes the physical objects represented include contaminated emergency service equipment. Contaminated equipment will require work by the EMCRS to decontaminate it. Other physical objects are buildings stabilised and fires controlled, which relate to the worksystem behaviours at this time. Only some of the physical objects attributes and values are shown here, due to space limitations of the representation. The full set has been described elsewhere (see Chapter 4, Section 4.3, and Chapter 5, Section 5.2).

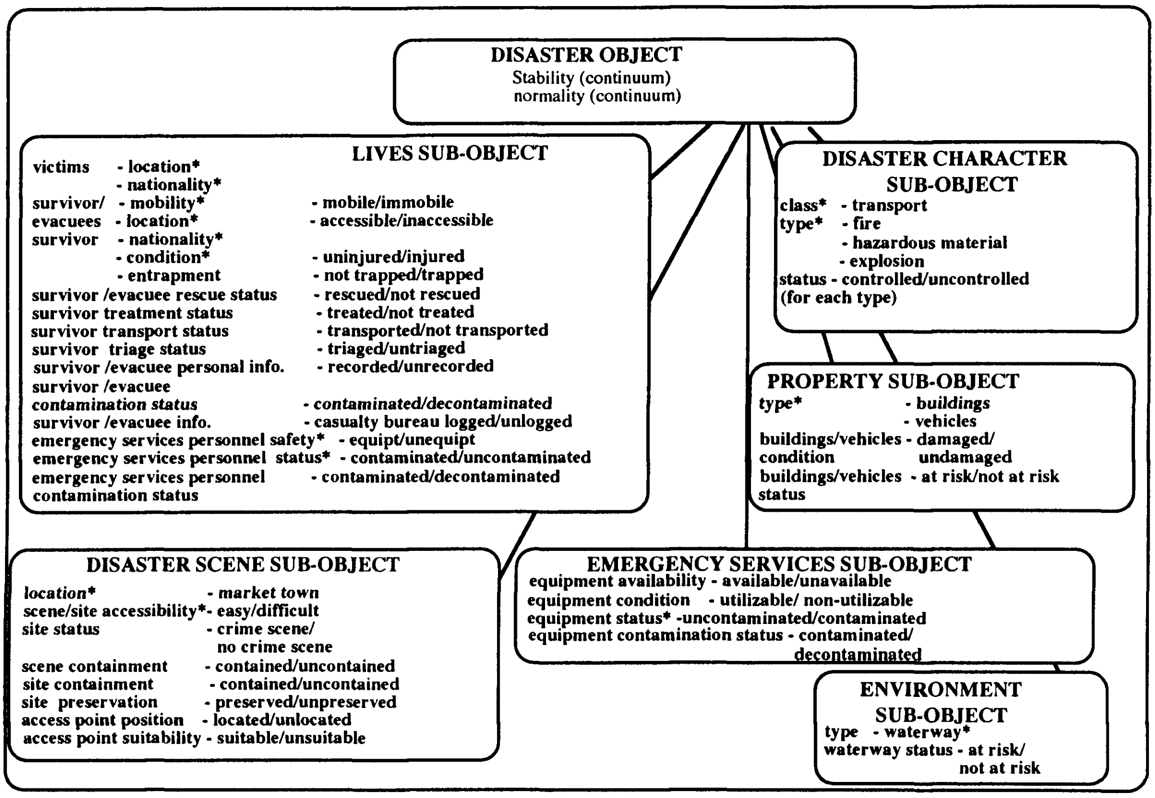


Figure 5 EMCRS Abstract domain objects

Figure 5 shows the EMCRS abstract domain objects attributes and values for Model 2. These are the same as those for Model 1, and as identified in Chapter 4. The full lines between the **Disaster** object and the other sub-objects define a part-of relationship. The attributes with a star (*) are dispositional; that is they need to be perceived by the worksystem but are not changed by it. These abstract objects are realised by the physical objects of the domain. It is not necessary to represent the abstract domain over time. All the abstract objects' attributes and values are represented in the domain. Therefore, abstract object attributes can be directly identified that correspond to the physical object attributes, as required.

EMCRS Model 2 has been presented. It is a Combined Agency (CA) model as it represents all the agencies within the EMCRS combined response (as is EMCRS Model 1.) These CA models have been used to identify behaviour conflicts within the EMCRS and thus, to diagnose co-ordination design problems. The performance expressions, associated with these CA models, have been identified as not being accurate. Single Agency (SA) models have been developed to rectify this problem. The SA and CA models are now related to give more accurate EMCRS performance expressions, for the five co-ordination design problems. Relating the models is Stage 7 of the method for design problem diagnosis, presented in Chapter 6. Method Stage 7 is given in Table 1 below and is applied in Section 8.2.

Method Stage	Action	Example for clarification
7	Refer to the Single Agency models of individual agency planned performance to accurately express EMCRS performance.	The Single Agency model for the Ambulance Service shows that the planned performance for the Ambulance Service is to liaise with the other agencies, specifically with the Fire Service in this instance, so that the regulation safety equipment required is known and acted upon. Planned performance would ensure that the Ambulance Service officers arrive at the inner cordon set-up with the required level of safety equipment. Thus, the officers can then enter the cordon to treat the injured. The actual performance of the Ambulance Service was to arrive at the Fire Service cordon and not to be allowed access, due to a lack of regulation safety equipment. Thus, the officers cannot enter the cordon, and cannot treat the injured. Therefore, actual performance is less than planned performance. The Single Agency model for the Fire Service shows that the planned performance for the Fire Service is to set-up an inner fire cordon making sure that other emergency service personnel are informed of the set-up and regulation safety procedures. The set-up of the Fire Service cordon was not progressed with the knowledge of the Ambulance Service. Thus, the actual performance is less than the planned performance in this respect. Secondly, the Fire Service actual performance is to recover the casualties to the edge of the Fire Service cordon, so that the Ambulance Service personnel can triage them. This performance would equal planned performance, as second only to the prevention of escalation of the disaster, priority should be given to the treatment and recovery of casualties from the site. However, the rescue function only has to be carried out, because the Fire Service cordon had been set-up with restrictions without consulting the Ambulance Service. Thus, overall actual performance with respect to this task is less than planned performance. Thus, the Single Agency models show a performance deficit for both the Ambulance and Fire Services' response in respect to this co-ordination problem. The performance expression from the Combined Agency models also shows a performance deficit for both agencies, so in this case is accurate.

Table 1 Method for Co-ordination Design Problem Diagnosis Stage 7

8.2 Performance expression

In this section, performance expressions for each of the co-ordination design problems, identified by the CA models (EMCRS Models 1 and 2) are given, first with respect to CA models and then with respect to the Single Agency (SA) models. The different model expressions are then related to provide a more accurate expression of performance for each problem. (In this instance, and for the purposes in hand here, desired performance is considered to be planned performance. Desired performance is desired task quality and acceptable user costs.) Reference is given to individual data points in Datasets 1 and 2, by number, and also to individual sections in the Single Agency Models.

8.2.1 Co-ordination Design Problem 1 Trampling/scene preservation

8.2.1.1 Performance expression of CA models

Extract from Exercise Scorpio narrative: 'Early information from witnesses suggests youths have been seen running from the section of rail track where the derailment took place and that vandalism may be responsible for the derailment.' Due to this information in the narrative the Police declare the site as a crime scene. (Data 1. 1b; Data 2. B2). The Fire Service are thus expected to behave accordingly in attempting not to trample the evidence. (Data 1. 4; Data 2. 6a) The Fire Service behaviour of carrying out minimal trampling will affect their performance by slowing rescue of casualties and slowing containment of the fire. (Data 1. 4o; Data 1. 5a) Even minimal trampling will affect the preservation of the scene, and so will affect the Police Service behaviours of preserving the site, and thus catching the vandals. (Data 1. 3j; Data 1. 6b; Data 2. 1c; Data 2. 3a; Data 2. 5d; and Data 2. 6a). The CA models describe an overall performance deficit for the EMCRS, through either (a) hindered goal achievement: trampling by the Fire Service reduces the chances of the vandals being caught by the Police Service; carrying out minimal trampling reduces rescue of casualties and containing of the fire by the Fire Service; or (b) unacceptable system resource costs: Police Service working too hard; Fire Service trying not too trample. The CA models, thus, describe a performance deficit for the EMCRS, as both the Police and the Fire Services have reduced performance for their tasks.

8.2.1.2 Performance expression of Single Agency Models

8.2.1.2.1 Planned performance for the Police Service

From the Single Agency model, the Police planned performance is to preserve the crime scene as much as possible, so that the criminals can be apprehended, but not to let this concern take precedence over the saving of life (P. 1.3). The Police plan specifies that saving of life takes precedence over preserving the scene. (P. 1.1). Therefore, the planned performance for the Police Service is to attempt to preserve the scene, but not to let scene preservation behaviours take precedence over life saving behaviours.

8.2.1.2.2 Planned performance for the Fire Service

From the Single Agency model, the planned performance for the Fire Service is to make every effort to preserve the scene intact, and to liaise with the Police Service about the need to preserve evidence, but not to let investigation work take precedence over the necessity to rescue casualties, fight fires etc. (F. 1.2). The protection of the scene and preservation of evidence are vital (F. 1.1), so the Fire Service must try not to trample the site. Thus, the planned performance is to try to keep trampling to a minimum, but not to allow non-trampling behaviours to take precedence over fire fighting or rescuing casualties.

8.2.1.2.3 Cross- referencing the models

The Police Service actual performance has a priority of preserving the scene and not saving lives, which will give acceptable Police Service resource costs (reducing the rescuing performance of the Fire Service, by trying to enforce reduced trampling). Thus, the actual Police Service performance is much less than their planned performance for an additional reason than hindrance of crime preservation behaviours, and Police workload too high, identified by the CA models. The actual performance of the Fire Service is to attempt not to trample the site, reducing their effectiveness for saving life. However, the planned performance is that they should attempt not to trample, but not let this take precedence over life saving etc. Therefore, the actual performance of the Fire Service, in attempting not to trample, will not affect task quality; rescue of casualties is expeditious, as they will not let non-trampling behaviours take precedence over life saving; and the system resource costs will be acceptable: Fire Service trample appropriately. Thus, the actual performance is equal to the planned performance, so there is no performance deficit for the Fire Service.

8.2.1.3 Relating the Models

The following representation gives a very clear illustration of the performance expression from the CA models and the SA models. Relating the two expressions, illustrates how the SA planned performance expressions affect the overall EMCRS performance expression.

The CA models describe actual performance not being equal to planned performance, as a performance deficit that is identified for both Police and Fire Services. The overall performance deficit can be re-interpreted using the SA models as follows: (SA1 is the Fire Service Single Agency model expression and SA2 is the Police Service Single Agency model expression.)

If the Fire Service (SA1) actual performance equals its planned performance (their trampling behaviours are appropriate and do not reduce their effective fire containment and casualty rescue), but the Police Service (SA2) actual performance is less than its planned performance (their crime scene preservation behaviours, hindered by Fire Service trampling, cause the Police to work too hard, and reduce their effective vandal apprehension), then CA actual performance (CA Pa) is less than the CA planned performance, given SA planned performance (CA (SA) Pp). However, the performance deficit (CA Pa < CA (SA) Pp) from the CA (SA) model is less than the performance deficit (CA Pa < CA Pp) of the CA model (the CA (SA) model identifies only the Police Service as having a performance deficit). Thus, the overall EMCRS performance deficit is less than originally identified by the CA models.

Thus, CA Pa < CA Pp (as Pa<Pp for both agencies).

If SA1 Pa = Pp and SA2 Pa < Pp,

then CA Pa < CA (SA) Pp

and (CA Pa < CA (SA) Pp) < (CA Pa < CA Pp).

8.2.2 Co-ordination Design Problem 2: Cordon Restrictions

8.2.2.1 Performance expression of CA models

Extract from Exercise Scorpio narrative: the explosion has created severe structural damage to the railway bridge, premises adjacent to the bridge in an approximate 30 metre radius and has created major leaks in two of the other tank cars. Structural damage of a moderate nature has occurred within an approximate 100 metre radius. In the light of this information, the Fire Service actual performance is to set up two inner cordons at 600m for explosion protection, which is at the canal, and 100m for structural damage (for clarity the 100m cordon will now be called the Fire Service cordon.) (Data 2. A10). The CA models describe 'actual' Fire Service behaviours of setting up an inner cordon to contain the disaster. (Data 1. 3g; Data 1. 4r; Data 2. C5). The Fire Service are responsible for personnel safety therein (Data 1. 4b; Data 2. 4d; Data 2. 4o). Entry into the cordon requires regulation safety equipment (Data 1. 6a; Data 1. 3g; Data 2. 6c). The cordon, however, was set-up without informing the Ambulance Service, of the regulation safety equipment required for entering it. The CA models describe the 'actual' Ambulance Service behaviours of arriving at the scene, without regulation safety equipment and so are refused entry (Data 2. 5a; Data 2. 9a). Without entry, their task quality is reduced as they cannot carry out triage and so, cannot prioritise casualty transfer to hospital. This will increase the workload of the Ambulance Service, more personnel and ambulances will be required to transport the casualties, as delay in casualty treatment will require more casualties to be sent to hospitals. The Fire Service has to move casualties to the edge of the cordon, for Ambulance Service triage (Data 2. 4i). These Fire Service casualty rescue behaviours reduce the task quality of the Fire Service for fire containment, and increase Fire Service workload. The CA models describe EMCRS actual performance as being less than desired performance, as a performance deficit is identified for both Fire and Ambulance Services.

8.2.2.2 Performance expressions of Single Agency Models

8.2.2.2.1 Planned performance for the Fire Service

From the Single Agency model, the planned performance for the Fire Service was to set–up an inner safety cordon (F 2.1) and to consult with the

Police and Ambulance Service, regarding the cordon set-up (F. 2.3). Responsibility must be taken for all those within the cordon (F 2.2.), and all personnel working within the inner cordon must be suitably protected (F 2.7). Non-Fire Service personnel must be made aware of, and conform to, the Fire Service safety procedures (F 2.4). Priority should be given to the treatment and recovery of casualties from the site (F 2.5). Therefore, the planned performance was to set-up the cordon in consultation with the Ambulance Service and, if, necessary recover casualties.

8.2.2.2.2 Planned performance for the Ambulance Service

From the Single Agency model, the planned performance for the Ambulance Service is the saving of life in conjunction with the other emergency services (A 2.1i), and treatment and care of those injured at the scene (A 2.1ii). The Ambulance Safety officer is responsible for ensuring that the correct level of protective clothing is worn (A 2.2i), and should liaise closely with the safety officers of the other agencies, especially the Fire Safety Officer. Thus, the planned performance for the Ambulance Service is to liaise with the other agencies, specifically with the Fire Service in this instance, so that the regulation safety equipment required is known and can be worn. Planned performance would ensure that the Ambulance Service officers arrive at the inner cordon set-up with the required level of safety equipment. Thus, the officers can then enter the cordon to treat the injured.

8.2.2.3 Cross-referencing the Models

The set-up of the Fire Service cordon was not progressed with the knowledge of the Ambulance Service. Thus, the actual performance of the Fire Service is less than the planned performance in this respect, as the Ambulance Service should have been consulted about the cordon set-up, and Fire Service workload increases as they have to rescue casualties. Second, the Fire Service actual performance is to recover the casualties to the edge of the Fire Service cordon, so that the ambulance personnel can triage them. This performance would equal planned performance, as second only to the prevention of escalation of the disaster, priority should be given to the treatment and recovery of casualties from the site, and the extra Fire Service workload required is therefore acceptable. However, the rescue function only has to be carried out, because the Fire Service cordon had been set-up with restrictions without consulting the Ambulance Service. Thus, overall actual performance with respect to this task is less than planned performance, as the extra Fire Service workload is unacceptable in having to rescue casualties. Therefore, actual performance for the Fire Service does not equal planned performance. The actual performance of the Ambulance Service was to arrive at the Fire Service cordon and not to be allowed access, due to a lack of regulation safety equipment. Thus, the officers cannot enter the cordon, and cannot treat the injured, which increases Ambulance Service workload. The actual performance does not equal the planned performance as the Ambulance Service have not been informed of the inner cordon and do have the required level of safety equipment, so cannot carry out their triage behaviours as desired, and Ambulance Service workload is increased.

8.2.2.4 Relating the models

The CA models describe actual performance as not being equal to planned performance, as a performance deficit is identified for both Fire and Ambulance Services. The overall performance deficit can be re-interpreted using the SA models as follows: (SA1 is the Fire Service Single Agency model expression and SA2 is the Ambulance Service Single Agency model expression.)

If the Fire Service (SA1) actual performance is less than its planned performance (their failure to inform the Ambulance Service of the cordon's set-up reduces fire containment, as they have to move casualties, instead of fire fighting, which increases their workload), and the Ambulance Service (SA2) actual performance is less than its planned performance (their casualty access behaviours reduced, increasing their workload), (Fire Service failure to inform them of the cordon set-up), and so also casualty assessment and prioritisation), then the CA actual performance (CA Pa) is less than the CA planned performance, given the SA performance (CA (SA) Pp). The performance deficit (CA Pa < CA (SA) Pp) of the CA (SA) model is equal to the performance deficit (CA Pa < CA Pp) of the CA model. A performance deficit occurs for both Fire and Ambulance Services. Thus, the overall EMCRS performance deficit identified by the CA model, in this instance, is accurate.

Thus, CA Pa < CA Pp (as Pa<Pp for both agencies.)

If SA1 Pa < Pp and SA2 Pa < Pp,

then CA Pa < CA (SA) Pp and (CA Pa < CA (SA) Pp) = (CA Pa < CA Pp).

8.2.3 Co-ordination Design Problem 3: Decontamination

8.2.3.1 Performance expressions of CA models

The Exercise Scorpio narrative states that there is severe structural damage to both to the railway bridge and premises adjacent to the bridge and there are also numerous fires in the area. The Fire Service actual performance is to protect property and to contain the fires. (Data 1. 4d; Data 1. 4j; Data 2. A7). Extract from Exercise Scorpio narrative: 'A number have also been contaminated by aviation fuel.' In the light of this information, the Fire Service actual performance is to recognise the need to set-up decontamination areas for fire-fighters and others (Data 2. 4u). (This need does not mean, however, that they actually set up the areas.) The Ambulance Service are responsible for decontamination. The Ambulance Service actual performance, in response to the narrative, is to attempt to carry out decontamination. However, the Ambulance Service do not have decontamination equipment and have to carry out decontamination in conjunction with the Fire Service. The Fire Service have decontamination equipment, but do not see it as their responsibility to decontaminate ambulances and others, who are not Fire Service personnel (Data 2. 6g). Any casualty, that is not decontaminated, before being put in an ambulance, will contaminate that ambulance (Data 2.7h). Any ambulance leaving the site, without being decontaminated, will be out of action for the rest of the incident, and if any hospital receives a contaminated casualty, then that hospital is deemed contaminated and cannot be used for the duration of the incident (Data 2.9b). Therefore, the CA models describe EMCRS actual performance as being less than desired performance, as a performance deficit is identified for the Ambulance Service. Ambulance Service task quality is reduced as they cannot carry out their decontamination tasks; Ambulance Service resource costs increase as non decontamination will contaminate Ambulance Service personnel and equipment and thus put them out of action.

8.2.3.2 Performance expressions of Single Agency Models

8.2.3.2.1 Planned performance for the Fire Service

There is no mention of decontamination in the Fire Service Single Agency model. Therefore, the planned performance for the Fire Service equals its actual performance, as they negate responsibility for decontamination.

8.2.3.2.2 Planned performance for the Ambulance Service

The Ambulance Service Single Agency model does not specifically state that the Ambulance Service are responsible for decontamination. (However, the Ambulance Service are responsible for decontamination, and this is specified with respect to the overall EMCRS (Dealing with disaster, 1994)), (and the Ambulance personnel know that they are responsible for decontamination too.) The Ambulance Service does not have decontamination equipment and so cannot carry out the decontamination, on their own. The Single Agency model states, that the Ambulance Service safety officer should seek appropriate advice for the Ambulance Incident Officer and/or Forward Incident officer of the correct treatment and procedures in cases of contamination of casualties, personnel, vehicles/equipment'. (A. 3.1) The plan does not specify, where the appropriate advice should come from, or who should act on the advice, once it is obtained. Therefore, there is nothing in the Ambulance Service model about who is responsible for decontamination, the planned performance is to find out treatment and procedures for contaminated personnel, casualties and equipment.

8.2.3.3 Cross-referencing the models

The actual performance for the Ambulance Service, identified from the CA models, was to attempt to carry out decontamination, but having no means of decontamination see this as the Fire Service's responsibility, increasing Ambulance Service resource costs to an unacceptable level. The planned performance for the Ambulance Service from the Single Agency model was to find out treatment and procedures for contaminated people and equipment, with acceptable resource costs. The actual performance is thus less than the planned performance, in that the appropriate procedures for decontamination have not been applied, giving unacceptable resource costs (contaminated ambulances etc.). The actual performance is not less than the planned performance, because decontamination has not be carried out, which would have been expected, as the Single Agency model planned performance for the Ambulance

Service does not state that they are responsible for decontamination. There is, thus, an issue with the plans, which will be discussed in the following section.

The actual performance of the Fire Service was not to take responsibility for decontamination, and therefore, ambulances etc. will leave the site contaminated. However, as the Fire Service plan does not specify planned behaviour for decontamination, it can only be assumed that the actual performance of the Fire Service equals its planned performance. The Single Agency model for the Ambulance Service, thus, shows a performance deficit, as the Ambulance Service does not manage to find out the treatment and procedures for contaminated casualties etc.

8.2.3.4 Relating the models

The CA models describe EMCRS as actual performance not being equal to planned performance, as a performance deficit is identified for the Ambulance Service. The overall performance deficit can be re-interpreted, using the SA models as follows: (SA1 is the Fire Service Single Agency model expression and SA2 is the Police Service Single Agency model expression.)

If the Fire Service (SA1) actual performance equals its planned performance (their fire-fighting and property protection behaviours being carried out according to their plan (their non-decontamination behaviours also are according to their plan) and resource costs for both tasks are acceptable), and the Ambulance Service (SA2) actual performance is less than its planned performance (their behaviours regarding decontamination not being carried out according to their plan, increasing their resource costs), then CA actual performance (CA P_a) is less than the CA planned performance, given SA planned performance (CA (SA) Pp). Therefore, the performance deficit (CA P_a $<$ CA (SA) Pp) from the CA (SA) model is equal to the performance deficit (CA P_a $<$ CA Pp) of the CA model. Thus, the overall EMCRS performance deficit, originally identified by the CA models, is accurate.

Thus, CA P_A $<$ CA Pp (as $Pa < Pp$ for Ambulance Service).

If SA1 $P_a = Pp$ and SA2 $P_a < Pp$,

then CA P_a $<$ CA (SA) Pp

and (CA Pa < CA (SA) Pp) = (CA Pa < CA Pp)

However, there is obviously a major concern with the plans in relation to this co-ordination issue. As described by the EMCRS model description, the knock-on effect of not decontaminating either casualties, vehicles or emergency service personnel will have a catastrophic effect on overall EMCRS performance for the whole disaster. The plans for both the Fire and Ambulance Service with respect to decontamination should be changed. For the Fire Service, as they are the only service with decontamination equipment, there should be specialist personnel allocated to operate the equipment to support the Ambulance Service in decontamination. In this way, the Fire Service will not have to take personnel away from their primary objectives of fighting fires and protecting lives and property. For the Ambulance Service, the plan should state that they are responsible for decontamination in conjunction with the Fire Service. This plan is only operationalisable if the Fire Service plan is changed accordingly.

8.2.4 Co-ordination Design Problem 4: Witness reporting

8.2.4.1 Performance expressions of the CA models

Due to information arising in the Exercise Scorpio narrative, regarding vandalism being suspected for the cause of the incident, it is declared a crime scene. Therefore, there is a need to treat all the people at the scene as witnesses (Data 2. B3). The Police Service want to be able to record witness information before the latter leave the scene (Data 1 3.l; Data 1. 1p). The narrative also states that there are a number of casualties at the scene. The Police Service set up a casualty bureau, where records relating to any persons who have been involved in the incident, are kept (Data 2. 1h). The Police Service actual performance is to set up a casualty bureau and attempt to record details of all casualties at the scene and pass this information to the bureau, with acceptable resource costs. The Ambulance Service actual performance in response to the casualties is to triage, and treat and/or transport casualties to hospital, with acceptable resource costs. (Data 2 A 12) The Ambulance personnel should attempt to record the personal details of casualties, but the most serious cases will be immediately sent to hospital. (Data 2 7k). The Police Service will not be able to record details of the most severely injured at the scene. Therefore, the CA models describe EMCRS actual performance as being less than desired performance, as a performance deficit is identified for the Police Service. They cannot carry out their logging tasks, and so increase their workload in having to track down casualty information.

8.2.4.2 Performance expressions of Single Agency models

8.2.4.2.1 Planned performance for the Police Service

The Single Agency model for the Police Service states that the Police Service should liaise with the Ambulance Service to maintain a count of casualties and details of the hospitals to which they have been sent. (P. 4.3). It does not state that the Police Service should delay the casualties from being sent, but information will be forwarded from hospitals (P. 4.4). The casualty receiving station officer will liaise with the Ambulance officer and log to which hospitals casualties have been sent (P. 4.5). Therefore, the planned performance for the Police Service is to attempt to log details of all casualties in the casualty bureau, but not to delay casualties. Information should be obtained at the hospitals, as required.

8.2.4.2.2 Planned performance for the Ambulance Service

The Single Agency model for the Ambulance Service states that the Ambulance Service should not delay in sending the casualties to hospital. The Police Service can record the personal details of the casualties at the hospital (A. 4.1). The planned performance for the Ambulance Service is to send the casualties to hospital, as required, not worrying about recording details.

8.2.4.3 Cross-referencing the models

The actual performance as expressed by the CA models for the Police Service is that the Police Service cannot log in the casualty bureau the most severe casualties, who have been sent straight to hospital. The planned performance is that information will be sent to the casualty bureau from the hospitals and that the Police Service should not delay casualty transportation by trying to log casualty details beforehand. Thus, the actual performance for the Police Service is equal to the planned performance. The resource costs deemed unacceptable with respect to tracking down witness information are acceptable costs with respect to the plan. The actual performance for the Ambulance Service, as expressed by the CA models, is to send the most serious cases straight to hospital without recording personal details. The planned performance is that the Ambulance Service should not delay in sending casualties to hospital by attempting to record personal details. The actual performance for the Ambulance Service is thus equal to its planned performance.

8.2.4.4. Relating the Models

The CA models describe EMCRS actual performance as not being equal to desired performance, as a performance deficit is identified for the Police Service. The overall performance deficit can be re-interpreted, using the SA models as follows: (SA1 is the Police Service Single Agency model expression and SA2 is the Fire Service Single Agency model expression)
If the Police Service (SA1) actual performance equals its planned performance (their non casualty bureau logging of serious casualties being according to their plan), and the Ambulance Service (SA2) actual performance is equal to its planned performance (their not delaying casualties to record details being according to their plan), then CA actual performance (CA Pa) is equal to the CA planned performance, given SA planned performance (CA (SA) Pp). The performance deficit (CA Pa = CA (SA) Pp) from the CA (SA) model is, therefore, less than the performance deficit (CA Pa < CA Pp) of the CA model (the CA (SA) model identifies no performance deficit for either agency). Thus, the overall EMCRS performance deficit is less than originally identified by the CA models.
Thus, CA Pa < CA Pp (as Pa < Pp for Police Service)
If SA1 Pa = Pp and SA2 Pa = Pp,
then CA Pa = CA (SA) Pp
and (CA Pa = CA (SA) Pp) < (CA Pa < CA Pp)

However, the Police Service believe that not recording personal details of witnesses at the scene, is likely to lead to that information being unrecorded. This outcome must mean that the plans for the receiving hospitals to pass information to the casualty bureau are not effective.

Without this information the criminal investigation by the police will be hampered. There is, therefore, an issue with the plans. The fact that the Police Service would rather delay casualties from being transported to hospital to gather witness information, which will produce a much greater deficit on overall EMCRS performance, (as the primary priority for all agencies is to save life), shows that there needs to be a change in the plans.

8.2.5 Co-ordination Design Problem 5: Access of fire appliances

8.2.5.1 Performance description of CA models

Due to information in the Exercise Scorpio narrative, a major incident is declared. At a major incident, the Police are responsible for access (Data 1. 1i; Data 2 A4; Data 2. B2), which is often chaotic (Data 1.1c). Therefore, the actual performance of the Police Service is to set-up access points to the scene for all the emergency Services. From the Exercise Scorpio narrative, there is aviation fuel flowing down the sides of the embankment onto the roadway, and there are numerous fires in the area. The Fire Service need to stem the flow of aviation fuel (Data2 C1), and need to fight fires and prevent escalation of the disaster (Data1. 4d) and will therefore need access for their fire appliances. The actual performance of the Fire Service is to attempt to stem the flow of the aviation fuel and to fight the fires, but they find that, due to poor access point location (Data1.3a; Data2.2a; Data2. 4n), they cannot utilise their equipment and therefore cannot carry out their tasks. Therefore, the CA models describe EMCRS actual performance as being less than desired performance. Without access for the fire appliances the Fire Service cannot carry out their fire containment, and property protection behaviours, and Fire Service workload is increased accordingly.

8.2.5.2 Performance expressions of the Single Agency models

8.2.5.2.1 Planned performance for the Police Service

From the Single Agency model, the planned performance for the Police Service is that they are responsible for setting up access points (P. 5.6), and that the first officer on the scene should identify the best routes for the emergency vehicles, parking, turning etc (P. 5.3). The incident control post is responsible for controlling access to the scene (P 5.1), and if possible a 'one way' system with defined access and exit routes for essential services, should be set-up to ensure rapid attendance of emergency vehicles at the scene (P. 5.5ii). Thus, the planned performance for the Police Service is to set-up the access points, if possible in sites where emergency vehicles can have rapid attendance, and control the access points.

8.2.5.2.2 Planned performance for the Fire Service

From the Single Agency model, the planned performance for the Fire Service is to direct all fire appliances to the immediate scene initially (F. 5.1), and then to rendezvous points set-up by the Police Service (but in consultation with the Fire Service with regards to location) (F.5.1). The Police Service are responsible for control of access to the incident site (F. 5.3). The planned performance for the Fire Service is, therefore, first to direct their appliances to the immediate scene, to carry out their fire fighting and escalation prevention behaviours, and then to rendezvous points set-up by the Police Service. However, these rendezvous point locations should be decided in consultation between the two services. These rendezvous points are not access points to the scene. A rendezvous point is a location, where emergency vehicles should be sent to await directions to the scene. Thus, the planned performance for access of appliances is that the Fire Service should be involved in determining where the rendezvous points are, but not where the access points are located – access points are not mentioned *per se* in the Fire Service Single Agency plan, but control of access is deemed a Police responsibility.

8.2.5.3 Cross-referencing the models

The actual performance for the Fire Service was that they sent their appliances to the access points set-up by the Police Service, but could not utilise their vehicles. They could not carry out their Fire Service behaviours in response to the incident, as the access points to the scene were not suitably located. The planned performance for the Fire Service is to send their vehicles to access points set-up by the Police, who exert control over access to the site. Therefore, the planned performance is equal to actual performance, inasmuch as the Fire Service has sent their vehicles to the Police access points, with acceptable resource costs, so there is no performance deficit for the Fire Service. (However, the actual performance, regardless as to whether it equals planned performance or not, is not satisfactory performance, as the Fire Service need good access for their appliances. There is a performance deficit for the Fire Service, as they cannot carry out their transformation behaviours, and have unacceptable resource costs. This would imply that the Single Agency plans for the Fire and Police Service should be changed to allow better liaison between the Police and the Fire Service with regards access.) The actual performance of the Police Service is to locate and set-up the access points to the scene, which equals the planned performance.

8.2.5.4 Relating the models

The CA models describe EMCRS actual performance as not being equal to desired performance, as a performance deficit is identified for the Fire Service. The overall performance deficit can be re-interpreted using the SA models as follows: (SA1 is the Police Service Single Agency model expression and SA2 is the Fire Service Single Agency model expression.) If the Police Service (SA1) actual performance equals its planned performance (their access set up behaviours have been carried out according to their plan), and the Fire Service (SA2) actual performance is equal to its planned performance (their vehicles being sent to the access points, according to their plan), then CA actual performance (CA P_a) is equal to the CA planned performance, given SA planned performance (CA (SA) Pp). The performance deficit (CA P_a = CA (SA) Pp) from the CA (SA) model, is therefore, less than the performance deficit (CA P_a < CA Pp) of the CA model (the CA (SA) model identifies no performance deficit for either agency). Thus, the overall EMCRS performance deficit is less than originally identified by the CA models.

Thus, CA P_a < CA Pp (as Pa<Pp for Fire Service).

If SA1 P_a = Pp and SA2 P_a = Pp,

then CA P_a = CA (SA) Pp

and (CA P_a = CA (SA) Pp) < (CA P_a < CA Pp)

However, the fact that the Single Agency model for the Police Service shows no performance deficit, does not reflect the fact that the access points, although suitable from the Police Services perspective, are obviously not suitable for the Fire Service. In the Police Service Single Agency model, rendezvous points and marshalling areas must be set up in consultation with the Fire Service. It is obvious from this co-ordination problem, that access points also need to be set up in consultation with the Fire Service. The Police Service plans should be changed to reflect this. Likewise, although there is no performance deficit shown for the Fire Service from the Single Agency model, this outcome does not reflect the fact that the Police Service location of the access points are unsuitable for the Fire Service and their vehicles cannot be utilised. The Fire Service plan specifies that rendezvous points and marshalling areas, although a Police responsibility, should be set-up in consultation with the Fire Service. The Fire Service plan should also state that access points should be set-up in consultation with the Fire Service.

8.3 Chapter Summary

This Chapter has presented EMCRS Model 2, the combined agency model for the same data used for Model 1, but with all the issues identified in Chapter 7 addressed. The model has been described, showing how the identified issues have been represented in the model. The second part of the chapter has addressed the problem of performance expression by the combined agency (CA) models (EMCRS Models 1 and 2). The performance effects of each of the identified co-ordination design problems have been re-expressed by cross-referencing the Single Agency performance expressions, as described in the Single Agency models. These new performance expressions have given rise to issues with the current contingency plans for each of the emergency services. These issues will be discussed in greater detail in the following chapter.

Chapter 9

Discussion and Conclusions

Introduction

This chapter presents a discussion of the thesis. Section 1 reiterates the aims of the research and discusses whether these aims have been met i.e. whether EMCRS models have been produced, that diagnose EMCRS co-ordination design problems and support reasoning about solutions to these problems. How the HCI-PCMT framework needed to be extended to produce these diagnostic models will also be addressed. Section 2 generalises the extensions to the HCI-PCMT framework for modelling multi-agent, multi-level command, multiple task work situations. Section 3 discusses the short-comings of the present research and areas for future work, which have implications for the wider development of substantive knowledge to support HCI design practices. The last section gives a summary of the thesis.

9.1 Meeting the aims of the research

The aim of the present research was to develop models of the EMCRS that support the diagnosis of EMCRS co-ordination design problems and the reasoning about solutions to these problems. In the EMCRS model development, the scope of an existing framework (HCI-PCMT) was extended to accommodate the EMCRS. The HCI-PCMT framework was developed for modelling single user, multiple task planning and control work. Using the framework to model the EMCRS aimed to extend the scope of the framework to accommodate multiple user, multiple task planning and control work. The resultant models served to diagnose EMCRS coordination design problems. These models constitute substantive HCI knowledge to support directly the diagnosis of design problems and allow reasoning about design solutions (and thus, indirectly, the prescription of design solutions). A diagnosis method for application of the framework was also to be proposed. The following sections discuss whether each of these aims have been met.

9.1.1 EMCRS diagnostic models

This research has developed a set of (HCI-PCMT) EMCRS models. To demonstrate whether these models are diagnostic, they need to be able to diagnose design problems, such that a designer can reason about design solutions to these problems. The remit of this research is not to prescribe design solutions. However, an attempt will now be made to propose solutions, primarily to clarify the nature of the proposed design problems, and thus demonstrate the applicability of these models. Diagnosing design problems requires ineffective performance to be identified, with respect to the quality of the work and the resource costs to the system in carrying out this work. Behaviour conflicts were diagnosed by the models as causing ineffective performance of the EMCRS, (with respect to task quality and resource costs), and were thus diagnosed as design problems.

The EMCRS models identified five co-ordination design problems. These co-ordination design problems are diagnosed as EMCRS actual performance not being equal to desired performance. Initial solutions to these design problems have already been presented in Chapter 6, when the design problem diagnoses by EMCRS Model 1, were presented. Having identified the planned performance of the agencies for these design problems in Chapter 8, more explicit design solutions can now be suggested.

9.1.1.1 Co-ordination Design Problem 1: Trampling/scene preservation

This co-ordination design problem was diagnosed as ineffective performance of both the Police and the Fire Services. The Police Service reduce their chances of catching vandals, if the Fire Service trample the site. The Police Service will have to work harder to gather the evidence if the site has been trampled. The Fire Service not trampling the site reduces their rescue of casualties and fire containment. The Fire Service will have to work harder in trying not to trample. In Chapter 6, the execution behaviours of the Police Service (declaring the site a crime scene and insisting on minimal trampling to preserve the scene) were identified as part of the cause of the design problem. The behaviours that affected the Police Service execution behaviours of preserving the scene were the planning and control behaviours of the operational commander. Planning behaviour as specified in the model is based on the plans and the information in the knowledge-of-tasks representation (in this case, for example, knowledge about the vandals). It has now been shown in Chapter 8, that the plan that the operational commander consulted (albeit an abstract representation of a plan) did not specify, that the Police Service, in preserving the scene, should hinder the Fire Service rescue and fire containment behaviours. The Police Service operational commander, thus, had an inappropriate representation of the plan. This representation has caused his planning behaviours, for specifying the execution behaviours of preserving the scene, to be inappropriate. Now that it has been identified, where in the planning system the problem occurs, reasoning about potential solutions to this design problem, are possible. A potential solution is to enable adequate training of the procedures, specified in the operational plans, such that inappropriate planning behaviours are not carried out, and such that actual performance equals desired performance, for the crime scene preservation behaviours of the Police Service, i.e. the behaviours are carried out as desired with acceptable resource costs. The Fire Service behaviours of carrying out minimal trampling are identified in Chapter 8, as not causing ineffective performance for Fire Service rescue and fire containment. Thus, there is no performance deficit, identified for the Fire Service, for this co-ordination design problem. Minimal trampling should be carried out by the Fire Service, if a crime scene has been declared, but non-trampling behaviours should not take precedence over life saving and preventing escalation of the disaster. The Fire Service execution behaviours of rescue and fire containment will still have a negative performance effect on the Police Service execution behaviours of preserving the scene, as whilst the Fire Service are carrying out these tasks, even with minimal trampling, the evidence will not be preserved. The execution behaviours of the Fire Service are affected by the planning and control behaviours of the Fire Service operational commander. Planning behaviour, as specified by the model, is based on plans and the information in the knowledge-of-tasks representation (in this case, for example, fires and trapped casualties; scene of crime declared). The plan that has informed this planning behaviour has been shown in Chapter 8 to be well specified with respect to the problem of trampling and in fact also implemented, as the Fire Service are attempting not to trample the site, but not letting non-trampling behaviours affect fire containment and rescue. Since the Police Service obviously view trampling as a serious problem, it is probably the case that the Fire Service, although they should be carrying out minimal trampling are not, and are destroying more evidence than is necessary. Thus, it is the execution behaviours of the operational personnel that are causing the problem. Whether this outcome is because the operational commander has not specified that minimal trampling should be observed, or whether it is due to the operational personnel ignoring the instructions about minimal trampling cannot be decided here, as the data do not make this clear. Therefore, a more detailed potential solution to this problem cannot be made explicit at this time.

9.1.1.2 Co-ordination Design Problem 2: Cordon Restrictions

This co-ordination design problem was diagnosed as ineffective performance of both the Ambulance and the Fire Service. The Ambulance Service not being able to access casualties, cannot carry out triage, and thus, treatment of casualties, and they have unacceptable resource costs. The Fire Service, not allowing the Ambulance Service access, will have to carry out rescue of casualties, instead of fire containment, increasing Fire Service workload. In Chapter 6, the execution behaviours of the Fire Service (setting up an inner cordon and maintaining specified safety regulations) were identified as part of the cause of the identified design problem. The behaviours, that affected the Fire Service execution behaviours of inner cordon set-up, were the planning and control behaviours of the operational commander. Planning behaviour, as specified in the model, is based on the plans and the information in the knowledge-of-tasks representation (in this case, for example, structural damage and many fires at the scene). It has been shown in Chapter 8, that the plan which the operational commander consulted, should have specified that set-up of the inner cordon should not be progressed without the knowledge of the Ambulance Service. The Fire Service operational commander, thus, had an inappropriate representation of the plan, which has caused inappropriate planning behaviours, that have contributed to the design problem. Now that it has been identified where in the planning system the problem is occurring, reasoning about potential solutions to this design problem, is possible. A potential solution is to enable adequate training of the procedures specified in the operational plans, such that inappropriate planning behaviours are not carried out, and such that actual performance equals desired performance, for inner cordon set-up by the Fire Service, i.e. the set-up is as desired and with acceptable resource costs.

The Ambulance Service execution behaviours of accessing casualties for triage and treatment are identified as part of the cause of this co-ordination design problem. These execution behaviours are affected by the planning and control behaviours of the Ambulance Service operational officer. Planning behaviour as specified in the model, is based on the plans and the information in the knowledge-of-tasks representation (in this case, for example, casualties and an inner cordon). It has been shown in Chapter 8, that the plan that the Ambulance Service officer consulted, should have specified that liaison should take place with the Fire Service about what safety equipment is required for entering the cordon. The Ambulance Service operational officer had an inappropriate representation of the plan, which has caused inappropriate planning behaviours, which have contributed to the design problem. A potential solution is to enable adequate training of the procedures specified in the operational plans, such that inappropriate planning behaviours are not carried out, and such that actual performance equals desired performance, for Ambulance Service triage and treatment of casualties, i.e. triage and treatment are as desired with acceptable resource costs.

9.1.1.3 Co-ordination Design Problem 3: Decontamination

This co-ordination design problem was diagnosed as ineffective performance of the Ambulance Service. The Ambulance Service cannot carry out decontamination of casualties and others, due to the Fire Service behaviours of property protection and fire containment. Ambulance Service resource costs are unacceptable (contaminated personnel and equipment cannot be used). The execution behaviours of the Ambulance Service (decontaminating casualties in conjunction with the Fire Service) have been identified as part of the cause of the identified design problem.

The behaviours, that affected the Ambulance Service execution behaviours, were the planning and control behaviours of the operational safety officer. Planning behaviour, as specified in the model, is based on the plans and the information in the knowledge-of-tasks representation (in this case, for example, contaminated casualties). It has been shown in Chapter 8, that the plan that the Ambulance service operational officer consulted was inappropriate, (in fact, little was specified on decontamination), which has caused inappropriate planning behaviours that have contributed to the design problem. Unlike the other two co-ordination design problems already discussed, the Ambulance Service safety officer does not have an inappropriate representation of the plan, but the plan itself is inappropriate. Also, it has been shown that the Fire Service are the only agency with decontamination equipment, but in their plan decontamination is not mentioned. Thus, a potential solution to this problem is to re-specify the Ambulance Service, and Fire Service plans with respect to decontamination. This re-specification should ensure that actual performance equals desired performance for decontamination, with respect to the task quality (casualties and others decontaminated) and acceptable resource costs (Ambulance Service personnel and equipment all usable).

9.1.1.4 Co-ordination Design Problem 4: Witness reporting

This co-ordination design problem was diagnosed as ineffective performance of the Police Service. The Police Service cannot log witness information in the casualty bureau, as the witnesses have been sent to hospital by the Ambulance Service. The Police Service workload increases as they have to chase up witness information. The execution behaviours of the Police Service (logging all witnesses) have been identified as part of the cause of the identified design problem. These execution behaviours are affected by the planning and control behaviours of the Police Service incident officer. Planning behaviour, as specified in the model, is based on the plans and the information in the knowledge-of-tasks representation (in this case, for example, the site is a crime scene). In Chapter 8, it has been shown, that the plan that the Police Service incident officer consulted, was inappropriate. The plan should have specified that attempts should be made to log details of all casualties in the casualty bureau; but not to delay casualties, and to get the information at the hospitals as required. This inappropriate plan representation has caused inappropriate planning behaviour by the Police Service incident officer, which has contributed to the design problem. A potential solution to this problem would be to ensure adequate training of operational procedures, as specified in the plans, for Police Service incident officers, such that actual performance would equal desired performance for witness reporting, i.e. witness information has been recorded as desired with acceptable Police Service resource costs.

The Ambulance Service execution behaviours of triage and transportation to hospital have been identified as part of the cause of the problem. These execution behaviours have been affected by the planning and control behaviours of the Ambulance Service incident officers. Planning behaviour, as specified in the model, is based on the plans and the information in the knowledge-of-tasks representation (in this case, for example, seriously injured casualties). In Chapter 8, it has been shown that the Ambulance Service behaviours of sending the most seriously injured to hospital without logging their details are appropriate behaviours, as specified in the Ambulance Service plan. Although these behaviours have an effect on the Police Service witness recording, as the Police Service cannot then get witness details at the scene, delay of casualty transportation is not an appropriate behaviour, as details of witnesses will be recorded at the hospitals. Thus, there is no performance deficit identified for the Ambulance Service, as actual performance is equal to desired performance for the Ambulance Service, i.e. casualties have been transported with acceptable Ambulance Service resource costs.

9.1.1.5 Co-ordination Design Problem 5: Access of Fire Appliances

This co-ordination design problem was diagnosed as ineffective performance for the Fire Service. The Fire Service cannot utilise their equipment for fire fighting etc. as the access points set-up by the Police Service are unsuitable. The resource costs of the Fire Service are unacceptable (the firemen will have excessive workload if they have no equipment). The execution behaviours of the Police Service (locating access points) have been identified as part of the cause of the identified design problem. These execution behaviours were affected by the planning and control behaviours of the Police Service incident officer. Planning behaviour, as specified in the model, is based on the plans and the information in the knowledge-of-tasks representation (in this case, for example, a major incident in a market town). Chapter 8 has shown that the planning and control behaviour of the Police Service incident officer was carried out according to his plan, i.e. that access points should be set-up by the Police Service. However, these access points are unsuitable for Fire Service appliance access. Therefore, the Police Service plan is inappropriate for specifying suitability of access points for Fire Service appliances. Thus, a potential solution to this problem is to re-specify the Police Service plan, to ensure that actual performance equals desired performance with respect to access, i.e. access point locations are as desired, and their set-up has acceptable resource costs for the Police Service.

The Fire Service execution behaviours of making the fire appliances utilisable for rescue, fire containment etc. are identified as part of the cause of the design problem. These execution behaviours were affected by the planning and control behaviours of the Fire Service incident officer. Planning behaviour, as specified in the model, is based on the plans and the information in the knowledge-of-tasks representation (in this case, for example, aviation fuel fires; trapped casualties). Chapter 8 has shown that the planning behaviour of the Fire Service incident officer, in sending their vehicles to the Police Service access points, so the appliances are utilisable, was according to their plan. However, the access points are unsuitable – the fire appliances are not utilisable. The plan consulted by the Fire Service incident officer has inappropriate information with regards to access point set-up. Thus, a potential solution to this problem is to re-specify the Fire Service plan (access point location should be set-up in consultation with the Fire Service), such that actual performance equals desired performance for having utilisable Fire appliances, i.e. the Fire Service appliances are utilisable and resource costs acceptable.

Thus, it has been shown that the EMCRS models developed within this research are indeed diagnostic models of the EMCRS as they can be used to diagnose planning and control co-ordination design problems, and support reasoning about how to prescribe potential planning and control design solutions. The EMCRS models thus constitute HCI substantive knowledge in support of EMCRS design problem diagnosis and reasoning about potential design solutions.

9.1.2 HCI-PCMT extension

The scope of the HCI-PCMT framework needed to be extended in order to be applied to the EMCRS. The HCI-PCMT framework , as shown in Chapter 2, Figure 2, has a representation and a set of axioms for producing diagnostic design models. The framework axioms for EMCRS have been presented in Chapter 4. The EMCRS axioms address some of the differences in nature of the EMCRS and the other domains previously modelled by the HCI-PCMT framework. The EMCRS axioms are considered to be extensions to the HCI-PCMT framework. The most important EMCRS axiom relates to how to describe a task and its sub-tasks. This description has important implications for the characterisation of multiple task work and subsequent identification of behaviour conflicts exhibited by the data. Thus, the EMCRS multiple tasks are the individual agency tasks, which are identified as sub-tasks of the domain. These sub-tasks carry out sub-object transformations in the domain, which affect disaster object transformations. Behaviour conflicts are identified, when sub-objects are not transformed as desired. Behaviour conflicts are diagnosed as co-ordination design problems by the EMCRS model. Without the EMCRS axiom extensions co-ordination design problem diagnosis would prove difficult, if not impossible.

Other characteristics of the EMCRS that were different from the previous domains studied by the HCI-PCMT framework, were identified as either issues with the framework representation, or with performance expression using the framework. Solutions to these issues were proposed in Chapter 7, which have been implemented in the final EMCRS Model 2. The latter, therefore, represents a changing worksystem with more than one level of operation and interactions between the levels. The HCI-PCMT framework extension is thus to:

- Represent a changing worksystem with a time-line and + for additional structures;

- Distribute the abstract cognitive structures across the different levels of the system and have input and output communication structures to represent interactions between the levels.
- For accurate performance expression of the EMCRS, where there are trade-offs between different parts of the system, Single Agency models giving individual agency performance with respect to their plans have been developed. HCI-PCMT framework extension would thus require the development of models for individual parts of the system with respect to their plans.

These HCI-PCMT framework extensions will be discussed in Section 9.2.

9.1.3 Method for Diagnosis

In Chapter 6, a method for co-ordination design problem diagnosis was proposed. Further additions to the method were presented in Chapters 7 and 8. This method has been applied to diagnose the EMCRS co-ordination design problems. Thus, the method has been operationalised and tested by the current researcher. The method is, however, initial – it would need further development for operationalisation and testing by other researchers. It has, however, been shown to be useful in its current application – EMCRS co-ordination design problems have been diagnosed. Future work would be to develop the method, so that it can be operationalised, tested, generalised and so validated.

9. 2 Generalisation

This research has presented diagnostic models of the EMCRS. These models have been developed through application of the HCI-PCMT framework, that was extended for application to the EMCRS domain. It is believed that the extended framework can be generalized in the following ways:

- The HCI-PCMT framework was extended to represent a changing worksystem. This issue is to be found in any complex system that does not have stable membership, e.g. changing battle-field formations; public services with peak demands etc. Time-slicing and a way of representing additional structures have been proposed as a means of describing such systems. Thus, the HCI-PCMT framework extension should be applicable to other systems with changing worksystems.

- The HCI-PCMT framework was extended to represent different levels of operation, and interaction between horizontal and vertical levels of the system. This issue is to be found in any complex system, where only certain parts of the worksystem interact directly with the domain, and where there are different levels of management, e.g. a hospital; military formations etc. The solution for this issue was to specify within the representation the different structures at the different levels of management, and to include a specific structure (input and output communications) to represent interactions within and between levels. This framework extension should, thus, be applicable to other systems similar to the EMCRS as described above.
- The HCI-PCMT framework has been extended to represent effective system performance, when there are trade-offs between different parts of the system. This last issue is to be found in any system, where there are trade-offs between different parts of the system, which affect performance, e.g. a university; system development etc. Performance can be expressed with respect to the resource costs, required by the worksystem and the desired quality of the work, carried out by the worksystem. Thus, the way forward for this last issue, is to break down the system into its component parts and model each separately. The result will provide an expression of performance in terms of the resource costs and the quality of the work carried out (with respect to domain object transformations) for the tasks of each component part. Then, by remodeling the complete system using these performance expressions, the system trade-offs become specified and ineffective performance of the whole system identified. This framework extension should, thus, be applicable to all systems where there are trade-off between different parts of the system that affect performance.

9.3 Short-comings and Future Research

The first issue that must be discussed is the EMCRS data. It is understood that data from a real disaster would give the EMCRS model greater ecological validity, rather than using data from training exercises. Access to such data, is, however, complicated, and most of the data would also be confidential, and thus, not ideal for use in a PhD thesis, which is published in the public domain. People with access to such data (for example, senior emergency service training and research personnel) should, however, be able to apply the current framework to such data, and produce models that would support co-ordination design problem diagnosis. However, due to the complex nature of the EMCRS, data at any lower level of description, than presented in the training exercises, would have been very difficult to analyse effectively. Also, the EMCRS is a management system for co-ordination of the planning and control in response to disasters. Thus, the EMCRS is specified at a high level, with respect to the operational, tactical and strategic levels of command. The EMCRS does not specify within a service how each individual person should co-ordinate with respect to their individual agency roles. The training exercises, where the EMCRS data were gathered, were set-up specifically to train the emergency service officers in how to use the EMCRS for the management of response with respect to operational, tactical and strategic levels of command. Thus, the trainees were all emergency service officers, and not operational level personnel. The exercise data were thus viewed as appropriate for modelling the EMCRS, for planning and control of the different command levels for disaster response. The aim of the research was to model the EMCRS to diagnose design problems, but more specifically planning and control co-ordination design problems. Thus, again data at this level of detail were considered appropriate for meeting the current aims. However, one problem of the data only being at a high level of detail has been identified in the previous section, when attempting to offer potential design solutions to the diagnosed design problem. In Co-ordination Design Problem 1, it is not clear whether operational personnel are not carrying out their commanders' orders, or whether the commander has specified the orders incorrectly. The data are not at a low enough level of detail to specify operational procedures, and thus the design problem is not expressed at a suitable level of detail, such that a definitive design solution can be proposed. This situation would be remedied with more detailed data gathered from either an actual disaster, a live exercise, or even a table-top training exercise.

Of course, there are other issues with the data, most importantly how it was recorded. Video and/or voice recording were not permitted within the training exercises. For later analysis, data that have been either video recorded, or voice recorded, are more robust than hand recorded data as they can later be amplified. The expertise of the data gatherer (researcher), with respect to this type of data recording, needs to be demonstrated. The researcher had worked on many research projects, which involved cases where data needed to be recorded for later analysis. This data recording was sometimes in the form of structured/semi-structured interviews that could only be recorded manually, due to confidentiality of the system under analysis (ACTS project Memo, 1997). The researcher, thus, had previous expertise in recording and analysis of data from note taking. Future work would therefore involve validation of the EMCRS model by application to data from an actual disaster. It is believed, however, that the co-ordination design problems diagnosed by the EMCRS model have merit with respect to 'real' EMCRS performance. The diagnosed co-ordination design problems were discussed with the emergency planning research group at the Home Office, who were persuaded of their existence and importance.

Within the EMCRS data, there were further potential behaviour conflicts, that could have been diagnosed as co-ordination design problems by the EMCRS model; for example, it is not only the Fire Service who trample the site, and thus do not preserve the crime scene, but also the Ambulance Service. Future work could use the EMCRS models to diagnose other potential design problems, and propose potential solutions to these problems.

The extensions to the scope of the HCI-PCMT framework have been discussed above. The extensions are related to the differences in the characteristics of the EMCRS system and the previous systems modelled by the HCI-PCMT framework. Each difference was identified as an issue for the framework, and solutions were proposed for each issue, which were implemented in the final EMCRS Model 2. There may be other solutions to these issues. Using a time-line and a + for additional structures was the solution implemented here, for representing a changing worksystem. Within the current research, this solution was seen as adequate mainly for model representation purposes, but also with respect to the level of detail of the data. More realistic data would involve more detailed model representation of the physical worksystem structures, and the changes in the worksystem would be more dynamic, i.e. there could be changes every few minutes. Using a time-line and an + for representation of additional structures might, therefore, be unsuitable and so a different solution to this problem might be required. The solutions to another issue – having input and output communication structures, for representing interactions within and between levels - is considered as a solution that would be expected to tolerate the test of real data. The reason is because this solution relates to the abstract description of the worksystem, and so more detailed data could be accommodated. More important in this solution is the representation of the different behaviours that are carried out by the different levels of command – i.e. that the tactical level only perceive through the operational level, and that the execution behaviours are only carried out by the operational level. These abstract structure distributions across the command levels have a great importance in the EMCRS response management; for example, tactical level personnel should not get involved with operational level executions. If they do, then EMCRS management will not be effective.

The last issue – that of accurately expressing EMCRS performance, when there are trade-offs between different parts of the system, and its solution - to model each agency individually with respect to its plans, is seen as a suitable and robust solution. The EMCRS performance diagnoses with respect to the individual agency plans, enabled more detailed design problem specification, such that potential design solutions could be proposed. The EMCRS models and accompanying extension to the HCI-PCMT framework are viewed as substantive HCI knowledge to support directly, diagnosis of EMCRS design problems and, indirectly, prescription of design solutions. Without the Single Agency models, the diagnosed design problems could not be verified, as possible solutions could not have been proposed. Thus, without this extension to the HCI-PCMT framework, verifiable diagnostic models of the EMCRS would not have been produced.

9.4 Summary

This thesis has presented research, constituting HCI substantive design knowledge, in the form of models that support diagnosis of design problems and reasoning about solutions to these problems. Such models have been developed. The EMCRS models diagnose EMCRS coordination design problems and support reasoning about solutions to these problems. The models were developed through application of the HCI-PCMT framework to data obtained from EMCRS training exercises. The HCI-PCMT framework had to be extended for this application. The extensions to the framework are generalisable to other systems with similar characteristics to the EMCRS. To support co-ordination design problem diagnosis with the EMCRS models, a method was proposed. This method is initial and must be further developed for operationalising and testing. However, it has been applied in the current research, albeit by the method developer, and thus, has been shown to aid in EMCRS model diagnoses. Future research would develop this method for operationalisation, testing, generalisation and so validation. The EMCRS data gathered for this research were from training exercises. Future research would apply the extended HCI-PCMT framework to more realistic data to verify the EMCRS model diagnoses.

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Appendices

Appendix 1

Exercise Scorpio Dataset 1

Raw data	Comprehensive data
SECTION 1	**View from single disciplinary syndicates**
Consideration 2: likely problems to face organisations	
1 Police problems	***The Police Service syndicate view of the likely problems facing the Police Service when responding to the major incident***
Data 1. 1 a) Major incident declared so gold control set up.	Gold control is the strategic level of command – once a major incident is declared a strategic level of command will be set-up (it may not actually be used). It is the police responsibility to co-ordinate the strategic roles of all the emergency services initially.
Data 1. 1 b) Scene protection	Police need to protect the scene as there is evidence of vandalism and thus the scene is declared a crime scene so evidence will need to be gathered. (There is a difference between the 'scene' and the 'site' – the 'site' is the whole area involved and the 'scene' is the nucleus where the main problems relating to the major incident are happening.)
Data 1. 1 c) Scene access - chaos	It will be difficult for the Police Service to control access to the scene, as the Fire Service will want to fight fires and the Ambulance Service want to get at the casualties.
Data 1. 1 d) Public warnings	As the incident is in a busy market town on market day it will be difficult to get information to the public.
Data 1. 1 e) Helicopter landing site	Where could the helicopter land? Problem to sort out a site.

Data 1. 1 f) Incident log - start early	Need to keep a log of the incident – must start early as otherwise will not be able to keep track of the incident.
Data 1. 1 g) Lack of information	Chaos at the scene so information flow will be poor.
Data 1. 1 h) Lack of resources	Will not have enough resources from local area.
Data 1. 1 i) Access to scene	As there are fires and hazardous materials access to the scene will be difficult for the Police Service as they will not have protective clothing.
Data 1. 1 j) Command structure	Need to keep to the gold, silver, bronze (strategic, tactical, operational) command structure to ensure proper management of the situation, and to enable good co-ordination with the other services.
Data 1. 1 k) Control room	Where will the control room be located- setting up is important.
Data 1. 1 l) Support control room staff	Lots going on and the control room staff are going to get very stressed, so will need support.
Data 1. 1 m) Information overload on phones - use BT RAYNET	BT RAYNET stands for the Radio Amateurs Emergency Network Ltd. RAYNET is a national voluntary organisation of licensed Radio Amateurs who provide additional communication facilities for the emergency services, public utilities and Government departments. It is a specialist system of communications that can be used by the emergency services in a major incident situation.
Data 1. 1 n) Co-ordination of other services - roles and responsibilities	Police Service are responsible for co-ordination of the response – need to make sure know which roles and responsibilities each Police officer has so that they can control the co-ordination with the other services.

Data 1. 1 o) Evacuation - advice needed from fire and others	There are general public in the buildings surrounding the scene; as there is potential for further explosions, need to evacuate these people, but get advice from the Fire Service for best means, routes for evacuation. Liaise with the Ambulance Service about evacuees who may be house bound etc.
Data 1. 1 p) Casualty clearance/ numbers	Casualties, as a generic term for Police purposes, fall into the categories of uninjured, injured, survivors, and deceased. The Police Service are responsible for clearing all these people, including recording their details, and at this incident there are a lot of casualties so this will be problematic.
Data 1. 1 q) Sightseers- control	Difficult to keep sightseers away.
Data 1. 1 r) Equipment	Will need equipment that is not already available, for specialist tasks.
Data 1. 1 s) Media	Keeping the media informed so that they will not get in the way of the services. They are still bound to be a problem.
Data 1. 1 t) Where should the RVP's go? Leaking fuel and running fires	An RVP is a Rendezvous point. The Police Service need to set up RVP's for the ambulances, police cars and fire appliances that arrive at the site. It is a problem where they should go due to the leaking fuels and running fires.
Data 1. 1 u) Mobility of cordon	May need to move the cordon, which will be a problem as extra personnel will be needed and deciding where to move it will be difficult.
Data 1. 1 v) Scale of incident time span resource allocation	Working out the resources required, over what time span, need to be based on the scale of the incident which will be difficult to work out at the beginning.

Data 1. 1 w) Vehicle removal	Having to remove vehicles, potentially damaged could be a problem as need to keep access and egress routes clear for the other services. Also need to remove vehicles to return to normality the disaster site. Will need to get the vehicle removal units on site soon.
Data 1. 1 x) Coroner	Need to get hold of a coroner. This may take some time - until the Coroner has arrived bodies cannot be moved.
Data 1. 1 y) Senior investigation officer manage crime scene	As it is a crime scene will need a senior investigation officer from the British Transport Police to manage the crime scene who may not be available immediately.
Data 1. 1 z) Safety of officers	Officers will not have the correct protective equipment to start with and will be required to help with rescue and may get hurt.
2 Police view of problems facing other emergency services.	***The Police syndicate view of the problems facing the other emergency services response.***
Data 1. 3 a) Access in and out of the scene	Ambulances not only need to get in to the scene but need to get out. Fire Service vehicles need to get to the scene and need good access.
Data 1. 3 b) Marshalling area	Where the marshalling area is situated may not be ideal for the other services.
Data 1. 3 c) Lack of information	All services will at the beginning be uniformed about the situation
Data 1. 3 d) Communications	Communication between and within services will be problematic until proper communications systems are set-up and even then communications are often a problem.
Data 1. 3 e) Numbers of casualties	There are many casualties who need to be seen to.
Data 1. 3 f) Safe area for casualties	Finding a safe area for casualties will be a problem due to the fires and leaking fuels.

Data 1. 3 g) Ambulance Service conflict with Fire Service re safety clothing etc. (similar problems for the Police Service too)	The Fire Service set-up an inner fire cordon to protect all personnel. No-one will be allowed access without regulation safety requirements as specified by the Fire Service.
Data 1. 3 h) Flow of information	Flow of information within a service will be problematic due to the chaos at the scene.
Data 1. 3 i) Escalation of the incident	As there are fires, and leaking fuels, the incident is likely to escalate.
3 Police conflict with other agencies.	***The Police Service syndicate view of the Police Service conflicts with the other agencies.***
Data 1. 3 j) Scene preservation/ fire exiting	The Police Service want to preserve the scene as it is a scene of crime. The Fire Service when they are exiting the scene will trample the site and cause damage.
Data 1. 3 k) Evidence gathering	The Police Service want to be able to gather evidence to ascertain the cause of the incident. The Fire and Ambulance Services will be trampling the scene when they are dealing with the casualties and the fires etc.
Data 1. 3 l) Witness/ casualties	The Police Service want to make sure that they have information about all potential witnesses so that they will be able to find out the cause of the incident. These witnesses may be casualties and be transported to hospitals before the Police Service can record their personal information in the casualty bureau.
4 Fire Service problems	***The Fire Service syndicate view of the likely problems facing the Fire Service when responding to the major incident.***
Data 1. 4 a) Explosion - plume	There is a plume of smoke from the initial explosion, which will causes visibility difficulties. Aviation fuel is not explosive, but the fumes are.

Data 1. 4 b) Health and safety issues	Fire Service are responsible for safety of all emergency service personnel within the inner cordon.
Data 1. 4 c) Communication within agency and with other agencies	Communications will be problematic due to the chaos of the incident initially
Data 1. 4 d) Fire fighting and escalation prevention	Will need a lot of Fire Servicemen and Fire appliances to control the fire and to prevent escalation of the disaster, which will not be available straight away.
Data 1. 4 e) Controlling resources - water, marshalling - maintain normal service	Deciding which resources are required where, what available water there is, and marshalling the vehicles will be problematic. Maintaining normal services elsewhere will be problematic as many Fire personnel and appliances will be required for the incident.
Data 1. 4 f) Cordons access controls - who sets them up, need early inter-service talks	There can be different cordons set up and who controls them should be discussed. If the Police Service have control it can be problematic for the Fire Service for access.
Data 1. 4 g) Primary priority fire get dragged off to casualties	The Fire Service primary priority is to fight the fire, but they will get dragged off to the casualties to rescue them from areas the Ambulance Service cannot reach.
Data 1. 4 h) Floating fuel on the river	The fuel will be an environmental hazard that the Fire Service are responsible for sorting out.
Data 1. 4 i) Bleve risk wind speed and direction	Need to find out the wind speed and direction as there is a risk of a 'bleve' -blowing of the explosion plume - which will cause contamination and cause problems for all services health and safety.
Data 1. 4 j) Life saving and fire fighting	Need to fight the fires but also help save life conflict as to which resources to put for which role.

Data 1. 4 k) Evacuation - safety	Need to make sure that people can be evacuated safely and this is the responsibility of the Fire Service.
Data 1. 4 l) Water/foam supplies	There are a lot of fires which will need water to put them out, where will the water come from. Foam can be used for the aviation fuel, but it will need to be supplied from somewhere.
Data 1. 4 m) Command and control issues – forward and sector - liaison	There will be forward and sector controls, who is in command can be a problem will need close liaison.
Data 1. 4 n) Assistance to other services during early stages limited to silver control	As the fire will be priority at the early stages the first Fire Service personnel on site will need to focus on this and will not be able to assist the other services. Silver control is the tactical level, or in this case the Incident officer.
Data 1. 4 o) Site preservation for evidence and inquiries	The fire needs to be controlled as does the aviation fuel and in so doing the Fire Service will trample the site. The Fire Service need to try and keep trampling to a minimum so that the site is preserved for evidence. This will cause problems for the Fire Service as keeping trampling to a minimum will reduce their performance with respect to controlling the fires etc.
Data 1. 4 p) Fire fighting and escalation prevention	Will need lots of personnel in order to fight the fire and prevent escalation of the disaster, which will be a problem at the beginning.
Data 1. 4 q) Access to incident sites, road and rail problems for evacuation	As the incident is on a railway line that cuts the main road in half, getting access at the required incident sites will be difficult especially for evacuation

Data 1. 4 r) Cordons need safe working area, identify whether safe for other emergency services to operate	Fire Service are responsible for safety of all emergency services at the scene. An inner fire cordon is set-up to protect personnel. Emergency service personnel other than Fire Service will not be allowed access unless the Fire Service believe that the area is safe for them to work.
5 Fire Service view of the main problems facing the other services.	***The Fire Service syndicate view of the main problems facing the other services in response to the exercise.***
Data 1. 5 a) Site preservation for evidence and inquiries difficult for Police Service	The Police Service will find it hard to preserve the site as the Fire Service will be trampling the site when fire fighting etc.
Data 1. 5 b) Police crime investigation people, evacuation of the area	The Police crime investigation people will find it hard to gather evidence due to the chaos of the scene. Evacuation by the Police Service will be difficult due to the hazards at the incident.
6 Fire Service conflict with other agencies.	***The Fire Service syndicate view of the Fire Service conflicts with other agencies.***
Data 1. 6 a) Health and safety problems – identify whether safe for other emergency service personnel to operate within the cordon	Fire Service are responsible for the safety of all emergency service personnel at the scene. Due to the hazards for the other services they need the right level of safety equipment to enter the cordon as.
Data 1. 6 b) Site preservation for evidence and enquiries	The Fire Service will be trampling the site and destroying evidence so that the Police Service will have problems with evidence gathering.
7 Ambulance problems	***The Ambulance Service syndicate view of the likely problems facing the Ambulance Service when responding to the major incident.***
Data 1. 7 a) Communications	Problems with communications within the Ambulance Service.
Data 1. 7 b) Forward control of Ambulance Service where?	Due to the hazards it will be problematic to find a good site for the Ambulance Service forward control.

Data 1. 7 c) Movement, destination and priority of pick-up	Problems with the movement of Ambulances, deciding priority of pick-up of casualties and the destination hospitals. Need forward control set-up to co-ordinate.
Data 1. 7 d) Basics medical support not available in all areas	British Association of Immediate Care Schemes - BASICS is a voluntary national organisation consisting of groups of doctors and individual doctors providing immediate medical care throughout the country. BASICS doctors can be called out by any of the emergency services 24 hours a day, 365 days a year via locally agreed contact points. Not necessarily available in all areas.
Data 1. 7 e) Manpower - A & E crews available, 50% of resources already committed	There will be some accident and emergency crews available, but 50% of all ambulance resources are already committed so getting enough manpower will be a problem.
Data 1. 7 f) Non emergency crews (skill, training, stress, health and safety)	Non emergency crews can be used, but there are problems with their skill level, training, stress and their health and safety.
Data 1. 7 g) Availability and experience of others - Red Cross, St John's ambulance	Red cross and St John's ambulance may be available, but not necessarily and if they are they may not have the right experience.
Data 1. 7 h) Staff safety at scene	There are lots of hazards at the scene and the ambulance staff probably do not have the right level of safety equipment so safety will be a problem.

Data 1. 7 i) Inter-agency communications and control of site access	Although there are communication systems set-up for all the services to communicate between each other, the communication can still be problematic, and information not flowing helpfully. Ambulances need good site access, to get in and get out to transport casualties and they need the control of the site access to be sensible.
SECTION 2	**View from multi-disciplinary syndicates**
Consideration 3: co-ordination of response	
8 Media	
Data 1. 8 a) Policy	Policy for dealing with the media needs to specified early on.
Data 1. 8 b) Interim statement	Interim statement produced for the media.
Data 1. 8 c) Vantage points	Vantage points for the media decided upon.
Data 1. 8 d) Media centre - where?	Where should the media centre be?
Data 1. 8 e) Regular meetings	Hold regular meetings with the media.
Data 1. 8 f) Co-ordinated press releases	Co-ordinate press releases.
Data 1. 8 g) Access to site	Should access to the site be allowed for the media?
Data 1. 8 h) Liaison officers	Allocate liaison officers to deal with the media.
9 Cordons	
Data 1. 9 a) inner cordon - police? Fire?	Cordons - inner cordon who should be responsible, Police or Fire? (An inner cordon is set up by the Fire Service.)
Data 1. 9 b) outer cordon -traffic diversions	Outer cordon set up by the Police Service with traffic diversions required.
10 evacuation and assembly areas	
Data 1. 10 a) Safe place for initial removal	Require a safe place for initial removal.
Data 1. 10 b) Records needed - names and addresses	Need to get names and addresses of everyone for records.
Data 1. 10 c) Possible longer term accommodation needs	Need to find places for possible longer term accommodation needs.

11 Survivors, friends and relatives reception centres	
Data 1. 11 a) Separate locations	Need to have separate locations for survivors and friends and relatives.
Data 1. 11 b) Log in and log out names and addresses	Everyone must be logged in and out with names and addresses.
Data 1. 11 c) Security - media infiltration	Require security to sop media infiltration.
Data 1. 11 d) Documentation who records	Need to have specialist documentation teams.
Data 1. 11 e) Telephones	Set-up of telephones is a priority.
12 Access - Marshalling rendezvous points	
Data 1. 12 a) Safety	Need to make sure that all access, marshalling and rendezvous points are safe.
Data 1. 12 b) Helicopter landing Medevac	Need a helicopter landing site for Medevac (medical evacuees).
Data 1. 12 c) Large area think Big	Need a large area for marshalling and rendezvous, bigger than you think.
Data 1. 12 d) Good access -protected routes if possible	Routes which provide good access and are not through danger zones are preferable.
13 casualty clearing	
Data 1. 13 a) Receiving station close to site - triage	Need a receiving station for casualties close to the site where triage of casualties can take place.
Data 1. 13 b) Ambulance loading point	Need to set up a loading point for ambulances.
Data 1. 13 c) Body holding - police responsibility, death confirmation, followed later by death certification	Need a body holding area controlled by the Police Service, to hold bodies once they have been confirmed dead, and before death certification.
14 Body holding area	
Data 1. 14 a) No mortuary procedures are carried out here	Need a body holding area set up, but this is just an area for bodies not for mortuary procedures.
15 temporary mortuary	
Data 1. 15 a) Full mortuary procedures are carried out here	Need to set up a temporary mortuary where full mortuary procedures can be carried out

Appendix 2

Exercise Scorpio Dataset 2

Raw data	Comprehensive data
Consideration 1: organisations and their roles/responsibilities	***View from multi disciplinary syndicates.***
Data 2. A 1) Fire Service standard pre-determined attendance for a train crash	Fire Service initial response is the pre-determined response for a train crash.
Data 2. A 2) Cordon Police responsible who else help?	Police responsible for cordon will Fire Service help too?
Data 2. A 3) Rescue Fire 3 pumps and an emergency rescue tender	Three water pumps for fighting the fire and an emergency rescue vehicle for rescue
Data 2. A 4) Police RVP, cordon, access and egress, document anyone leaving	Police are responsible for the rendezvous points, cordon, access and egress to the site and must document anyone coming in and leaving.
Data 2. A 5) Ambulance mobilise as many vehicles as possible and many senior people. RV point not direct to scene sorted by senior officer.	Ambulance Service will need as many vehicles as possible and will need senior people to co-ordinate the operation. A rendezvous point should be sorted by a senior officer for Ambulances outside the scene.
Data 2. A 6) Widen cordon	Due to hazards, and number of people who will need to be within the cordon, the cordon will need to be widened.
Data 2. A 7) Fire - immediate rescue and control of fire	The Fire Service are responsible for immediate rescue and control of the fire.
Data 2. A 8) Ambulance holding area, casualty control	Need an Ambulance holding area as will not want all ambulances at scene at once, so can control the movement of casualties.
Data 2. A 9) National rivers and water authority	Need to inform the national rivers and water authority as there is aviation fuel running into the canal and the river.

Data 2. A 10) Fire cordon explosion (600m) 100m structural damage	Set up fire cordon by the Fire Service one for protection from explosion at 600m and one for protection from structural damage at 100m from the nucleus of the incident.
Data 2. A 11) Police scene management	Police Service are responsible for management of all the services within the scene.
Data 2. A 12) Ambulance casualty collecting point - triage, ambulance rendezvous point distinct so that they can get away quick.	Need an ambulance casualty collecting point where triage is taking place and an ambulance rendezvous point which is at a separate location so movement of ambulances is efficient.
Data 2. A 13) Ambulance squads cascade calling system	Set up cascade calling system to alert ambulance squads.
Data 2. A 14) Social services support team at hospitals	Request social service support teams at hospitals.
Data 2. A 15) Declare major incident after 15 minutes	Major incident declared after 15 minutes of assessment (the type of incident, the number of casualties and the chaos at the incident site have lead to the major incident being declared).
Data 2. A 16) Coroner	Need to inform the coroner of the incident as he/she will have to confirm victims are dead before the bodies can be moved.
Data 2. A 17) Environmental agencies – environmental experts	Need environmental agencies involved as there are environmental hazards and the expertise of these agencies will be required.
Data 2. A 18) Local authority technical services	Need local authority technical services to be activated to aid in the response.
Data 2. A 19) Hospital support teams/other	Hospital support teams and other hospital teams need to be set-up.
B) ***Police response***	***View from multi-disciplinary groups***
Data 2. B 1) 1 person assess situation	The first person on the scene must assess the situation and pass information to the Police Service, but must not get involved in any response to the situation.

Data 2. B 2) Major incident - cordon (initial) controllable with number of people got access to and from.	Major incident declared, an initial cordon must be set-up to control access to and egress from the incident site.
Data 2. B 3) Crime scene - witness and possibly scene management offenders	Due to the potential of vandalism causing the incident the scene must be treated as a crime scene. Need to treat all at the scene as witnesses. Need to be aware of scene management offenders and protect the scene.
Data 2. B 4) More people widen cordon.	As more people arrive at the site must widen cordon to allow access.
Data 2. B 5) Emergency Services RVP.	Set-up the emergency services rendezvous point.
Data 2. B 6) Two marshalling areas for a through flow	Set-up two marshalling areas for a through flow of emergency service vehicles.
Data 2. B 7) Below canal 1 RVP	One rendezvous point situated below the canal.
Data 2. B 8) Make sure ambulance have access	Need to make sure that the Ambulance Service have access to the site to collect casualties.
Data 2. B 9) RVP for changing crews over - incident control police keep flow going	Set-up a (RVP) rendezvous point for changing over crews. Make sure that the flow of emergency crews is controlled, to keep response to incident stable.
Data 2. B 10) Ambulance holding area a distance away.	Set-up an ambulance holding area a distance away from the scene to allow easy access and egress for ambulances
C Fire response	***View from single disciplinary groups***
Data 2. C 1) Stem flow of ruptured tanks	Stop the flow of aviation fuel from the ruptured tanks on the train.
Data 2. C 2) Reconnaissance need other assistance	Will need help from the Police Service to survey the scene and ascertain what response is needed.
Data 2. C 3) Establish route and marshalling area	Need to work out best route for Fire Service vehicles for best access to the scene, and a marshalling area that coincides with the route

Data 2. C 4) Liaise with the Police Service with the assistance of safe routes	Need to let the Police Service know which routes to the scene are safe.
Data 2. C 5) Inner cordon	Set-up an inner fire cordon to protect emergency service personnel and others from injury.
Data 2. C 6) Evacuation of residents with local police	Need to carry out the evacuation of local residents will need information from the local Police as to which residents need evacuation and the local Police will also help in the evacuation.
Data 2. C 7) Involved with rescue liaise with the Ambulance Service	Will need to be involved in rescue of casualties, will need to liaise with the Ambulance Service to find out how they can help.
Data 2. C 8) Stemming the flow	Need to stop the flow of aviation fuel.
Data 2. C 9) RTA 4 bronze commanders	Road traffic accident requires 4 Bronze commanders
Data 2. C 10) Fire station silver control point	Set-up silver control (tactical level of operations) at the fire station.
Data 2. C 11) Ambulance quick liaison with Fire Service of the number of casualties	Ambulance Service need to liaise with the Fire Service quickly to find out the number of casualties so the number of ambulances required and receiving hospitals can be informed.
Consideration 2: likely problems to face organisations	***View from single disciplinary groups.***
1 Police problems	
Data 2. 1 a) Major incident declared so gold control set up.	It is the Police Service responsibility at a major incident to initially co-ordinate the strategic roles (gold control) of all the emergency services and other organisations involved.
Data 2. 1 b) Manpower mutual aid from neighbouring forces	Will need a lot of manpower - the local force will not have enough personnel so requests will need to be made to neighbouring forces for help.

Data 2. 1 c) Evidence gathering and preservation	As the scene is now a crime scene will need to preserve the scene so that evidence can be gathered.
Data 2. 1 d) Support control room staff	Lots going on and the control room staff are going to get very stressed, so will need support.
Data 2. 1 e) Communications – scene. Access overload BT RAYNET	Communication at the scene will be problematic. If there is access overload on the communication channels then BT RAYNET can be contacted. RAYNET stands for: Radio Amateurs Emergency Network Ltd. RAYNET is a national voluntary organisation of licensed Radio Amateurs who provide additional communication facilities for the emergency services, public utilities and Government departments.
Data 2. 1 f) Control of traffic and crowd control (public order)	Problems with traffic control especially as the incident has effectively cut the town in half, and need to divert non-emergency traffic away from the scene. Crowd control may be a problem.
Data 2. 1 g) Evacuation hazards - advice needed from fire and others	There are general public in the buildings surrounding the scene, as there is potential for further explosions, need to evacuate these people, but must find out from the Fire Service best means and routes for evacuation, and liaise with the Ambulance Service with regards any evacuees who may be house bound etc.

Data 2. 1 h) Casualty bureau set up	Need to find a suitable place to set-up the casualty bureau. The purpose of the Casualty Bureau is to provide a central contact and information point for all records and data relating to persons who have, or who are believed to have been, involved in an incident. It has three fundamental tasks: to **obtain** relevant information on the persons involved, or potentially involved; to **process** that information; and to **provide** accurate information to relatives and friends, the Investigating Officer and H.M. Coroner.
Data 2. 1 i) Casualty clearance	Casualties, as a generic term for police purposes, fall into the categories of uninjured, injured, survivors, and deceased. The Police Service are responsible for clearing all these people, including recording their details, and at this incident there are a lot of casualties so this will be problematic.
Data 2. 1 j) Control of scene and elsewhere	Police Service are responsible for keeping control – this will be problematic as the scene is complex with lots of hazards, and the site is in the middle of a busy town.
Data 2. 1 k) RVP's possibly 2?	Possibly set-up two rendezvous points – one either side of the incident so emergency vehicles can have easier access and egress.
Data 2. 1 l) Press liaison (PRO)	Need to set-up press liaison early to keep the press informed, to stop the press from being a nuisance.
Data 2. 1 m) Coroner	Need to get hold of a Coroner. This may take some time - until the Coroner has arrived bodies cannot be moved.

Data 2. 1 n) Senior investigation officer manage crime scene	As it is a crime scene will need a senior investigation officer from the British Transport Police to manage the crime scene who may not be available immediately.
Data 2. 1 o) Welfare of own people at scene (Local authority rest centres)	Need to make sure that the officers at the scene are looked after – find out where the local authority rest centre has been set-up and inform the personnel.
Data 2. 1 p) International implications Foreign embassies, interpreters foreign office, VIP to scene	As there were foreign tourists on the bus, this incident has international implications, so the foreign embassies will need to be contacted, interpreters found and VIPs may arrive at the scene who will have to be managed.
Data 2. 1 q) Finance who pays?	Strategic command need to work out who is paying for the emergency response resources etc.
Data 2. 1 r) International body handling people (KENYONS)	For international body handling the KENYONS can be contacted. The Kenyon Emergency Service are specialist funeral directors with experience in operating at the scene of disasters, where the death toll is high.
Data 2. 1 s) Consider hospitals - give hospital reception teams	Need to send hospital reception teams to the hospitals nominated as receiving hospitals for the major incident.
Data 2. 1 t) Major incident advisory team	Contact the major incident advisory team, who will give guidance for operations, based on previous experience of major incidents. The team comprises police officers each of whom has personally been responsible for certain operational aspects of disaster management. The team will not take over the running of the disaster response, but just give advice.

2 Police Service view of problems facing other emergency services	
Data 2. 2 a) Access in and out of the scene	Ambulances not only need to get in to the scene but need to get out. Fire Service vehicles need to get to the scene and need good access.
Data 2. 2 b) Resources	It is a large incident and many resources are going to be required for all services which will be difficult to access.
3 Police Service conflict with other agencies	
Data 2. 3 a) Problems with maintaining the site as a crime scene as the fire and ambulance crews need to rescue casualties and property will be damaged.	The Police want to preserve the scene as a crime scene. The Fire and Ambulance Service need to rescue casualties and in so doing will damage the evidence.
4 Fire Service problems	
Data 2. 4 a) Access: one R.V.P. either side of the bridge with control	As the incident has cut the town in half there will need to be two rendezvous points one either side of the bridge to enable good access.
Data 2. 4 b) R.V.P. initial and 1 hour into the incident	Will need to have an RVP initially and then move it after one hour into the incident as the RVP will be too close to the scene, and not a large enough area to cope with all emergency vehicles.
Data 2. 4 c) Control of the scene	There are many hazards at the scene which the Fire Service will have to control, which will be problematic until enough personnel and equipment are made available.
Data 2. 4 d) Health and safety of all in the scene	Fire Service are responsible for safety of all at the scene – this will be problematic as the scene has many hazards.
Data 2. 4 e) Communication within agency and with other agencies	Communications will be difficult due to the hazards and due to different communications used by each agency.
Data 2. 4 f) Casualty area	Where should the casualty area be sited?

Data 2. 4 g) Terrain and incidents over a wide area	The terrain will be problematic, and there are separate incidents – fires, running fuels, casualties under the bridge, which will all need controlling.
Data 2. 4 h) Environmental problem	Aviation fuel can cause an environmental problem, which the Fire Service will have to deal with.
Data 2. 4 i) Rescue	The Fire Service will have to rescue people due to the hazards at the incident, which will take personnel from fighting the fires and controlling the other hazards at the scene.
Data 2. 4 j) Maintaining normal service – need a multi brigade response – alert other nearby agencies	A normal Fire Service will need to be maintained. This incident will require a lot of resources, so other agencies will need to be alerted to help.
Data 2. 4 k) Incident control room (operations room)	Will need to set-up an incident control room to co-ordinate the response.
Data 2. 4 l) Communications: Fire Service have different channels - need one person from each agency together	The Fire Service use different communication channels to the other services. To maintain close liaison will need to physically have one person from each agency together, probably at the incident control post.
Data 2. 4 m) Foam damage limitation units	If foam is used for the aviation fuel, then will need foam damage limitation units to stop the foam from being an environmental hazard.
Data 2. 4 n) Access for fire fighting and rescue	Need good access - the Police Service set-up the access points which will not necessarily be deemed suitable by the Fire Service which will cause problems for the Fire Service response.
Data 2. 4 o) Health and safety for all (accountability for no's)	Fire Service are responsible for safety of all emergency service personnel within the inner cordon. Need to log personnel in and out as are accountable for numbers.

Data 2. 4 p) Cordons - assistance may be needed	To control access to the inner fire cordon may need assistance from the Police Service.
Data 2. 4 q) Communications - inter agency command channel	Set-up inter agency command channel for communications between all the services.
Data 2. 4 r) Close liaison command and control / sector controls / commander	Need close liaison between the different levels of control.
Data 2. 4 s) Environment issues and water authorities/ canal	There will be problems with the water and canal authorities with respect to the environmental issues of aviation fuel, and the foam for dealing with the fuel.
Data 2. 4 t) Media	Keeping the media away from the scene will be problematic.
Data 2. 4 u) Decontamination areas fire-fighters and others	Need to set-up decontamination areas but where to put them will be a problem.
Data 2. 4 v) Reduce risk of further chemical leak	Problem to stop the fuel from leaking from the other carriages.
Data 2. 4 w) Casualty handling/ help	Will need to help with casualties which will take away resources for fire fighting etc.
Data 2. 4 x) Protective clothing	Protective clothing will need to be worn by all Fire Service personnel at the scene. There needs to be enough protective equipment for all personnel.
5 Fire Service view of the main problems facing the other services	
Data 2. 5 a) Ambulance Service going into hostile areas	Ambulance Service personnel will not be allowed access to hostile areas without the correct protective equipment. Even with protective equipment it will be hazardous for the Ambulance Service personnel.
Data 2. 5 b) Ambulance Service getting enough people at the scene,	There are a lot of casualties and therefore a lot of Ambulance personnel will be required this will be problematic as the personnel are not readily available.

Data 2. 5 c) Ambulance Service no senior officers	Ambulance Service will have no senior officers at the scene initially (the Ambulance Service does not have that many senior officers), which will cause a lack of co-ordination of operations for the Ambulance Service.
Data 2. 5 d) Police crime investigation people, evacuation of the area	There will be problems for the Police crime investigation people due to trampling of the site by the Fire and Ambulance personnel. Evacuation will also be a problem for the Police due to numbers of evacuees, status of the evacuees and safe routes for evacuation.
6 Fire Service conflicts with other agencies	
Data 2. 6 a) Preservation of the scene - trampling	The Police service will be trying to preserve the scene, the Fire Service will be trampling the scene when carrying out their response.
Data 2. 6 b) Access of appliances	Good access is needed for the fire appliances. The Police Service decide where the access points will be which will not necessarily be where the Fire Service want them.
Data 2. 6 c) Safety of personnel, not necessarily equipped to the fire brigades satisfaction	The Fire Service are responsible for safety of all personnel at the scene, who will not necessarily have the right level of protective equipment, and will therefore, not be allowed access.
Data 2. 6 d) Inner cordon entrance and exit	The inner cordon entrance and exit will need to be controlled by Fire Service personnel. There will be people who want to have access who are not properly equipped and the Fire Service will have to maintain control.
Data 2. 6 e) Tags etc. as responsible for those going in and out	Need to tag everyone going in and out of the cordon.

Data 2. 6 f) Problem foam is an environmental hazard (use for the aviation fuel)	The foam that will be used to control the aviation fuel will cause environmental problems.
Data 2. 6 g) Decontamination of ambulances and people (conflict)	The Fire Service have decontamination equipment but do not see it as their responsibility to decontaminate ambulances and people who are not their own personnel, as they will need their personnel for carrying out other primary tasks.
7 Ambulance – problems	
Data 2. 7 a) Responsibility of all patients at the scene	The Ambulance Service are responsible for all patients at the scene. There are a lot of patients and there may be injury to others during the incident, who the Ambulance Service will also be responsible for.
Data 2. 7 b) Resourcing problems both of personnel and vehicles	Will need lots of resources which will not be readily available.
Data 2. 7 c) Liaison at the scene	Liaison at the scene will be problematic due to a lack of senior ambulance officers.
Data 2. 7 d) Forward controls	Forward controls will need senior officers, who will not be readily available.
Data 2. 7 e) Safety at the scene - maintain life get the casualties out	Need to keep Ambulance personnel safe, but also need to maintain life by getting the casualties out. Ambulance personnel will not necessarily have specialist safety equipment.
Data 2. 7 f) Getting medics to the scene not involved with transport of the injured	Will need to get medics to the scene extra to Ambulance personnel, who will need to be alerted and transported.
Data 2. 7 g) Maintaining normal service - day care patients etc.	This incident will require a lot of personnel and equipment, but normal services will need to be maintained as well which will be difficult

Data 2. 7 h) Decontamination of casualties before they are put in the ambulance	Need to decontaminate casualties before they are put in an ambulance, otherwise the ambulance will become contaminated and will be out of action for the rest of the incident.
Data 2. 7 i) Access	Need suitable access for ambulances where casualties can be loaded. The Police decide the access positions which may not be suitable from the Ambulance Services perspective.
Data 2. 7 j) Co-ordination of volunteers - Red Cross, St John's ambulance	Co-ordination of volunteers will require personnel who are potentially required for other tasks.
Data 2. 7 k) Names and addresses of casualties	Recording names and addresses of casualties can be problematic when the casualties are severely injured and with lack of personnel to record the information on site.
Data 2. 7 l) Space to work	Will need space to triage patients, and treat if necessary which could be problematic at this incident due to the incident location.
Data 2. 7 m) Safety at scene - advice from Fire Service	Need to keep personnel safe at the scene – will need to take advice from the Fire Service about where it will be safe for personnel to work.
8 Ambulance Service view of problems facing other emergency services	
Data 2. 8 a) Injury to Fire Service and others	Due to the hazards at the scene the Fire Service and other emergency personnel may be injured.
Data 2. 8 b) Evacuation of buildings may have bedridden people so need to help police	The Police Service are responsible for evacuation. There may be bed-ridden evacuees, whom the Police need to help in evacuating.

Data 2. 8 c) Assist people to casualty bureau	The Police and Fire Services may need to assist people to the casualty bureau, which will take personnel away from carrying out more important tasks.
Data 2. 8 d) Keeping ambulances out of the way but need access	The Police Service will need to keep the Ambulances out of the way, but still allow access.
9 Ambulance Service conflicts with other services	
Data 2. 9 a) Sensible restrictions in the inner cordon	Need access to the inner cordon to rescue/triage casualties. If the restrictions set-up by the Fire Service are too severe, then the Ambulance Service personnel will not conform to the recommended safety requirements and therefore, will not be allowed access.
Data 2. 9 b) Decontamination	There will be contaminated casualties and others at the scene. The casualties will need decontaminating before they are taken from the scene, otherwise ambulances, and Ambulance Service personnel, will become contaminated, as will receiving hospitals who receive contaminated casualties. Any contaminated vehicle, or hospital will be put out of action for the whole incident. The Fire Service have the decontamination equipment so will need to carry out the decontamination. The Fire Service see their decontamination equipment as use for their own personnel, and will be too busy carrying out their own response to the incident to carry out decontamination of others.

Consideration 3: co-ordination of response 10	
Data 2. 10 a) Incident officers – meet every two hours, share core information, agree plan, produce minutes.	The tactical level officers for all services should meet every two hours to share information and agree a co-ordinated plan. Minutes must be produced.
Data 2. 10 b) Standing down after 4 hours	After 4 hours the services will be able to stand down from their major disaster position.
Data 2. 10 c) Need bronze/forward control	Need control at an operational/forward (bronze) level, to ensure co-ordination of operations.
Data 2. 10 d) ACO not go to the scene	Ambulance Commanding Officer not go to the scene.
Data 2. 10 e) Incident control points – outside inner, inside outer cordon.	There should be incident control points set-up outside the inner cordon but inside the outer cordon.
Data 2. 10 f) Inner cordon – canal	The inner cordon should be set-up at the canal.
Data 2. 10 g) Outer cordon rd junction	The outer cordon should be set-up at the road junction.
Data 2. 10 h) 2 marshalling areas	There should be two marshalling areas set-up.
Data 2. 10 i) Rendezvous points to book in and out	There should be two rendezvous points, must book everyone in and out of the points.