USING A FRAMEWORK FOR CO-ORDINATED DECISION-MAKING IN EMERGENCY MANAGEMENT TO ASSESS MULTI-USER SIMULATORS

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ABSTRACT

To assess multi-user training and evaluation simulators, a framework for characterising co-ordination between emergency management (EM) decision-makers is required. The framework presented here concerns decision-making undertaken by individuals within a workgroup. Co-ordinated decision-making requires each decision-maker to consider, and intervene in, the emergency domain *and* the EM workgroup in parallel. Each stream of consideration comprises mental representations with shorter- and longer-term horizons. Decision-making within a given horizon comprises a cycle of perception, assessment, decision and action. Use of the framework to assess multi-user EM simulators is illustrated.

INTRODUCTION

With the spread of flexible, multi-user simulators for emergency management (EM), there are increasing opportunities to train co-ordination between EM decision-makers, and to evaluate an organisation's preparedness to support such co-ordination. To assess the effectiveness of such simulators, a view of the task that session supervisors and scenario writers use them to perform is required. This paper characterises this task as simulation - generating and recording co-ordination issues. In the paper, an initial framework for characterising co-ordination issues in EM is presented. Use of the framework to assess multi-user simulators is then illustrated.

GENERATING AND RECORDING CO-ORDINATION ISSUES

Certain training methods and preparedness evaluation methods specify a common task - the generation and recording of co-ordination issues. An *issue*, here*, refers to a highly selective, special purpose model of the mutual influence of an interactive EM workgroup and an emergency domain (see next section). Generating issues refers to the elicitation and exhibition of such interaction and mutual influence. Recording issues refers to accumulating 'raw data' about such interaction and mutual influence in a retrievable form. Many training methods, both specific to EM and to learning more widely, implicate the generation and recording of issues (e.g. Wiener *et al.*, 1993). Review of issues (simulated or actual) may prompt reflection and discussion, and indicate the kind of additional knowledge or skill that is required. The number and nature of issues may indicate the level of competence acquired by a trainee. Many preparedness evaluation methods also implicate issues (e.g. Seifert and Hutchins 1992). Issues may prompt and inform diagnosis. They may also comprise a key element of evaluative statements. In sum, issues are the potentially instructive, insightful, and provocative findings that support subsequent pedagogic or evaluative activity. Consideration of a simulated or actual issue may support either training, preparedness evaluation, or both, depending upon the activities which precede, go on around, or follow, its generation and recording, and the workgroup and emergency involved. The separation and encapsulation of a common simulation task from related, purpose-specific training or evaluation tasks encourages the development of flexible simulators. Provided that a simulator generates appropriate issues, and records them in appropriate ways, a single simulator may, in principle, be

* In the absence of a desired or expected behavioural 'norm', attribution of error may be problematic, so the less prejudicial term issue is preferred. In EM, there is frequently little or no consensus about the desired behaviour of decision-makers beyond the content of preparedness plan, and even then, the appropriate interpretation of the plan for particular emergency situations may be disputed.

used for either purpose, thus encouraging economies of scale.

To characterise the simulation task of multi-user EM simulators, it is necessary to consider in detail the type of issue to be generated and recorded - issues of co-ordination between EM decision-makers. To this end, an initial framework is presented below. This framework considers the behaviour of EM workgroups and their objectives i.e. what is done, and the human cognitive structures that support such behaviour i.e. what decision-makers think. The framework adopts a cognitive/systems perspective, rather than a social or organisational one, and continues to be refined in the light of its application.

A WORKGROUP MANAGING AN EMERGENCY

According to the framework**, an EM workgroup comprises a set of interactive behaviours (see Figure 1). A number of decision-makers interact with each other (face-to-face and *through* technology) and with technology. These types of interaction are thought to be distinct (Heath and Luff 1991a). The intention of the EM workgroup is to change the state of EM Services in the field, and so influence the emergency domain more widely. An emergency, here, comprises Hazards and 'Protectanda' (entities to be protected). Protectanda comprise EM Services, the Natural Environment and Non-EM systems. EM Services, in turn, comprise People, Equipment and Infrastructure. For example, an EM workgroup may comprise: the on-site chiefs of the Emergency Services and the railways; their respective off-site, local controllers; their radios, telephones and fax machines; and their computer systems, such as resource data-bases and dispersion models etc. This workgroup may seek to reduce the threat posed by three hazards - toxic gas, fire and the electric power to the rail tracks - to many protectanda, including: the Fire, Ambulance and Police Services plus the emergency staff of the railway company; land, air and water resources; and the wider community and its property, such as adjacent rail and road traffic, neighbouring buildings and their occupants. The Fire Service in turn comprises field operatives, hoses, gas masks, fire trucks, etc. and their network of fire hydrants.

CO-ORDINATED MANAGEMENT DECISION-MAKING

According to the framework, emergency management decision-making is supported by two distinct sets of mental representations - one for decision-making with respect to the workgroup, the other for decision-making with respect to the emergency (see Figure 2). Representations about the workgroup or the emergency may be further distinguished according to their temporal horizon - planning representations have a longer-term horizon than execution representations. Planning and execution both comprise four types of representation - perceptions, assessments, decisions and promulgations (literally, representations for making public). Since these representations tend to be up-dated sequentially, they may referred to jointly as a 'cycle'. Thus, there are four cycles of representations - workgroup planning, workgroup execution, emergency planning and emergency execution. Planning and execution cycles are linked - assessments of the current situation may influence the gathering of longer term background (e.g. whether it is necessary to do so), and the plan output may influence the assessment of the current situation (e.g. which features of the situation are of interest). Planning and execution cycles also access, and deposit in, a common information base. This information base includes: (i) preparedness plans of various scope and level of detail, from within-Service procedures to joint-Service, total response plans; (ii) knowledge of emergency response, such as factual information about, for example, the geographic area and dangerous chemicals, together with more general models of, for example, the spread of fire, the effects of counter measures and the life-cycle of an emergency; and (iii) knowledge of EM workgroups, such as factual information about, for example, colleagues' purposes, skills, potential conflicts of interest, and dependencies upon each other, and more general models of, for example, colleagues' communication patterns, responses under pressure, and the impact of alternative workgroup configurations.

This characterisation of the mental structures that support management decision-making behaviour adapts a model of the command and control process† (Richards *et al.* 1985). The primary aim of the adaptation was to associate co-ordination with a distinct and additional kind of decision-making, rather than a simple, automatic 'interface'. In addition to considering and intervening in an emergency, a co-ordinated decision-maker also considers, and intervenes in, the behaviour of their colleagues. Many ethnographic studies (e.g. Heath *et al.* 1993; Heath and Luff 1991b), suggest that effective group working has many diverse and subtle characteristics. For example, effective group working may involve surrepticious monitoring of colleagues' equipment and behaviour, making one's own activities clear to possible on-lookers by the way the

** The framework adapts a view of the interaction of humans with computers (originally devised to support the design of 'user-friendly' computer interfaces (Dowell & Long, 1989).

† The command and control process model was originally devised to support the procurement of military command systems.

activity is done, timing offers of collaboration to coincide with the natural pauses in work, gradual progression towards increasingly collaborative kinds of interaction, designing messages for many types of hearer, broadcasting potentially relevant information whilst minimising interruption, and implicitly encouraging, or explicitly directing, colleagues' behaviour. This paper assumes that such sensitivity and complexity arises from deliberate thought.

To illustrate the framework, let us consider an on-site Fire-Chief responding to a rail accident, at which there is a fire and a leak of toxic gas. With respect to emergency decision-making, on arrival, the Fire-Chief may seek to identify the contents of the rail wagons, the velocity of the wind, and the number and severity of casualties etc. (perceptions of emergency situation). He then forms a view of the dangers posed by the toxic gas and fire (assessment of emergency situation (see Figure 2.)) and decide that, for their own safety, all personnel must wear protective clothing under the plume of toxic gas (decide emergency intervention). Instructions to his men to wear such clothing, and to prevent those not wearing protective clothing from getting too close, are then passed (promulgation of emergency intervention). The Fire-Chief may also monitor the number and rate at which fire trucks are arriving and the speed with which police road blocks either side of the plume are established (perception of emergency background). Together with his assessment of the current situation, he judges that, over the longer term, the planned response is threatened by restricted access to the accident. This restricted access is a result of the combined effect of the electified rail-track and the toxic plume (assessment of emergency plan). He thus plans to turn off the electrical power to the rail-tracks first, thus relaxing the constraints on access, and then get the fire under some sort of control first (decision emergency plans). The Fire-Chief declares this plan to his aides, superiors and on-site chiefs of other EM Services (promulgations of emergency plans). The emergency plan influences future assessments of the emergency situation. For example, the Fire-Chief may be particularly sensitive to the spread of the fire, since failure to stop it spreading may require further planning.

With respect to workgroup decision-making, the Fire-Chief may perceive that the railway Depot Manager has arrived (perception of workgroup situation) but appears somewhat distressed and distracted (assessment of workgroup situation). Consequently, the Fire-Chief decides to 'keep an eye on' the Depot Manager, at least until the power is turned off (decide workgroup intervention). When the Depot Manager is close by, the Fire-Chief may say to his second-in-command (in a voice loud enough for the Depot Manager to overhear), "I'm going to check that the power has been turned-off in a few minutes, and then I'll be able to tell you whether or not the next fire truck to arrive can approach from the other side." (promulgation of workgroup directives). The Fire-Chief may also see that journalists are already arriving - the accident is convenient for the newspaper office (perception of workgroup background). Together with his assessment of the current workgroup situation, he judges that the workgroup plan is threatened by the prompt arrival of an unusually large number of journalists (assessment of workgroup plan). Consequently, the Fire-Chief decides that more police officers than usual will be required to ensure that the cordons are not breached. He also decides that a press officer will be needed on-site sooner than usual to answer journalist's questions (decision workgroup plan). The Fire-Chief may then ask the on-site police chief whether he is arranging this (promulgation of workgroup plan). The workgroup plan may influence future assessments of future workgroup situations. For example, the Fire-Chief may be particularly sensitive to the apparent workload of police officers, since excessive workload may require further planning.

USE OF THE FRAMEWORK

This framework for co-ordinated EM decision-making may be used to describe the co-ordination issues that must be/are generated and recorded in a simulation.

Let us imagine that an emergency management organisation requires a simulator that will generate and record *all* kinds of co-ordination issue. A prototype multi-user EM simulator (perhaps like the one outlined by Andersen, this volume) is demonstrated to this organisation. The scenario for the session postulates the de-railment of a goods train, which results in a number of injured people, a plume of toxic gas, and a burning wagon that threatens to cause an adjacent tanker of liquid petrochemicals to explode. The roles of local Emergency Service controllers are played by the supervisor and his aides. On-site chiefs of fire, police, public ambulance and private ambulance services are played by 'trainees'. Let us further imagine that two issues that were generated and recorded during this session.

Co-ordination Issue 1: Driving Through the Plume

En route to the rendez-vous, the fire trucks passed through the plume of toxic gas, rather than taking a less direct, but safer route. In real-life, those aboard the fire trucks would become rapidly sick, require hospitalisation and play no further part in the response. Video-tape recordings suggested that the Fire-Chief (who was notionally aboard one of the trucks at that time), had little information about the emergency, and so had no reason to assess the situation as requiring an alternative route (emergency management - execution). Similarly, he did not perceive that others in the workgroup may possess relevant

information. Consequently, the Fire Chief did not intervene in the workgroup by getting the local fire service controller to relay, or go and get, information from the public or the police patrol car, who were already on-site (workgroup management - execution). It was unclear from the recordings, however, whether the Fire Chief's behaviour was attributable to his interpretation of preparedness plans (for example, who is responsible for ensuring that Fire Service personnel are not exposed to unnecessary danger), his knowledge of emergency response (for example, that goods trains may carry dangerous chemicals), or his knowledge of EM workgroups (for example, at this stage of an emergency, the police may have the good information because of their contact with the general public and ubiquitous patrol cars (Information Base).

Co-ordination Issue 2: Turning the Power Off

About half an hour into the response, the local fire controller was heard in audio-recordings to perceive that emergency personnel were moving onto the rail-tracks. He assessed that, if the electrical power was still on (and as far as he knew it was), there was a risk of electrocution from downed power cables (management of emergency - execution). In case the Fire-Chief was unaware of this concern, he decided to prompt the fire-chief by asking him whether the power had, indeed, been turned off (workgroup management - execution). It turned out that the Fire Chief knew from the outset of the emergency that the power was, indeed, off. From close contact with the railway before the session, the Fire Chief knew that, although the cables and pylons for carrying electric current were in place, the electricity network was not yet operational. The Fire Chief correctly assessed the local controller's ignorance and reassured him immediately (management of workgroup - execution).

Assessment

Let us imagine that the simulator only ever generated and captured issues such as 1 and 2, regardless of the scenario employed and the supervisor's roles††. Such a simulator would be limited in that: (i) it does not invoke planning representations for either the emergency response or EM workgroup; and (ii) the nature of the information base that underlies co-ordination is not always exposed. Such a simulator would be adequate for training and preparedness evaluations that wished to address only shorter-term thinking in co-ordination, such who may be able to obtain certain information. The simulator would be inadequate, however, for training and evaluating longer-term thinking, such as the expected ability of the workgroup to respond to unusual demands. Such a simulator may also require additional means of recording the reasons for decisions and the information brought to bear upon them.

FUTURE DEVELOPMENT OF THE FRAMEWORK

Our experience of using the framework suggests that additional aspects of co-ordination must be characterised in order to adequately assess multi-user EM simulators. In particular, the pattern of information exchange between EM decision-makers is not expressed. For example, the initial phase of one simulation we visited was characterised by information about the emergency situation flowing from the off-site, local controllers to their respective on-site chiefs. Later phases were characterised by a flow of information in the reverse direction - from on-site chiefs to off-site controllers. The pattern of communications is likely to be a relevant co-ordination issue for training and preparedness evaluation, but it is difficult to express concisely within the current framework. Also, the knowledge that decision-makers apply is described in too little detail. For example, the framework does not distinguish between presumed and assured knowledge, despite the fact that inappropriate presumption and the desire for confirmation have been heavily implicated in many sessions that we have observed. It is disappointing consequence of the framework that the above assessment was imprecise about the kind of knowledge that was, and was not, recorded. Future work may redress such limitations, possibly through Hierarchical Task Analysis, and/or Job Process Charts (Tainsh, 1985).

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†† The issues described actually arose during a trial session we observed. However, these issues are not a complete or representative list of the issues which actually arose during that session. Thus, the assessment presented does not do justice to the prototype, and so the prototype remains anonymous.

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Figure 1: A Workgroup Managing an Emergency

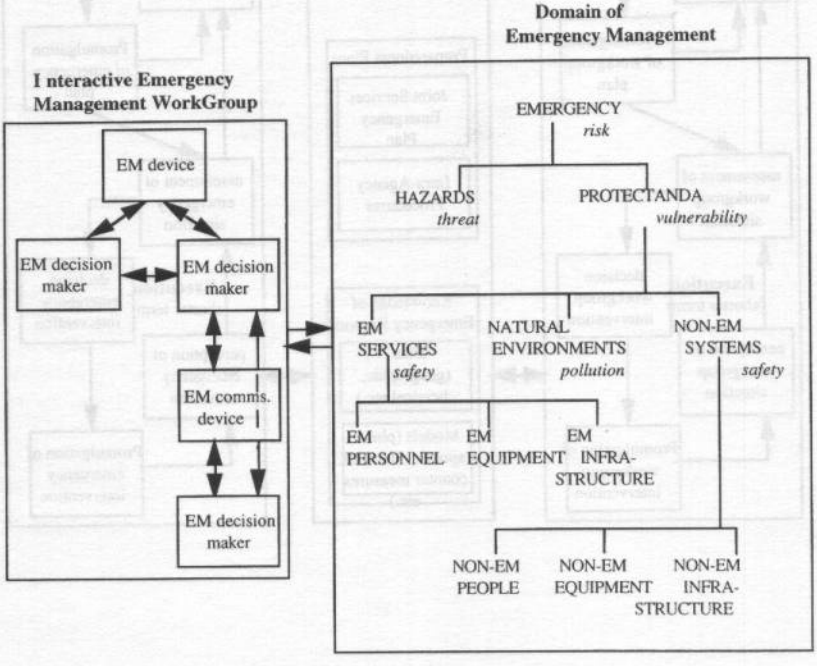

Figure 2: Structures that Support Co-ordinated Command Decision-Making