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Advanced Information Technology

Information Technology for Accident and Emergency Management

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ADVANCED INFORMATION TECHNOLOGY

Information Technology for Accident and Emergency Management

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Abstract. The potential risk of critical situations at hazardous industrial plants has drawn increased attention to emergency organisations. The emphasis on these organisations is to minimise the environmental effects of serious, although unlikely, disturbances in operation. Experience gained from previous incidents and emergency drills has revealed the complexity that must be faced in making these organisations work properly. Modern information technology may be used in order to develop more reliable preparedness systems. These problems are being treated in a joint Nordic project, NKA/INF, with participating research institutes from Denmark, Finland, Norway, and Sweden. The project started in 1985 and is expected to be finished in 1989. This report gives an overview of the project and a short description of the conceptual ideas behind the project.

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INTRODUCTION

There is an increasing potential for severe accidents as the industrial development tends towards large, centralised production units. In several industries this has led to the formation of large organisations which are prepared for accident fighting and emergency management. The functioning of these organisations critically depends upon efficient decision making and exchange of information[1]).
The staff in charge are faced with decisions which:

- must be made relatively quickly,
- involve complex judgements,
- involve making trade-offs between partly incompatible demands,
- must be based on technical data that are difficult to access,
- involve many decision makers and experts.

It is a commonly shared belief that timely and correct decisions in these situations could either prevent an incident from developing into a severe accident or mitigate the negative consequences of an accident. It is also a commonly shared belief that in those cases where poor decisions have been made it has been because of insufficient access to information and expert knowledge during the decision making process.

Problems observed within emergency preparedness organisations during drills or by analysis of accidental situations, e.g., in nuclear power plants, are omissions, confusion, and misunderstandings. Especially in the minutes just after the occurrence of an accident, operators may make the accident worse by taking precipitate action under the stress of the emergency. This happened at Three Mile Island[2]).

The problems can be divided into at least three different categories. The first category is of technical nature and is associated with communications, the second one is related to decision making and the interdependence between tactical and strategical decisions, while the third category has to do with the understanding of information that is communicated.

- The technical problems can be caused by anything from an overload of the equipment used to difficulties in handling these devices. This may result in delays with consequently less time for decision making, or - even worse - mixing up the order of events.

- The interdependence between tactical decisions regarding information management and the strategic decisions related to the appropriate protective actions has been seen to cause problems. As an example the staff in the on-site emergency organisation centre (EOC), who make most of the decisions regarding the information flow to the off-site organisation, are primarily occupied with the accident management task; therefore, e.g., lack of man-power may result in insufficient or unclear information. This will certainly have a negative influence on the strategic decisions made by the off-site organisations as, e.g., the Nuclear Power Inspectorate and the county EOC.

- Understanding of communicated information turns out to give problems because much of the information from the on-site to the off-site EOC is of technical and/or radiological nature, and not all personnel involved have this kind of competence.

In parallel with the development of organisations for emergency management, a dramatic development within electronic information technology is taking place and, quite naturally, widespread efforts are made to exploit this technology in the design of decision support systems for operating crews during plant disturbances and accident control, and for support of the general emergency management organisation.

OVERVIEW OF THE PROJECT

The project started as part of the new Nordic programme in 1985 and is expected to be finished early in 1989. A time schedule is given in Figure 1. This gives the structure of the project that is started by a pilot phase in which the existing preparedness organisations in the area of nuclear emergency situations have been described. Input has been taken from the Loviisa nuclear power plant in Finland for the on-site organisation, and from the Swedish nuclear preparedness organisation for the off-site organisation. Results from this phase are used as a basis for decision models to be developed in the main phase for improvement of decision making in complex situations. Even though these investigations have been based on work in the nuclear field, it is the intention to adjust the preparedness system to make the results applicable in the chemical industry as well. Furthermore, an expert system overview has been given in this phase[3].

In the main phase a detailed scenario analysis has been performed together with a conceptual analysis of dynamic decision making. Great efforts have been put into the detailed study of the basic functions of information flow, in emphasising the most important centres - county EOC and the EOCs at the National Institute of Radiation Protection and the Nuclear Power Inspectorate for the off-site organisation, Plant Emergency Manager for the on-site organisation - and in trying to identify the type of information transferred between different operational functions in the main centres. From this analysis data and knowledge needed to develop an effective decision support system have been specified. This

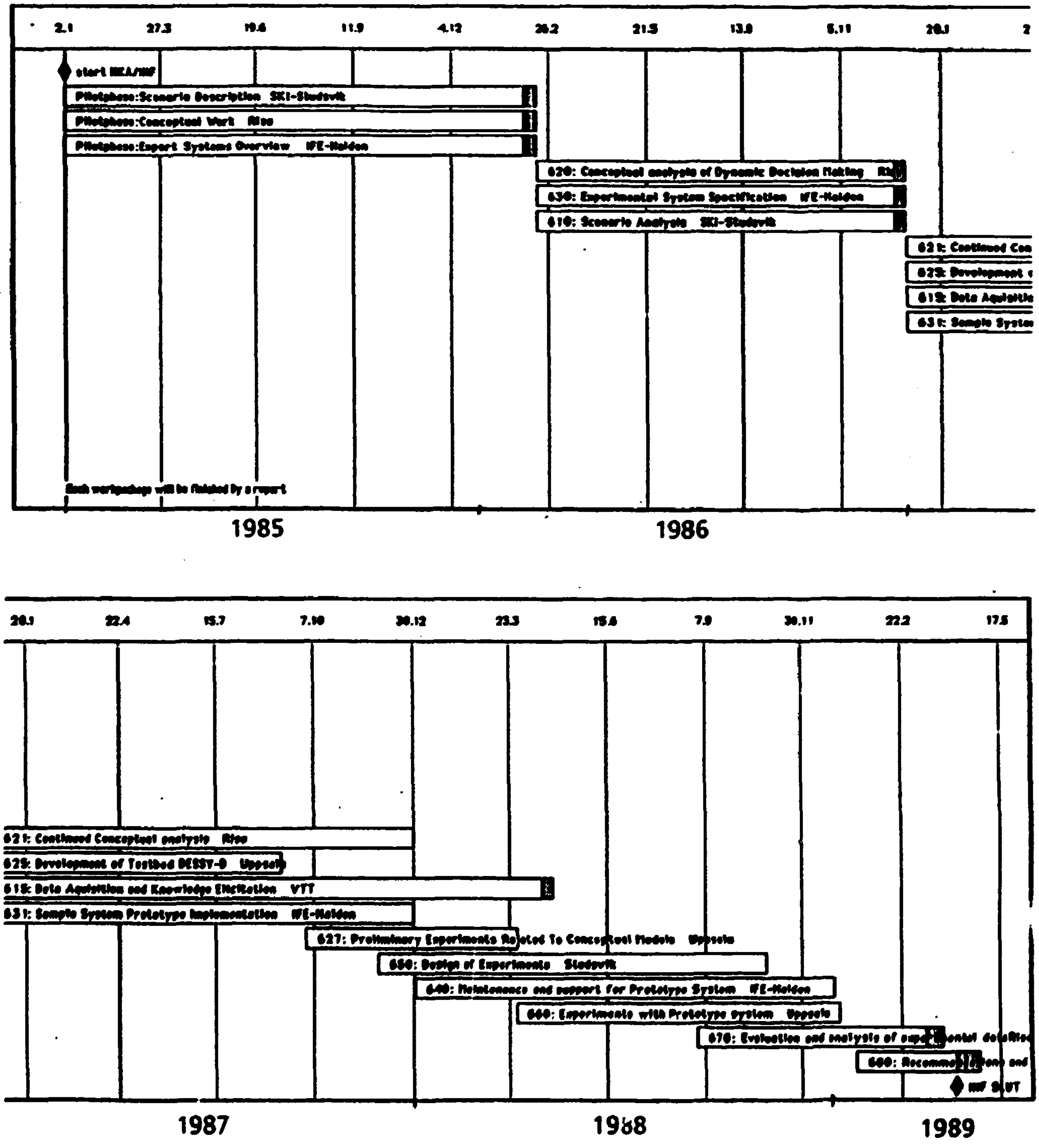

Figure 1. NKA/INF time-schedule

has been performed for the off-site and on-site organisations separately, and will be presented in more detail elsewhere[4),5)].

Following the specification phase an implementation strategy has been selected and implementation has been initiated. Features that have been considered to make prototyping fast and incremental are for instance: easy-to-use and powerful window systems, incremental compiling, and help functions at different levels. Shortly, the whole system is being built so that it is easy to expand the data base, the knowledge, the reasoning mechanism, etc.[6)].

The aim of this project is not to develop a complete decision support system to cope with all aspects of emergency situations, but to develop prototype systems to support decision making in time slices of emergency situations.

In total, four different experiments will be performed at four different scenarios, two on-site and two off-site and, correspondingly, four different prototype systems will be developed to support decision making in these situations. The results using the prototype systems will be compared with drills using "normal" procedures to demonstrate the advantage of the system. All scenarios shall demonstrate detection, diagnosis, formation of plan of action, and execution.

These experiments will provide us with material for empirical evaluation of the combined effect of the data base, the implementation strategy, and the conceptual model for the developed part of the decision support system.

The prototype systems will be optimised by an iterative procedure, and the final product will be used for recommendations and guidelines for a possible further development into a complete decision support system capable of coping with all emergency situations in risky industrial plants.

CONCEPTUAL WORK

A short presentation of the conceptual work will be given here[7], whereas detailed presentations of development of the support system off-site and on-site, respectively, including description of functions, system, and evaluation have been given separately[4],[5].

The aim of this work is to develop a general conceptual model for different kinds of emergencies, rather than a model for a specific kind of emergency.

The starting point is the fact that decision problems are inherently complex, and the problem is to find a way to simplify problems to a manageable level of complexity.

In this project three alternative solutions have been discussed:

- Hierarchical organisation.
- Emergency management as a control system.
- Distributed decision making organisation.

Hierarchical organisation

To impose a hierarchical system seems directly to meet the requirement mentioned above, as this means to introduce a series of descriptions of the system which differ with respect to their level of abstraction. This makes it possible to control the level of complexity in the sense that only a limited number of units have to be considered at each level of the hierarchy. Nevertheless, as hierarchical organisations had been analysed in some detail, it was found that this form of organisation has considerable problems in the context of emergency management:

- The structure of a hierarchical organisation should be congruent to the structure of problems to be solved. In emergency management it is impossible to foresee every kind of emergency situations.

- Delays are unavoidable as well in transmission of information, receipt of feedback, and execution of commands. Therefore, a hierarchical organisation is feasible in a relatively stable system, but not in emergency management which might be highly dynamic.

- The basic assumption behind the felt need for a hierarchical command and control system is that the emergency creates total disruption so that a command and control system is needed to create some order and to get the social system going again. In fact, the results from studies of emergencies suggest that there is no general disruption, and that major parts of the social system go on functioning in very much the same way as they did before the emergency[8)]. The problem for emergency management is then to design a system that could aid the processes of co-ordination and self-organisation, rather than a system for creating a new structure.

The conclusion of these considerations is that hierarchical systems are of limited use in emergency management.

Emergency Management as a Control System

The point of view in this context is that emergency management can usefully be considered a control system. The purpose of the control system is to keep the level of damage and injuries in society at some predetermined level, a level which is generally not made explicit, but which is nevertheless somehow known to the system.

The control perspective provides two basic control strategies: feedback and feedforward, the former being that of returning the system to a normal state after some deviation has occurred, while the latter involves an attempt to construct a strategy which prevents a deviation from occurring.

In case of emergency management, it is clear that a feedforward strategy is to be preferred. A basic question, is therefore whether and under what conditions a feedforward strategy is possible.

Needed functions for such a system are that:

- it must be able to detect deviations,
- it must be able to diagnose the cause of these deviations,
- it must be able to return the system to a normal level.

- To make efficient detection, providing possibilities for a feedforward system, it is necessary not to detect damage or injuries themselves, but to detect variables that cause damage or injuries. So, feedforward strategy relies upon feedback control of variables related to the damage/injury variable.

- Even though it is easy to diagnose the type of emergency, the problem of how to diagnose the causes and magnitude of new and unfamiliar emergencies is not an easy one. In the end, the ability to make correct diagnoses may not rest so much with the organisation for emergency management as with the general level of scientific development of a society.

- The action side of emergency management can be divided into two general classes of activities: damage/injury control and relief/ repair operations. In most cases these two classes of action will be coupled; therefore, the question is not whether the one or the other kind of operation is to be chosen, but what is the best mix of actions.

It is possible to construct time-area diagrams for combinations of emergencies and control operations which make it possible to understand the nature of various emergencies and the control operations which are possible in different forms of emergencies, as well as to judge how much resources should be used, see Figure 2 as an example with an exponential developing emergency situation and a linear developing action for emergency fighting. Thus, the condition for actually defeat of the emergency is that the emergency fighting resources can be manipulated in such a way that the fighting function intercepts the emergency function before the slope of the latter function exceeds that of the former function.

In principle, diagrams of this kind can be used as a form of decision support at the county EOC level. However, there are good models for computing the actual time-area functions only for a limited number of emergencies, e.g., the spread of clouds and radiation. For many kinds of emergencies, however, computational models will have to be developed. This limits the present usefulness of the time-area diagrams as an actual decision support tool. Moreover, to be used for decision support, the diagrams must be supplemented with some measure of uncertainty. It is not clear how such measures can be obtained at present.

The framework analyses forms of action of different levels of abstraction. At the highest level - the one which is compatible with the time-area diagrams mentioned above - there are three forms of actions. The first of these involves <u>removing the source</u> of the emergency, the second <u>raising a barrier</u> between people and the emergency, and the third <u>removing the people</u> from the site of the emergency. The time-area diagram will help in the choice of action at this level.

Distributed Decision Making Organisation

One of the problems mentioned previously has to do with feedback. If feedback is slow compared with the rate of change in the process to be controlled, centralised control is impossible and control has to be decentralised. This creates problems in the case when coordination is needed. This problem has received no

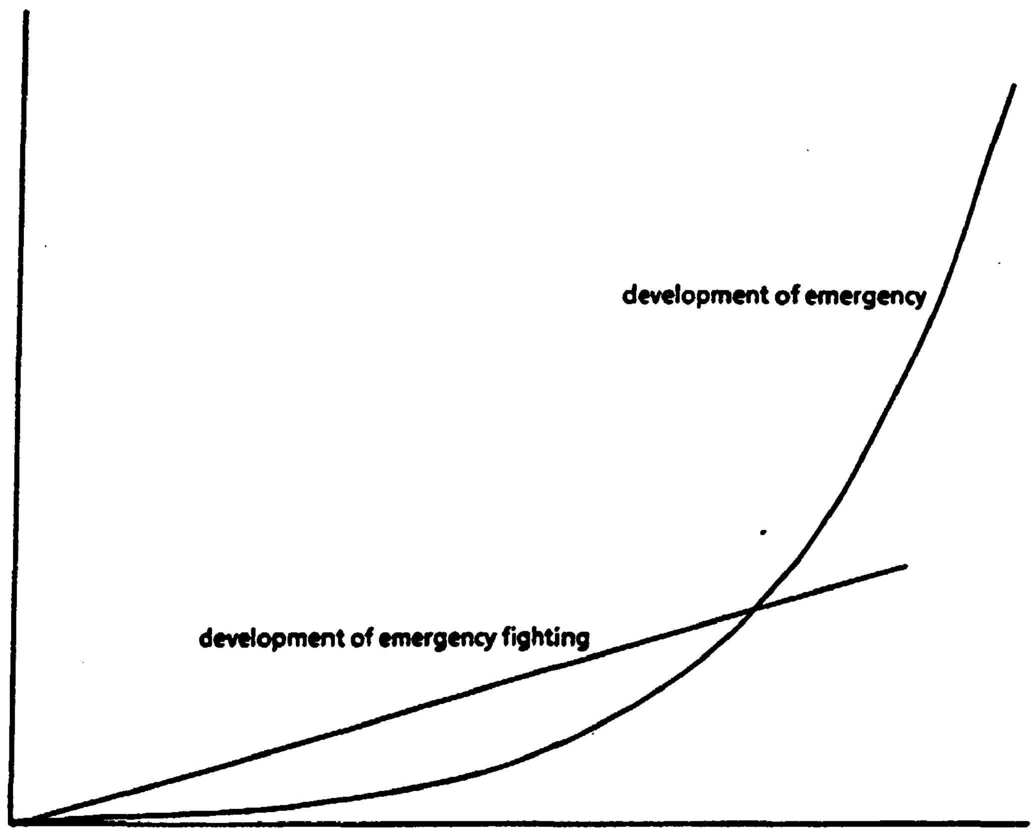

Figure 2. Time-area diagram

attention from organisation theory, so very little is known about what sorts of organisation might actually work in a dynamic environment.

Recently, the problem of distributed decision making has been discussed in military contexts in connection with planning for battlefield scenarios involving the loss of communication. One idea here has been that of feedforward control by means of doctrine. This, however, suffers from the same problem as other forms of feedforward control in chaining environments.

Other problems being considered in the analysis are:

- What is the minimum level of communication needed for coordination?

- What is the minimum level of organisation?

- How are intentions communicated?

- What are the possibilities for self organisation in dynamic contexts?

Evaluation of the Decision Support System

Evaluation of a decision support system (DSS) may proceed along two lines. The first one involves analytical evaluation, the second empirical evaluation.

The first category may be seen as a normative theory which specifies the steps necessary for a good decision. The decision maker starts by implementing some plan, notices the consequences using the DSS, and evaluates them in terms of expectations. Finally, decision is made as to whether the result is acceptable or not, including the kinds of displays provided, and the knowledge required for understanding these displays.

Empirical evaluation is desirable as well, as there are some aspects of the evaluation problem that cannot be solved analytically.
Two main questions for empirical evaluation are:

- Will the DSS actually be used?

- When the DSS is used, will the decision be better than when it is not used?

The first of these questions can only be evaluated in the context of a total system where different systems compete for the decision maker's attention, and is outside the scope of this project. The second question may be answered for time-slice prototype systems, but even here more limited evaluation of some selected aspects of the system might be beneficial, not to involve systems or decisions not using the DSS being evaluated.

It is suggested that we start the evaluation process by the analytical evaluation. This should lead to clarification of the nature of the support provided by the DSS. It will make it possible to design the empirical part of the evaluation process.

FUTURE PLANS

As has been mentioned in the "Overview of the project", the final product is recommendations and guidelines for further development into a complete decision support system coping with emergency situations, but it is not our plan to develop such a system.

By now the NKA/INF project has played a major role and may be seen as a preprogramme for an ESPRIT II proposal including participants from seven European countries.

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