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Emergency management as co-ordinated cognitive modelling on different time-scales

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as Co-ordinated Cognitive Modelling
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Abstract

The management work of major operations consists of cognitive modelling on different time scales and co-ordinating such models. The work in one time scale is co-ordinated by cognitive modelling in a higher time scale. The aim of emergency management is to achieve control. A basic condition for effective management is that cognitive modelling functions in the work of each engaged time scale. A hypothesis is formulated based on bad experiences to establish anticipation, total and long-term management: *When there are difficulties in establishing rapid and effective management one main reason is that when there on one time scale is a need for co-ordination using mental models in a higher time scale, the cognitive modelling on this higher time scale is delayed in relation to the need on the shorter time scale.* Further research in order to study this hypothesis is discussed.

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Summary

This report is a result of the work in projects for The Swedish Rescue Services Agency and for The National Board of Civil Emergency Preparedness. The problem is defined as difficulties in establishing rapid and effective management in major fire-fighting and rescue operations. The analyses result in a view that emergency management can be seen as cognitive modelling. The management work of major operations consists of cognitive modelling on different time scales and co-ordinating such models. The work in one time scale is co-ordinated by cognitive modelling in a higher time scale.

The aim of emergency management is to achieve control. A basic condition for effective management is that cognitive modelling functions in the work of each engaged time scale.

A hypothesis is formulated based on bad experiences to establish anticipation, total and long-term management:

When there are difficulties in establishing rapid and effective management one main reason is that when there on one time scale is a need for co-ordination using mental models in a higher time scale, the cognitive modelling on this higher time scale is delayed in relation to the need on the shorter time scale.

Further research in order to study this hypothesis is discussed.

Sammanfattning

Denna rapport är ett resultat från arbete i flera projekt åt Räddningsverket och Överstyrelsen för civil beredskap. Problemet definieras som svårigheter att etablera snabb och effektiv ledning vid stora räddningsinsatser. Analyserna resulterar i en syn att räddningsledning kan ses som kognitiv modellering. Ledningsarbete vid stora räddningsinsatser består av kognitiv modellering i olika tidsskalor och att samordna sådana modeller. Arbeten i en tidsskala samordnas genom kognitiv modellering i en längre tidsskala.

Syftet med räddningsledning är att få kontroll. Ett grundvillkor för effektiv ledning antas vara att kognitiv modellering fungerar i varje tidsskala i ledningsarbetet.

En hypotes formuleras baserad på erfarenheter av svårigheter att etablera förutseende och övergripande ledning:

När det uppstår svårigheter att etablera snabb och effektiv ledning är en huvudanledning att när det i en tidsskala uppstår behov av samordning genom en mental modell i en längre tidsskala så är den kognitiva modelleringen i denna längre tidsskala försenad i relation till behovet i den kortare tidsskalan.

Fortsatt forskning för att studera denna hypotes diskuteras.

Background, problem and aim

I have worked with several projects concerning different aspects of emergency- and disaster management. This work has caused me to see the initial phase of emergency- and disaster management as an especially critical one. Coping with the initial phase seems to be a critical condition in establishing management and how the management continues to deal with the emergency or the disaster.

The main reason for the problem is that necessary anticipation, totality coping and long-term management are established too late in relation to the dynamics of the emergency or disaster. Connected to this there are two specific problems. The first is that it seems difficult to anticipate drastic, unforeseen developments of an emergency or disaster and that the management steps are established too late. The second is that decision makers seem to be absorbed with visible problems in a short term and carry out decision making minute by minute.

The wreck of "Estonia" in 1994 is an example of a drastic, unforeseen disaster and of late management reaction. At the first mayday no person in the engaged Marine Rescue Communication Centres imagined a situation where a ship with about 1000 people on board could disappear from the surface of the sea in less than half an hour and that there could be hundreds of people in the water. The first impression of the situation was that "Estonia" had a leak. A pump was loaded in the first helicopter (Larsson and Nohrstedt 1994). Step by step the extent of the disaster became clear. The management coped with the situation step by step at first until information from the situation motivated management acting.

Management behaviour from a training scenario is another example of being concerned with visible problems in a short term and acting minute by minute. The scenario was a major train accident. The management behaviour was characterised by the following.

- *The commanding fire officer was absorbed with the problems in a short term in the damage area.*
- *The commanding fire officer made decisions minute by minute.*
- *There was a late establishment of a management structure.*
- *There was a late establishment of a staff.*
- *There was very little anticipation.*
- *There was no long-term strategy established for the whole rescue operation.*

To sum up, the problem can be described in terms of difficulties in establishing anticipation, coping totally and long-term management in major fire-fighting and rescue operations.

The aim is to discuss emergency management as co-ordinated cognitive modelling in different time-scales and to formulate an explanatory hypothesis expressing why there are often bad over-all long-term emergency management.

Coping with different kinds of emergencies

Coping with an emergency as a number of decision problems can be discussed in relation to the dynamics of the emergency (Fredholm 1991). The dynamics of emergencies can be divided into three main categories. Each category is a name for the type of dynamics, which is characteristic when the emergency management has to start.

Dynamic states are characterised by rapid changes and mostly by expanding developments. A fire is a typical dynamic state.

Unstable static states are characterised by situations in stillness when the coping process starts. A rash move can start a changing and developing process. The stillness is a kind of an unstable equilibrium. An operation after a landslide is such a situation. The dynamic phase has usually already occurred when the emergency management starts.

Stable static states are also characterised by situations in stillness when the coping process starts. There is however a stable equilibrium. There is no or little risk for the situation to be worse within the nearest time. A traffic accident without personal injuries is such a situation.

The division into these three main categories is relative and arbitrary. A technically seen static situation can medically be seen very dynamic.

Different decision making demands

These three main categories of emergencies involve different decision making demands. The dynamic states comprise the most stressful situations. The decision making is under strong time pressure. An important tactical aim is often to stop the expanding development. Saving lives has to be done rapidly.

The unstable static states demand caution and possibly careful planning during a long time before acting. There is more time to discuss and analyse the problems and the measures. A main tactical aim is to bring the situation from being unstable to being stable. This often has to be done with care.

The stable static states are hardly an emergency management problem. The problems concern recovering.

During the last years Sweden has been hit by several major emergencies. There have been two major emergencies at sea. On the ship "Scandinavian Star" there was a fire. More than 150 people died. The wreck of "Estonia" was a disaster. More than 800 people died. Different parts of Sweden have been exposed to flooding and landslides. No people have died but houses have been destroyed. Two major emergencies involving dangerous chemicals have happened. Both have been train accidents in which carriages with dangerous chemicals have been derailed. No chemicals leaked out. In both these emergencies many people had to be evacuated for safety's sake during the rescue work, in one of them about 9500 people.

Those emergencies can be discussed in terms of the three different categories. The two railway accidents were clearly unstable static situations. The problems were to salvage the carriages without making the emergency worse. There was time to analyse and plan and to take it easy.

These experiences are a base for discussing society's capacity to cope with different emergencies. It seems that society has more and better capacity to cope with different types of static situations than dynamic ones. This is not strange. The problem is that planning and training do not take into consideration the important differences between the different types of emergencies.

The problem concerns the capacity to make co-ordinated decisions at different levels of the management. In a static situation you have time to follow the sequence *planning*, *executing* and *evaluating*. In a dynamic situation the sequence is disturbed by the dynamics of the emergency. The co-ordination of the decision making at different levels of management has to be more dynamic and flexible. The over-all and long-term management has to take into consideration decisions made by decision makers at "the first line" and the possible consequences of different developments of the emergency.

Foreseen and unforeseen emergencies

A usual intention is to be as prepared as possible. Planning and training are aimed to prepare for a wide range of emergencies. Experience shows two things. The first is that people have difficulties in anticipating the worst cases. It seems as if people for different reasons often are not capable of imagining drastic and bad situations. Therefore planning and training often are too limited. The other is that emergencies do not develop exactly as the emergency planning presupposes.

The conclusion is that the capacity to shape the management in the specific situation determined by the specific emergency is very important. Three main domains can be seen as basic conditions in shaping the management of the specific situation.

The first is the planning and the preparedness. This domain can be more or less developed. Well done and up-to-date planning and preparedness are a good condition to start from. In this there is training too.

The second is knowledge of the emergency as a more or less dynamic or static situation, of the management as a process and of the resources.

The third is the emergency and its specific characteristics.

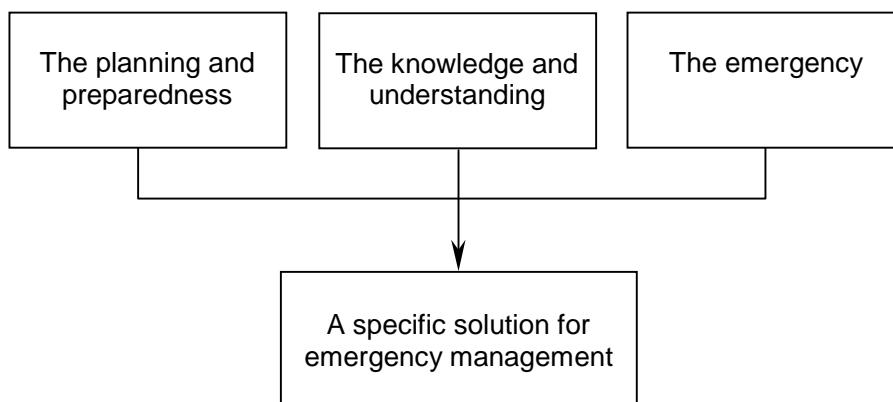


Figure. 1. Domains of important conditions in order to shape a specific emergency management.

The central core of the management coping problem

The central core of the reasoning is that the solution to the management problems in a specific emergency depends on 1) the quality of the planning and the preparedness, 2) the state of the knowledge and understanding of different emergency types and of the processes of emergency management, and 3) the type, extent, dynamics and complexity of the specific emergency.

The coping problem is to make an optimal solution based on these three conditions. The usual approach is to make a more or less developed plan and preparedness. The problem of ad hoc adapting the planning and the knowledge to the specific situation is maybe underestimated. The planning and preparedness have to be the base for flexible adaptation.

In discussing the use of plans people sometimes say that planning does not fit the development of the reality. Therefore there is no use for plans. This is not the conclusion from the reasoning in this report. Instead the point is that thorough preparation work results in a good base to act flexibly from.

The planning problem can be discussed from a basic mental model, which seems to be a basic condition behind conventional rhetoric concerning planning. The basic idea is that planning can be performed separately from and before the course of events for which the planning is intended. The sequence is *planning*, *implementing* and *following up*.

When an emergency occurs and emergency management has to start there is another basic condition for the planning. The dynamic of the real world and the interaction with this has already started when the management and its planning processes start. The idea of the management process is the sequence of *sizing up*, *countering* and *following up*.

The sizing up is the process, which results in the estimate of the situation. *The countering* is the current planning and acting in order to meet and cope with the dynamics of the emergency. An important condition in this is the previous planning and preparedness. *The following up* is the sizing up of the measures taken. The three parts of the sequence are not separated. They appear in different states of integration.

The reasoning above leads to the conclusion that emergency management consists of partly the pre-emergency planning and preparation processes (based on the assumptions of the sequence of *planning*, *implementing* and *following up*), and partly of the ad hoc coping processes as an answer to the occurred emergency (based on the assumptions of the sequence of *sizing up*, *countering* and *following up*).

A theoretical basis for emergency management

Emergency management can primarily be seen as a number of decision making processes. In his research on dynamic decision making Brehmer (1994a) says that the goal of decision making is to achieve control. This is valid for emergency management. The goal of emergency management is to achieve as good a control of the situation as possible.

Brehmer (1994a) points to four general conditions for control.

- There must be a goal (the goal condition).
- It must be possible to ascertain the state of the system (the observability condition).
- It must be possible to affect the state of the system (the action condition).
- There must be a model of the system (the model condition).

From a general aspect these conditions can be presumed to be valid for emergency management.

Emergency management as co-ordinated decision making in different time scales

Brehmer (1994a) says that there are three compelling characteristics of real world decision problems. They are *complexity*, *dynamics* and *opaqueness*. He says that the decision problems are complex in the sense that they require the subject to consider many different elements, e.g. many different - and possibly conflicting - goals. He says they are dynamic in some or all of the four general conditions described above. He says that they are opaque in that they do not reveal all their characteristics automatically to the subject, thus requiring him to form and test hypotheses about their state and characteristics.

Emergency management in the meaning of coping with complexity, dynamics and opaqueness can be discussed from two important aspects. The first is that one person cannot cope with all the actual decision problems. Several people have to co-ordinate their decision making in some kind of a co-ordinating structure. The second is that the decision making processes run in different time scales.

Brehmer (1994a) discusses distributed decision making. The problems that occur in the control of complex, dynamic and opaque systems are so large that they require the efforts of a group of people. Brehmer says that there are three important problems in distributed decision making.

One is the development of shared situational awareness (a shared model of the system, including a good understanding of the goals of the group, or, if there is a leader , the intentions of the leader).

A second problem is the sharing of resources.

A third problem is the co-ordination of resources.

The coping of the complexity, the dynamics and the opaqueness occurs in decision making processes in different time scales. In the work on the damage area there are time scales in seconds and minutes. There are seconds or minutes between the sizing up of the situation and the feedback of the executed measure. In the long-term and over all management there are time scales in hours, days, weeks and maybe still longer. The co-ordination of the work on different time scales has to be ordered in some kind of a structure. One such usual structure is a hierarchy.

The co-ordinated processes discussed in relation to the four basic conditions to achieve control

The time scale of the decision work is seen as an important condition in discussing the co-ordinated decision processes. Working in a short time scale gives different conditions and demands from working in a long time scale. Typical for working in a short time scale is the short time between the made measure and the feedback. Typical for working in a long time scale is the long time between the made measure and the feedback. If a decision maker has to act directly on feed back it gives no time for thinking. But when there is a long time between the made measure and the feedback that long time has to be bridged by mental activity. When people have to cope with extensive complex situations it is often the time which shapes the need for coping models shaped by mental activity (Brehmer 1997).

The work in different time scales can be discussed in relation to the four general conditions to achieve control.

There must be a goal

To work in a short time scale mostly means to work under hard time pressure. There is no time to evaluate different goals. A description of decision makers' behaviour in such situations Klein gives in his model *Recognition Primed Decision Making* (Klein et al 1986 and Klein 1993). This model gives a description of experts' decision making under time pressure. The decision maker is dependent on recognition and classifying the situation in an appropriate way. When he or she recognises the situation he or she knows the way in which such situations usually are coped with.

Klein brings out two mental processes. The first is an evaluation of the situation. This is done based on recognition. After that there is a mental simulation of a course of action. If this seems to be good the decision maker acts. He or she makes no careful analyses of several alternatives of action. If the course of action does not seem to be good another possible course of action is chosen. In this way the decision maker act sequentially till he or she finds an alternative which is estimated as functional. The basis for this cognitive activity is earlier experiences and recognition.

This kind of decision making is rather rapid and intuitive. The decision maker is usually in direct contact with the situation and the actors. He or she will have almost direct feedback.

In decision work in longer time scales there is a need of more mental work in forming goals and strategies. The size up has to be more careful. The decision maker has to anticipate and work with hypothetical mental representations. He or she also must compensate delays in the flow of information with mental models.

In this cognitive modelling work the decision maker also has to co-ordinate the mental situations of other decision makers. He or she has to form a model, which co-ordinates, includes and gives support to all models of the other decision makers working in different and shorter time scales.

It must be possible to ascertain the state of the system

Working in short time scales mostly means that the decision maker gets direct feedback from his or her more or less directly visible acting area.

Working in longer time scales means a lot of problems in evaluating the situation. The space of sources of information is of a wide range. The collecting and integration of information has to be governed by some model. In this the delays of information are a very important condition to notice.

It must be possible to affect the state of the system

The possibility of affecting the state of the system can be seen as a function of the coping of that dynamics which appear within and between different levels of management working in different time scales. This is the way to the solution of the co-ordination.

Brehmer (1994b) discusses co-ordinated actions in an organisation with distributed decision making. He says that co-ordinated action in an organisation can come about in at least three different ways. The first possibility is commands, i.e., each decision maker is told when and where he or she is to carry out his or her action. The second possibility is co-ordination by means of a plan. The actions of the individuals are prescribed and the units carry out these actions without any need for communication. The third possibility is that the co-ordination comes about as a consequence of decisions made by the individual decision makers. There is no leader who issues commands but the individual decision makers themselves decide where and when to perform their tasks.

Emergency management is a dynamic combination of these three possibilities. The third situation is an important condition. In an accident the commander of the first arrived units makes a lot of decisions. These are the base on which later decisions on a longer time scale are made by later engaged officers. These decisions concern more long-term and over all management.

There must be a model of the system

Brehmer (1994a) says that in military contexts, the term "situational awareness" is often used to denote what is here called a model. He says that situational awareness involves having an overview of the situation with some idea of what is about to happen. He says further that it is thus the kind of knowledge that is required to choose an appropriate course of action, just as the model is what is required to choose the appropriate course of action in, say, a process control context.

Decision makers acting in short time scales according to Klein's model RPDM (as discussed above) have got their models or situational awareness mostly from experience. The experience has built up integrated and tacit models of typical situations and possible courses of action in these situations. This "tacit knowledge" is what the decision maker uses in an intuitive way.

The decision makers' work on longer time scales often means co-ordinating decision makers working on shorter time scales. The situations are often very complex and are seldom typical situations which can be a base for experience and recognition. The decision work has to consist of mental work concerning models of the emergency situation, goals and courses of action. Anticipating is an important part of that work. In this the work consists of forming mental representations of both present conditions and anticipated possible conditions.

Those mental representations are important instruments in the management work. They form a frame for the decision makers working on shorter time scales. They have to be communicated between different decision makers in different positions in the management context.

Emergency management as cognitive modelling

The conclusion of the reasoning above is that it is possible to see management concerning the coping with complexity, dynamics and opaqueness in longer time scales and concerning co-ordination of several decision makers working in shorter time scales as cognitive modelling.

The management work consists of forming models for coping with complexity, dynamics and opaqueness in different concrete and practical aspects. It concerns for example the sizing up of the whole situation in the short and long term, an over-all aim and different goals in order to reach the over-all aim, courses of action in different periods of time, different organisations' resources, co-ordination of different rescue organisations, etc.

The work in longer time scales also concerns the perceiving of other decision makers' cognitive models. According to the reasoning earlier that one way of co-ordination comes out as a consequence of the decisions made by the individual decision makers, a commander working in a long time scale has to perceive and understand the cognitive models of the decision makers working in shorter time scales. This is material in his forming of a long-term over all strategy.

This reasoning emphasises the cognitive activity and the shaping and communication of cognitive conceptions as very important condition in emergency management, when there is a need for work in different time scales.

Figure 1 gives a structure for the cognitive modelling. One important part is the planning and preparedness. This work gives basic models of possible emergencies and possible courses of action. Experiences have taught us that plans and prepared thinking seldom fit in the real world development. A good knowledge and understanding (a good cognitive modelling) of different types of emergencies, of different coping problems connected to different types of emergencies, of different resources, and so on, are good conditions to use in the pre-planning in a flexible and fitting way. A critical phase of the modelling work is when an emergency has occurred and a specific solution of the management has to be built up according to that specific emergency. The cognitive modelling has then to perform co-ordination on different time scales.

The above analysis related to the problem

The problem, which was the starting point for the analysis, was described as difficulties in establishing anticipation, totally coping and long-term management in major fire-fighting and rescue operations. The problem was concretised in that the commanding officer was absorbed with problems in a short term in the damage area, that the commanding officer made decisions minute by minute, that there was a late establishment of a management structure, that there was a late establishment of a staff, that there was very little anticipating, and that there was no long-term strategy for the whole of the rescue operation.

In the terms of the analysis above the problem can be described as bad cognitive modelling. The commanding officer was caught working on a short time scale. He neither started working on a longer time scale, nor did he order resources aimed for that.

The core of the problem is that in a major accident work on a short time scale in the affected area and in other places is in the need of co-ordination and framing models on a longer time scale.

The difficulties of establishing anticipation, total and long-term management can be expressed in the following hypothesis:

When there are difficulties in establishing rapid and effective management one main reason is that when there on one time scale is a need for co-ordination using mental models in a higher time scale, the cognitive modelling on this higher time scale is delayed in relation to the need on the shorter time scale.

This hypothesis can be expressed in another way. The goal of emergency management has earlier been discussed as achieving control. An idea behind the hypothesis is that this is the goal on each time scale, which is established at different levels of management. Effective management work is seen as dynamic co-ordinated decision processes at different levels concerning different time scales and there the four general conditions of control are satisfied on every time scale (level of management).

The usual situation in an emergency is that units working on short time scales are first engaged. Commanders working on longer time scales are often engaged in a later phase, first when there is a need of co-ordination on the shorter time scales.

Further research

The material for the hypothesis above is the analyses of difficulties in establishing rapid and effective management in major fire-fighting and rescue operations. The analyses were made in projects for The Swedish Rescue Services Agency and The National Board of Civil Emergency Preparedness. (Fredholm 1994a, 1994b, 1995, 1996a, 1996b, 1997a, 1997b, 1998).

The analyses are based on principally three domains. They are the 1) problems of management in major fire-fighting and rescue operations, 2) practice of management in major fire-fighting and rescue operations, and 3) research on dynamic and distributed decision making (Brehmer 1987, 1991, 1994a, 1994b, 1997) and naturalistic decision making (Klein, Orasanu, Zsombok 1993; Klein, Calderwood, Clinton-Cirocco 1986; Klein 1993; Lipshitz 1993a; Lipshitz 1993b).

The problems and practice of management are analysed in relation to results, models and perspectives in research on dynamic and distributed and naturalistic decision making. All that has resulted in the reasoning and the hypothesis above.

Further research ought to be directed in examining the validity and the nuances of the hypothesis. Three possible courses of action are visible.

1. *Post-analyses of real operations.* This means studying the operations by analyses of documentation and by interviews.
2. *Observations.* This means the possibility of observing the real management work in emergencies and training.
3. *Studies with experimental design.* This means shaping different situations with different degrees of co-ordinating models on the highest time scale in different phases of the management and to let people practise in those situations.

During the earlier analyses a special ethical problem has appeared concerning post-analyses of real operations and observations. Commanders have interpreted analyses as unreliable criticism. The problem is to which extent the role of different actors ought to be obvious in the analyses and in the argumentation of the results.

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