# Functional specifications of a decision support system for emergency management

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## Abstract

The future Maritime Headquarters Coastguard Centre of the Royal Netherlands Navy will lead various maritime operations. These are on the one hand regular operations, and on the other hand emergency operations. Command and control in the latter case is referred to as emergency and incidents management. In this respect two factors are determining the quality of the decision-making process. First, the time pressure: what are the exact facts, and which procedures should be followed. Often there is no occasion for discussing the options with other personnel. Second, the social-political sensitivity of the decisions: information concerning the emergency or incident should be expressed in a controlled manner. The officer primarily concerned with the execution of emergency and incident management is the Duty Staff Officer (DSO). This paper describes a research project geared towards the definition of the functional specifications of a decision support system supporting the task execution of the DSO. First, insight into the tasks, authorities and responsibilities of the DSO has been gained. Next, the decision-making process with respect to one specific scenario has been described: based on the functions to be accomplished within the operations room of the Maritime Headquarters, tasks have been allocated to human operators and technological systems. Finally, the operational needs of the Maritime Headquarters on the one hand, and human factors principles on the other, provided the basis for the functional specifications of a decision support system. The functional specifications comprise the functions the system should accomplish in supporting the DSO's tasks (the task level), as well as the interactions with the user through the interface (the communication level).

## 1. Introduction

The future Maritime Headquarters Coastguard Centre of the Royal Netherlands Navy will lead various maritime operations. These are on the one hand regular operations, and on the other hand emergency operations. Command and control in the latter case is referred to as emergency and incidents management. In this respect two main factors are determining the quality of the decision-making process. First, the time pressure: what are the exact facts, and which procedures should be followed. Often there is no occasion for discussing the options with other personnel. Second, the social-political sensitivity of the decisions: information concerning the emergency or incident should be expressed in a controlled manner. Essential in the process of emergency and incidents management is that rule-based behaviour is delegated to computers enabling the personnel to make the relevant considerations (knowledge-based behaviour) (Rasmussen, 1983). The officer primarily concerned with the execution of emergency and incident management is the Duty Staff Officer (DSO). The question answered in this study was which functional requirements a decision support system supporting the task execution of the DSO should meet. First, the analysis based on the Cognitive Work Analysis method (Vicente, 1999) will be discussed. Next, formulating functional specifications from a human factors point of view will be described. This is followed by an illustration of the actual functional specifications of the decision support system. Finally, the implications for applying the decision support system as a training tool will be elaborated upon. For a more extensive and complete discussion of this study, see Van Berlo, Lindenberg and Timmer (2001).

## 2. Cognitive Work Analysis

Vicente (1999) describes a method for systematically designing complex sociotechnical systems: the Cognitive Work Analysis (CWA). CWA comprises several steps that will be briefly described in this section.

### 2.1 Work domain analysis

A work domain analysis results in a functional description of the environment of the Maritime Headquarters Coastguard Centre, and the boundaries within which it operates. This description is independent of the specific tasks to be performed, by whom, using which tools. Emergency and incidents management is concerned with neutralising threats with respect to a) personnel and relatives, b) material and infrastructure, c) organizational processes and public safety, d) military safety, e) politics, and f) environment, or to control the damage. Examples of emergencies and incidents are a helicopter crash in sea, a sunken submarine, misbehaviour of personnel during a port visit, and destroyed villages on an island as a result of a hurricane. Information concerning an emergency or incident can enter the opsroom of the Maritime Headquarters Coastguard Centre in various modalities, for instance: reports by operational units, telephone calls by relatives or other civilians, or regular media.

### 2.2 Control task analysis

A control task analyse describes the tasks to be performed, but not yet by whom (humans and/or computers), or the exact procedures to be followed. The description of the tasks should take into account the context-specific situations. In this case, the analysis focuses on the Duty Staff Officer located in the operations room (opsroom), who is primarily concerned with the execution of emergency and incident management. Often, he is the first one to receive information on the emergency. He has to assess the situation (is the information reliable, is the situation serious) and take appropriate actions (e.g. inform/warn others, register information, activate others, transfer the emergency management to a higher echelon). Complicating factor is the time pressure and uncertainty of the information the DSO has to deal with.

### 2.3 Strategies analysis

A strategies analysis describes the strategies that can be applied in executing the tasks identified in the previous steps. This description is still independent of who will eventually perform these tasks. It is important to identify possible strategies (not only the currently used) and indicators to assess performance. An adequate method to follow is a descriptive field study. Therefore we walked-through a scenario describing a collision of a minesweeping vessel of the Navy with a fishing boat in international water. This walk-through made clear that two kinds of information are crucial for the DSO: situational and potential information. Situational information covers the condition of the unit (with respect to, e.g. material or persons), the condition of the environment (e.g. physical [sea, weather, ports], operational [e.g. tasking] or juridical [e.g. international laws]), and the condition of the infrastructure (e.g. maps, storage of ammunition and weapons, tele- and data-communication, security). Potential information covers all persons and services the Royal Netherlands Navy has to its disposal to tackle the emergency and its consequences, for instance with respect to informing relatives of personnel, deploying medical teams, financial compensation, naval engineering advise, or arranging a press centre.
Based on the results of the analysis, a functional description of the opsroom has been made with respect to the management of emergencies and incidents. The following functions are identified: gathering information, assessing the situation, taking decisions/actions, recording, and evaluating/monitoring the own performance. These functions will be briefly described next, and are also depicted in Figure 1.

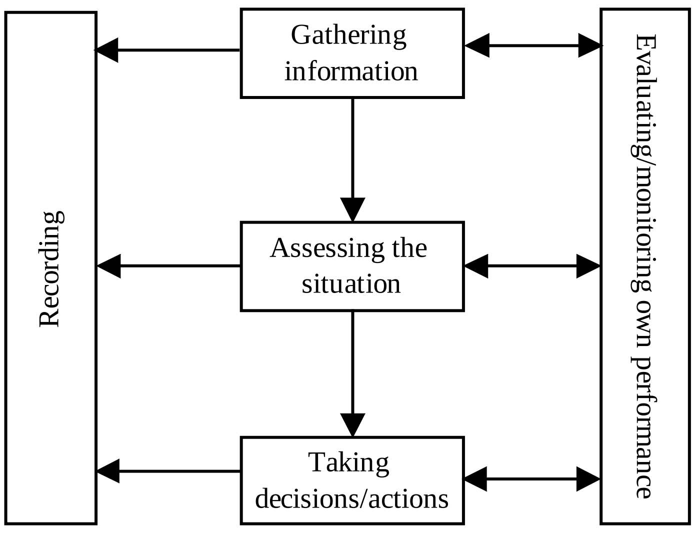


Figure 1: Functional decomposition of the opsroom.

I. Gathering information
   a) interpreting the information by identifying the 5 W's:
      - what: type and size of emergency
      - where: location
      - when: day and time
      - who: people involved
      - what actions are already taken by others
   b) asking for additional information:
      - situational information
      - potential information

II. Assessing the situation
   a) determining the threats
   b) estimating the size and impact of the emergency

III. Taking decisions/actions
   a) stating priorities
   b) informing persons/organisations
   c) co-ordinate with persons/organisations
   d) monitoring local emergency management
   e) consulting persons/organisations
   f) activating/deploying personnel
   g) transferring the emergency management to a higher echelon

IV. Recording
   a) incoming information
   b) decisions taken in the opsroom
   c) actions, decisions, events in 'the outside world'

V. Evaluating/monitoring the own performance
   a) continuously verifying information, assessing the situation, estimating the changing threats, are the adequate actions undertaken, et cetera.

In first instance, this is a linear sequence. After the first loop (the initial report of an emergency), however, this becomes an iterative process.

## 2.4 Social organizational and cooperation analysis

A social organizational and cooperation analysis describes the relations between actors (humans and systems). The tasks are entirely or partly allocated to the various actors. It is here that it is determined how actors work together, how information will be exchanged, and what norms are stated. This organisation should be flexible to some extend, for instance when an officer is missing). A decision support system should adapt to this flexible organisation of the work.
Based on the functional description of the opsroom a distribution of tasks has been made between the operator (Duty Staff Officer) and the decision support system: this is depicted in Table 1.

| FUNCTION | OPERATOR | SYSTEM |
|---|---|---|
| **Gathering information** | | |
| Handling the initial report (identifying 5 W's) | - Talks to announcer<br>- Records the information | - Displays recording-format (5 W's: what, where, when, who, which actions) |

| | | |
|---|---|---|
| Requesting additional information | - Records the information<br>- Initiates the deployment of the potential | - Has database with situational information<br>- Has database with potential information, including names and telephone numbers |
| **Assessing the situation** | | |
| Determining the threats | - Determines nature of threat<br>- Adds new threats | - Displays checklist with possible threats |
| Estimating the size and impact of the emergency | - Makes assessment of risks (high/medium/low) | - Displays flow-diagram supporting the risk assessment |
| **Taking decisions/actions** | | |
| Stating priorities | - States priorities (based on situational information and possible risks) | |
| Informing persons/organisations | - Contacts persons and organisations | - Contacts persons<br>- Generates names and telephone numbers (based on the risks) |
| Co-ordinating (e.g. with higher echelons, security personnel, local emergency management team) | - Contacts persons and organisations | |
| Monitoring of local emergency management | - Checks whether procedures and checklists are followed | - Displays relevant procedures and checklists |
| Consulting persons/ organisations | - Contacts persons and organisations | - Displays tables with potential information, including names and telephone numbers |
| Activating/deploying personnel (e.g. higher echelons, other services) | - Calls other team members<br>- Calls higher echelons<br>- Calls other services | - Names and telephone numbers of other team members<br>- Names and telephone numbers of higher echelons and other services (based on risks) |
| Transferring the emergency management to a higher echelon | - Composes the briefing<br>- Gives the briefing | - Generates relevant information for the briefing |
| **Recording** | | |
| Records incoming information | - Records the information | - Displays recording format |
| Records decisions/actions taken in the opsroom | - Records the information | - Displays format (e.g. which decision/action, who involved, time, who is informed, result) |
| Records decisions/actions taken in the outside world | - Records the information | - Displays format |
| **Evaluating/monitoring own performance** | | |
| Evaluating/monitoring own performance | - Takes necessary actions (e.g. contacting persons, recording information, taking decisions, et cetera) | - Has agents who keep track of information, decisions and/or actions are recorded, persons are contacted, et cetera |

Table 1: Functional distribution of tasks between operator and decision support system.

## 2.5 Worker competencies analysis

A worker competencies analysis describes the knowledge and skills required for humans to adequately perform the tasks within a certain environment and given a certain organisation of the work to be done. A useful terminology is the distinction between skill-, rule-, and knowledge based behaviour (Rasmussen, 1983). An

interface with a complex sociotechnical system should support these three types of behaviour.
Handling high-risk emergencies is always supported with standard procedures, and can therefore be categorised as rule-based behaviour, although not every step in the procedure should be rule-based. In a decision support system these procedures can be presented digitally. In case no procedures are available, the DSO is required to perform knowledge-based behaviour. This can be guided by more general support, based on the functions (see Figure 1) and the possible threats with respect to personnel and relatives, material and infrastructure, organizational processes and public safety, military safety, politics, and environment.

## 3. Specifying functional requirements: a human factors view

Software development is an iterative process with three phases: analysis, design, and implementation. Within every phase, evaluations should be conducted, namely analysis, formative and summative evaluations. This study is in the analysis phase. Goal of this phase is formulating specifications based on human factors principles as well as operational needs (see Figure 2).

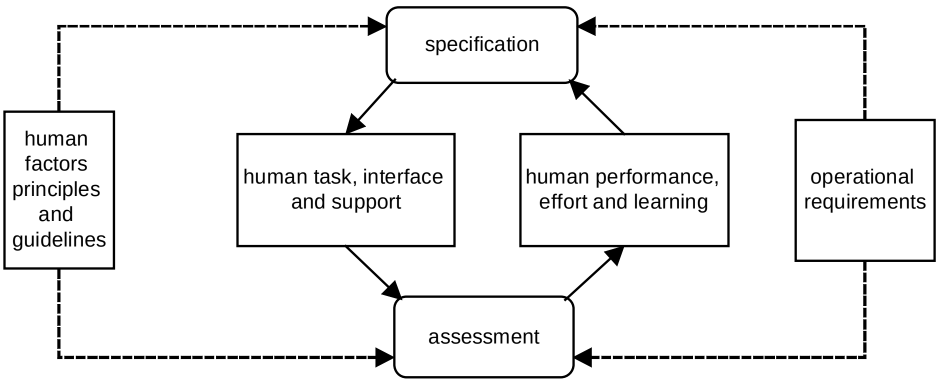


Figure 2: Software development based on human factors principles as well as operational needs (Neerincx & Van Doorne, 1997).

Formulating functional specifications (not only of a decision support system) should meet the following requirements (Neerincx & Lindenberg, 1999): uniform (only one interpretation), complete (full coverage of the system), testable (in order to assess whether it is implemented), consistent (no contradictions), flexible (modifications are possible), and traceable (rationale should be clear).
Bottlenecks of the DSO in the opsroom are high workload, executing several parallel tasks, switching between tasks, and losing situational awareness. A well known risk in situations like this is the phenomenon of ‘cognitive lock-up’, or focusing on only one aspect of the task execution and neglecting the others (Kerstholt, Passenier, Houttuin & Schuffel, 1996). This can result in the operator getting out of the primary loop and being reduced to a passive processor of information, resulting in a lack of understanding the situation. An operator should therefore be actively involved in processing the information. On the other hand, however, it should be realised that the operator cannot do everything in an adequate or timely fashion, or fully exploits the functionalities of the computer. Consequently, task performance should be a joint effort of the operator and the decision support system, in which the support is focused

on those aspects that are complex for the operator (Kerstholt, Passenier & Degrell, 1998).

Cognitive task performance and mental effort are less affected by time-pressure, and more by the complexity of the task and the number of task switches (Neerincx & van Besouw, 2000). A decision support system for emergency management should therefore support at least (cf. Neerincx & Van Doorne, 1997):

- task-set integration by means of an information handling function: presenting general and integrated overviews of the status of the system (i.e. the emergency management). The design should enable:
  a) presentation of the current status of the emergency management, and development over time;
  b) quick and easy access to required information, with adequate orientation cues and explanations.
- task-set switching by means of an action plan including:
  - an overview of tasks that need to be executed, or are currently being executed ('emergency scheduler');
  - the corresponding context-specific procedures ('rule-provision') to adequately perform the task.

  The design should enable:
  a) automatic and timely presentation of information (requiring no effort by the user);
  b) presenting context-specific, procedural, and just-enough task knowledge;
  c) easy operation of the user interface (minimal and consistent interaction between operator and system);
  d) an active involvement of the operator during the execution of procedures.

## 4. Functional specifications of a decision support system

The functional specifications are formulated on two levels: the task level (Neerincx & Van Doorne, 1997) and the communication level (Williges, Williges & Elkerton, 1987). At the task level it is determined what goals and information needs the system should meet. At the communication level the focus is on the handling and information presentation of the user interface. The functional specifications on both levels will be described in the following two sections; a complete overview can be found elsewhere (Van Berlo et *al*., 2001).

### 4.1 Task level

The functional specifications on the task level comprise the functions the system should accomplish in supporting the DSO's tasks. The specifications describe the gathering of information, assessing the situation, decision making and taking actions, registering information, evaluating and monitoring the progress, and the flexible use of the system. Each category will be briefly illustrated.

A) The decision support system should filter and combine information in order to support the construction of the situational awareness.

A situational database should be built containing information with respect to the status of the own personnel, of the environment, and of the infrastructure. This information should also be presented in a chronological order to get a deeper understanding of how the situation is evolving and to take anticipating actions. A potential database should be built containing information with respect to all the material, equipment, services and personnel that is potentially at the organisation's disposal. Depending on the type of emergency, this database automatically filters the relevant information presented to the operator. Both databases should be updated automatically via the respective networks. This also requires the mutual exchange of classified information.

B) The decision support system should enable the operator to assess the situation quickly and reliable.

The specific type of emergency should be identified as quickly as possible. By typing keywords, or clicking on hypertext, a limited number of emergencies are displayed. The operator makes the final selection. Based on this selection, the appropriate procedures are automatically displayed. New types of emergencies should be added.

C) The decision support system should support the operator interactively in making the adequate decisions and in taking appropriate actions.

The support should contain context specific, procedural steps. The information should be minimalistic, i.e. just enough. However, every procedure should cover a complete process. In case no specific procedures are available, the system should provide a more general procedure based on the functions to be accomplished (section 2). A database containing lessons learned from previous emergencies should be consulted if required. The operator should always be able to search for alternative procedures and to overrule the filtered and automatically presented information from the potential database. A 'scheduler' monitors the execution of the procedure: which steps have been or are currently being executed (e.g. as indicated by the operator in checkboxes), and which steps still need to be done.

D) The decision support system should enable the recording and aggregation of all information.

All information should be recorded in a standard format: incoming reports (the 5 W's), actions and decisions taken in the opsroom (e.g. which, by whom, when), and actions and decisions taken in the outside world. The recorded information should be aggregated to a higher level of abstraction enabling the DSO to have a quick and general overview. Also a briefing for higher echelons should be constructed based on the recorded information.

E) The decision support system should support the monitoring and evaluation of the own performance.

Some possible means of assessing whether the emergency management by the DSO is done in an effective and efficient manner, are: have all 5 W's been identified, have all steps of the procedure been checked, how long ago has information been added, are databases being searched, et cetera. For every procedure specific criteria should defined in order to assess the own performance.

F) The decision support system should be deployed in a flexible way.

In due time, an assistant will support the DSO during the emergency management: a multi-operator mode should therefore be implemented. Consequently, taking over a procedure by the (assistant) DSO should be possible. Emerging technologies, like video-conferencing, should be implemented if needed.

### 4.2 Communication level

The functional specifications at the communication level comprise the interactions with the user through the interface. These specifications describe the compatibility, consistency, context, structure, feedback, workload, individualisation, and flexibility/maintenance. Overall, these specifications cover the operation of the system by the operator, and the presentation of the information. For instance:

- Consistency: a similar action (e.g. a mouse click) on a similar object (e.g. an item in a menu) should cause a similar interface reaction (e.g. displaying a pull-down menu). The presentation of information should be consistent on aspects like layout, colours, graphical presentation, et cetera.
- Structure: navigating through the system should be easy. The system should therefore have a clear structure of functions and information.
- Workload: dialogues should cost minimal effort. In case of information overload, the operator should be able to manipulate the way information is presented. Non-relevant information should not be presented.

Because these specifications are of a more general nature, the interested reader is referred to other documents (e.g. Lindenberg, 2000; Van Berlo *et al*., 2001).

## 5. Towards a training tool

Getting personnel involved in emergency management as prepared as possible for doing their job is a major challenge. New tools and technologies, like the decision support system described above, can provide necessary on-the-job performance support. Besides this on-line support, it is important to extend the decision support system with a training functionality. This will enable the users of the system to explicitly and systematically train in emergency management, something that can hardly be done in real life due to both the low frequency of occurring emergencies and practical constraints (e.g. no time, no training program, no training staff, and no fellow trainees). The focus of the emergency management training should be on individual task performance (by the DSO) as well as on team task performance (i.e. including the assistant DSO, or involving higher command levels). In this way it is possible to gain experience in high-risk operations in a controlled manner and without operational risks. Essential in this respect is the definition of several critical scenarios based on which the individuals and teams can train. These scenarios should be based on clear training objectives that can be measured in order to assess the quality of the training. This requires the formulation of concrete and observable performance indicators. These performance indicators enable the assessment of the proficiency level of the personnel, and give insight into the aspects of the (team) task performance that need to be improved (Van Berlo & Schraagen, 2000). Moreover, training results can also be used as a quality check of the several aspects of the emergency management itself, for instance the availability and quality of checklists and procedures, the availability and quality of the information in the databases and the exchange of information over the networks. Ideally, the training and exercises should be conducted from any location, so a training need can immediately be met. In order to expand the decision support system with such a training module, the functional specifications covering this web-based learning and (distributed) team training should be formulated.

## 6. Conclusion

Emergency management is a time critical, open and low frequency practised task. Especially during the first phase, immediately after the initial report, a clear picture of the situation is lacking, time-pressure is evident, and information is incomplete. During emergency management, the workload of the DSO is usually very high, but making the right decisions as quickly as possible is of paramount importance. It is therefore the intention to support the DSO's task performance by means of a decision support system. In this study it is systematically determined which functional specifications such a system should meet. Therefore a method for designing complex sociotechnical systems, the Cognitive Work Analysis, has been followed. Based on both human factors principles and operational requirements, the functional specifications have been formulated on two levels: the task level and the communication level. The functional specifications have been defined in close collaboration with the final users of the system, and are exemplified by means of a specific scenario. This has resulted in a clear and common view on the functional requirements of the system. Based on these specifications, the Royal Netherlands Navy is now in the process of defining the technical specifications and building a prototype of the decision support system.

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