TIEMS 2001 – International Conference on Emergency Management
Oslo- Norway – June 19 – 22, 2001
Session 2 – Web Based and Virtual Decision Support Tools for Risk and Emergency Management – Paper 2.6

Computerised Procedures for Emergency Management

Rossella Bisio (Halden Reactor Project - Norway),
John-Einar Hulsund (Halden Reactor Project - Norway),
Svein Nilsen (Halden Reactor Project - Norway)
Massimo Sepielli (ENEA Ente per le Nuove Tecnologie, l'Energia e l'Ambiente – Italy)

Institutt for Energiteknikk
OECD Halden Reactor Project
P.O.Box 173
N-1751 Halden - Norway
Rossella.bisio@hrp.no

Keywords: Computerised Procedures, Training, Emergency plan.

Abstract

Correct and fast execution of emergency plans and related operation procedures is an important element in the management of accidents in nuclear and chemical industries, transportation infrastructures, and environmental disasters.

Computerised procedure systems (CPS) are one technological answer for helping appointed institutions in coping with injuries, by bearing and enhancing many critical functions required by an emergency rescue operation, which usually presents a very short timeframe. Nonetheless the design and implementation of CPSs are non-trivial tasks. One reason is that operators' task structure is not known in detail, not even to the operators themselves. The task structure is the ground knowledge realized in a CPS, both with respect to the type of support offered by the system and interaction elements included in the human computer interface). Since the process of documenting the operator tasks is bound to be an iterative process, building a CPS from scratch will in most cases be unfeasible, and therefore a CPS must be flexible enough to be 'easily' modified to meet the additional requirements.

Halden Reactor Project (HRP) has developed a CPS, named COPMA-III (Computerised OPeration MAnual) from its long experience in supporting activities in nuclear power plant control rooms. The system offers a high level of flexibility that can make it a good candidate to face application in other fields too.

A case-study of computerisation of procedures is currently ongoing as an ENEA - HRP co-operation related to the emergency and relief plans of critical roadway infrastructures.

1. Introduction

Computerised Procedure Systems (CPS) [1] are one technological answer for helping appointed institutions in coping with injuries, by supporting and enhancing many critical functions required by an emergency rescue operation, which usually must be carried out in a very short time.

A case-study of computerisation of procedures is currently ongoing as a ENEA - HRP co-operative work, related to the emergency and relief plans of critical roadway infrastructures, such as Frejus and Mont Blanc Italian-French tunnels. The choice of this case study is not casual, since the "fire in tunnel" is a problem much felt in Italy and Norway, after the occurrence of some disasters. The 24^{th} March 1999 pushed up to the public attention a tragic eventuality: in the tunnel of the Mont Blanc 41 persons died and other were severely injured when a truck took fire at the 6,5 km of the tunnel.

Prevention of such kind of disasters involves many factors, not last international political decision about encouraging-discouraging road traffic versus railway transportation. But even the best possible prevention cannot guarantee the unexpected to happen, and to be prepared to intervene is the only way to limit consequences. Technology, and CPS in particular, can play a key role in supporting people in their task to face emergencies.

The task structure is essential to the making of the CPS, both with respect to the type of support offered by the system and interaction elements included in the human computer interface (HCI). The information compiled and structured on the individual screens is closely modeled to an assumed working practice within the control room. The integration with the remaining displays of the HCI is also important, to facilitate the concurrent use of the CPS and the remaining HCI. If these assumptions are wrong, the system could be used far less than expected, or even worse, unnecessarily overload the operators' activity.

The process of documenting the operator tasks is bound to be an iterative process. By interviewing the operators and observing them in work, a main task structure may be proposed. Later on this task structure needs to be amended, taking into account tasks and responsibilities that were not thought of originally. The presence of a CPS may in itself change the tasks of the operator. Typically, data collection from panels may not be needed anymore if the CPS compiles all data that is needed to perform a certain step within the procedure. The assumed changes to the operator tasks will increase the uncertainty about the usability of the eventual CPS.

Altogether this creates a high risk that the first version of the CPS is not going to be fitting within the working environment of the operator. While the system is being tested and after the CPS has been put in operation it will arise situations when changes to the system is required. For such changes to be implemented it is important that the current system can be modified to meet the additional requirement. Building the system from scratch will in most cases be unfeasible. Meeting additional requirements exposed after the construction of the system is facilitated by the provision of good configuration possibilities.

Wide configuration possibilities are one of the main design principles behind the COPMA-III CPS tool. Procedure content is formalized by means of the XML (Extendible Mark Up Language) standard, allowing a wide variety of procedure structures. Both operator support and the CPS HCI are configured using XSLT (Extendible Stylesheet Language Transformations). One set of XSLT transformation rules takes the XML representation of the procedure as input and produces a structure than can be interpreted by the system. This interpretation will implement the support offered to the operator in executing the procedure. Another set of XSLT transformation rules builds together an HTML interface that will constitute the CPS HCI. Just changing the set of XSLT rules may reconfigure the CPS, keeping the XML representation of the procedure unchanged.

The aim of the above mentioned ENA-HRP cooperation is converting existing 'paper-based' procedures in 'computer-based' procedures, and to use COPMA-III for executing computer-based procedures and verify the system performance in cooperation with other work support tools .

2. Analysis of Emergency Plans in Roadway Tunnels.

In this section we present the results from the analysis of emergency plans to apply in case of accident in a tunnel or, more general, in a roadway. This study is intended to identify the actors, the role of procedures and the functions required during emergency in order to provide requirements for a CPS.

2.1. Emergency Management Team

When an accident happens a team of people readily intervenes to mitigate the consequences as much as possible. The team involves distributed and co-operative organizational structures, which are by mandate or voluntarily claimed to cope with emergencies. Figure 1 shows an overview. The *emergency manager*, usually located on-site the emergency domain, coordinates the patrols of police, fire fighters, medical organizations, volunteers. The emergency manager is in communication with local and central authorities, scientific and civil agencies. The result is the creation of an interdisciplinary relief team, which must be coordinated across the traditional institutional borders.

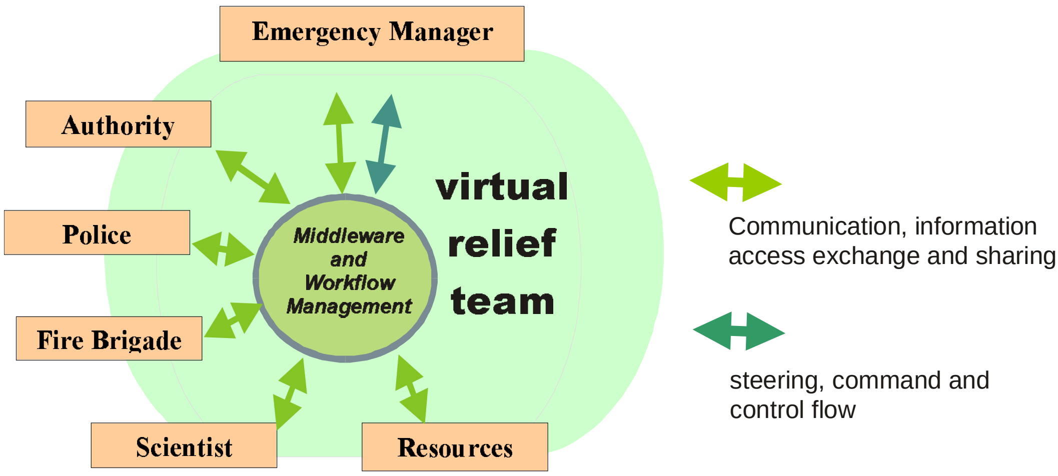

Figure 1 Emergency Team

During an emergency situation, emergency managers have to take decisions by consulting several information sources: domain information, real-time and historical databases, emergency procedures, and predictive models. Starting from this, they decide goals and choose strategies, and plan the intervention assigning human and technical resources, on the basis of their experience, as well as with the help of external scientific *knowledge*, socio-political priorities and orders from authority (so called, *preferences*). Cognitive experts call this reasoning model an unstructured decision-making [3]. In the framework of knowledge, a basic task of on-site emergency managers is the choice and the application of the most suitable emergency procedures, rules, plans, selected from existing, with a certain dose of flexibility to adapt to the current situation.

2.2. Emergency Activities Loop

From the analysis of emergency plans the presence of repetitive cycles of decision-making activities emerges. The cycle encompasses the followings phases:

1) *Situation assessment*: from raw data they correlate features and create a higher level description, detect an abnormal event, try to have a clear picture of what is happening. This is the background for the next steps.
2) *Task planning:* decide what to do according to the gravity of the situation, this means to choose the suitable emergency procedures, or to choose the appropriate task within a given procedure or an appropriate interpretation of that procedure.
3) *Action planning:* the procedure sometime is 'abstract', suggesting what to do in that-kind of situation, but probably it does not take into account particular constraints, or the suggested action is abstract, in order to accomplish it, it is necessary to perform other more detailed actions that must be decided on line. In other terms this means that an adaptation to the real situation could be necessary.
4) *Action implementation*: the chosen action must be executed, the operative support takes place.
5) *Effect verification*: by no way the execution of the action can guarantee that the problems has been solved, so effects must be checked by monitoring the situation, to see if the expected effects have been achieved or other problems arise. This leads back to the first step, until from the situation assessment we can detect that the emergency is ended.

This cycle is typically *human operator based*; Emergency managers take control and supervision all the cognitive cyclic activities, relying on a considerable amount of information, knowledge and experience.

A relevant part of the knowledge used during emergency management is 'procedural'. With hard time constraints, and in multi-organizations context even planning of tasks/actions cannot be left to complete 'reinvention', but must rely on stereotypical scenarios and plan-templates: procedures. In complex system control tasks situation assessment and diagnosis are also complex task; leaving apart critical aspects and jump to erroneous conclusions could be as likely as fatal. A predefined schema of steps, determined off-line, where no time constraints influence the solution and the knowledge of the system can be carefully exploited, can be very helpful. Monitoring the situation can also take advantage form a predefined list of things-to-look-at, thresholds to verify, observations to make 'in time'.

2.3. Emergency functions

An analysis of existing emergency plans suggests what are the instances of typical time-critical functions that are candidate to be supported, improved and speeded up by CPS, namely:

- real-time data retrieval from the emergency domain (location and extension of the area involved, meteorological situation, etc.);
- communication and co-ordination among the (geographically distributed) co-operating organizations (emergency manager, local and central authorities, scientific and civil agencies), particularly meaningful in France-Italian tunnels where authorities of two States must be alerted;
- command and control of on-field patrols (police, fire fighters, medical organisations, volunteers);
- information to the public, TV and press;
- retrieval of supporting information from databases (procedures, maps, laws, telephone lists, means and equipment, archive of past emergencies, population and territorial data, document templates, etc.);
- connections with what-if analysis based on model-based and rule-based tools;
- structured data recording of the procedure execution and related events, for subsequent analysis

2.4. Main requirements to a CPS

As discussed in the previous section, management procedures are dominant during emergency, consequently, it is natural to think of a CPS as an effective tool to improve efficiency and reduce errors in emergency management. Main issues for CPS in this application are to make the necessary information, procedures and procedures related data quickly available, and facilitate information exchange among involved organizational units.

Team work

The first aspect emerging is the teamwork. Many people intervene, members of different organization. Roles, focus of attention, point of view, level of detail, responsibilities are different not only at level of the single person but also at the organization level. In this specific case, the teams go behind the border of one state and involve two states: Italy and France. These conditions imply that a support system should provide different man machine interfaces, adapted for the specific task of different users, presenting different details and information. Furthermore it should provide interfaces in different languages and easy access to the other nation terms, parallel organization, equivalent responsibility.

Distributed architecture

In the structure of the task a group of organization work more closely, other loosely. It is important to define precisely the limits of the CPS, which organizations will involve and connect the CPS to more classical communication facilities (like fax) when it is the case. Still the distribution of the involved organizations could be critical. In a control room a CPS can rely on a local network. In this application the scope is enlarged to a long distance network, where problems of security arises and reliability is an important issue.

Very High Integration

When the CPS plays a primary role it must be fully integrated in the normal operation cycle. From the Human Factor point of view the system should act as a 'member of the team', not only in emergency. For human beings could be more difficult in emergency situation to interact with an *unusual* system. Further, a CPS is expected to receive and send messages-commands to other different type of systems, for example: data acquisition system from the field, to show important measure evolution as the procedure is applied; specialized diagnosis system to trigger the right procedure; alarm systems, to be alerted for starting related procedures.

Procedures are not the only source of information that a CPS should present, but there are other related important information, the maps of the straight area for example, a GIS system is one of the main systems in supporting interventions. But also more detailed information about procedure itself, information not normally displayed, should be available on request by the user/operators.

Virtual Reality (VR) deserves a special mention; it offers very effective tools to help emergency managers and operators in understanding the situation. In particular, CPS, GIS systems and VR tools might be used in integrated manner, for obtaining in the beginning a quick search of the accident domain on maps, and later for accessing and entering the virtual environment (i.e. the tunnel from a tunnel data bank). The involved area could be represented either not affected from damage (fire, smoke, explosion, structure deformation, physical hurdles), or affected, by using fire and smoke simulation models. This can give the emergency manager a powerful tool for making decisions, and to patrols to operate, both at training / preparedness level and at practical level.

Procedures changes/evolution

Procedures involving different organizations are likely to change more than procedures involving one single centre. Maintenance procedure tools and standard format are in this context particularly relevant.

Dynamic adaptation to the real situation

A procedure is a pre-planned sequence of conditioned actions that helps to solve a problem. Sometimes a procedure enforces actions, but other times it simply suggests what to do. Whether the action is really necessary depends on the actual situation that could be different from the one foreseen by the procedure designers. Procedures should be instantiated into a particular context; the CPS should allow the user to flexibly adapt the procedure to the real situation when this is advisable.

3. COPMA-III a configurable CPS.

COPMA-III has been developed at IFE as a result of a many years experience in supporting procedures in nuclear power plant control rooms. COPMA-III is a CPS and a software tool that assists computerised procedure system development. Computerised procedure systems can have many different Human Computer Interfaces, so COPMA-III emphasises configuration of the operator interface. Moreover, computerised procedure systems may have various ambition levels for assisting the operators. Thus COPMA-III also permits configuration of the nature and level of operator support.

Past experience with complex systems has emphasized the importance of separating knowledge, from its various use situation. Along with flexibility, this is the second main principle behind COPMA-III. The knowledge, in this case the set of procedures, is represented by means of the W3C standard XML (Extensible Markup Language), from which each part of the system extracts the relevant data for its task. COPMA-III runs in a distributed environment, it has multi-user capability, including the support for cooperative tasks. It deals with several types of procedures, with different structure/models. It provides customized HCI for each type of operator. Internationalisation capability is available too. It can implement different execution strategies, not only strictly sequential. It allows for different levels of automation of procedures, including different levels of automation inside a single procedure.

The current version of the COPMA-III system is divided in two main parts: an off-line and an on-line part. In the off-line part the procedures are defined and the COPMA tool is configured. In the on-line part the operator uses the resulting system with the defined procedures.

The current off-line system has the following structure:

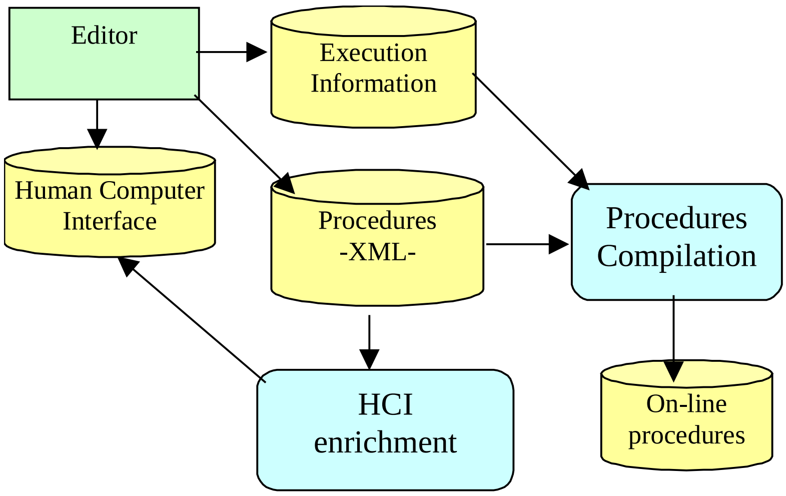

Figure 2 – **Off- line system.** XML procedures are the starting point to create *on-line* files, that is, files for procedures execution and visualization. The database symbol has been used to refer to groups of related files.

Procedures are the primary source of information to COPMA-III. They can be supplied by a tool, like a common text editor, a specialized editor, or by a development process that creates the suitable XML files: the basic underlying procedure structure in a COPMA-III. All procedures are tagged according to an XML Data Type Definition and stored as a collection of files. Those files constitute the master copy of the procedures; all other procedure files in the system are derived from the XML tagged procedure files. The XML files define the content of the procedure, while all other files accentuate certain aspects of the content, such as use and visualisation.

COPMA-III configuration consists mainly in providing the transformations to create different ‘interpretations’ of the same procedure. For example, the topmost database, named “Execution Information” in the figure, contains XSL transformation rules to create an executable version of the procedure. A step of procedure compilation applies the transformation rules to a procedure and creates a corresponding file defining the kind of operator assistance offered by COPMA (On-line procedures).

Other transformation rules are supplied to create the HCI. The HCIs of COPMA-III are web-based applications, so most of the information for creating the HCI is related to dynamic HTML technology. Special display information, like flow graphs to illustrate procedure structures, can be semi-automatically created by a step labelled "HCI enrichment".

The on-line system has the following structure:

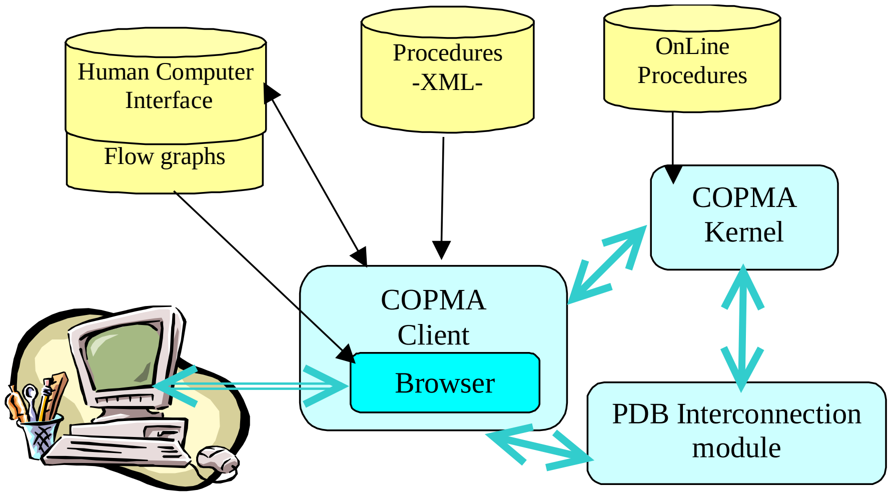

Figure 3 – Run-time environment. Each module shows notes about implementation language**.**

COPMA-III is a combination of three different types of modules, they may have more than one instance each: the COPMA kernel, the COPMA client and the PDB (Process Database) Interconnection module.

The COPMA kernel supervises the complete procedure execution and broadcasts relevant information to all connected COPMA clients. The COPMA kernel also performs automatic actions; it can monitor conditions and issue action requests to actuators.

Live 'process data' may be transferred via the PDB Interconnection module, both to the kernel and client.

The COPMA client collects global information both from the Kernel and the Interconnection module and displays them in an appropriate way. Received information is processed according to the local condition at the control point, taking into considerations aspects such as the type of user connected, his/her role, he/she current task, his/her last request. Ideally COPMA client transforms the flow of global information into a customised view, coherent with the local situation and easily *readable* by the connected operator. The COPMA client includes a browser component for the HTML rendering.

4. Supporting Emergency Management with COPMA-III

COPMA-III is born in process control environment, but can be considered as a general-purpose tool. A few COPMA features can be exploited in a general system for supporting emergency like Emergency Decision Support Systems - E-DSS [4], those features are indicated in the following with a black point, other features, indicate with a white point, are not yet implemented and must be further analysed and developed.

Team support

- COPMA-III supports the execution of multiple procedures in parallel and cooperative activities, taking care of part of the automatic distribution of information, messages and commands within the emergency teams;

  - the concept of team and cooperative users is under development in order to improve representative power and flexibility in presenting information to the user

Distributed architecture

- COPMA-III has a distributed architecture based on a local network.

  - Issues arising exploiting a large area network should be carefully investigated.

Integration

- COPMA-III activates and receives asynchronous data from external systems. The connection to external systems, provided the basic layer for communication, is programmable/configurable as well as the HCI.

- HTML based HCI allows to easily include support for audio video and anything else this fast evolving technology permits.

  - Other display tools are under investigation; of particular interest in this application is the connection with VR.

Environment for procedure execution:

- COPMA-III provides the possibility to perform automatically most common monitoring and conditional check

- It is able to deal with and to work contemporarily with different kind of procedures (e.g. emergency condition, abnormal conditions), with different levels of detail and different level of automation.

- Providing context data: Information about the status of the controlled process, status of current operators' activities and procedures are integrated in the HCI, and customised for each user-role.

- Procedure navigation among procedures is fully supported and can be configured according the needs.

  - Procedure adaptation: currently it is possible to implement several execution strategies, for example strictly sequential or user-determined. In the future more 'parametrical' type of procedure will be investigated.
  - Reporting: feature under developing

Environment for procedure development:

  - At present there is no support. Assistance during the whole procedures life cycle is recognized as a crucial aspect also in the control room environment. We are going to afford the problem synergistically, from the control room environment and the emergency management, sure that will lead us to a better solution that will be soon available in COPMA-III.

5. Conclusion

The application of CPS in emergency management in roadway infrastructures is at a preliminary step. Most of characteristics of COPMA-III make it a promising CPS to play the primary role in an emergency management support system. Not all the requirements examined in this paper are covered by the current version of COPMA-III, but it is still evolving and new functionalities are planned be added. One example is procedures maintenance facilities. Emergency procedures in a control room are different from emergency procedures in a crisis-management centre. Two aspects must be mentioned: Control room procedures, and specially CPS, have been studied for a long time, providing a significant amount of knowledge, CPS for crisis management have received less attention. Even if procedures within the two domains are obviously different, the reasoning of the humans that use them, what they need when they operate in an emergency context, is common to both domains. That is why we believe that re-using the experience developed in the former field it is not only possible but it will be cost effective in the long term for both fields.

References

[1] J.M. O'Hara, J.C.Higgins, W.F.Stubler, J.Kramer: Computer-Based Procedure Systems: Technical Basis and Human Factors Review Guidance. NUREG/CR-6634, U.S.Nuclear Regulatory Commision, January 2000

[2] http://www.ife.no/copma

[3] A.M.Gadomski. "The Nature of Intelligent Decision Support Systems. Intelligent Decision Support Systems for Emergency Management". The HALDEN Project Workshop, October 1997. http://tispi.casaccia.enea.it/activities/emergency/eme-idss/sld001.htm

[4] C. Balducelli, A.M. Gadomski. An Active Decision Support System for Emergency Management: Bottom-up and Top Down Approaches. National Meeting on Risk Evaluation and Management inside civil and industrial environment, Pisa, 6-8 October 1998

Autors' notes

Rossella Bisio: started work at HRP in the Computerised Operation Support Systems division in 2000 after more than 10 years of experience in telecommunication field, master degree in Computer Science, her main interest is intelligent support systems.

John Einar Hulsund: has a master degree in experimental particle physics from the University of Bergen, Norway. He has been working with computerised procedures and the COPMA system at HRP since 1997.

Svein Nilsen: is working as section leader of the knowledge based system section at the HRP. His theoretical background is a master degree in computer science from the University of Oslo. Practical experiences include alarm systems, computerised procedure system and other operator support systems.

Massimo Sepielli: Degree in nuclear engineering, a post-graduate degree in nuclear plant safety and environmental radio-protection. He has been working as researcher at ENEA since 1983 in the fields of computer-based (nuclear and chemical) plant supervision, diagnosis, control and emergency management. He is currently Italian Delegate in OECD Halden Reactor Project for the Man-machine interface research programme.