Operational Risk Management: How an I-DSS may help

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ABSTRACT.

Operational Risk management, the least covered component of Enterprise Wide Risk Management, needs intelligent tools to implement Comprehensive Emergency Management Programs.

In this paper we discuss how an Intelligent Decision Support System (I-DSS), based on Fuzzy Logic, can be used for supporting the management of complex and critical systems, especially under contingency situations, with limited resources' availability. This I-DSS is a contingency/emergency management tool and its objectives are: to help users make good decisions under critical and stressful situations; to decrease global risk (e.g. prevention); to increase the level of response (e.g. improved reaction through instruction and simulation); and to ensure process description's consistency analysis.

KEYWORDS: *Operational Risk Management, I-DSS, Fuzzy logic.*

1. Introduction

Resource management in crisis scenarios (e.g. fire in a oil tank) is crucial and can represent the difference between damage and catastrophe. Decision making must be executed with all available information, exploring existing capabilities and having in account the specific operational scenarios. Under operational risk contexts, the decision process is complex because of the multiple criteria to evaluate many different components and the fuzzy nature of information (e.g. “critical equipment”, “fundamental for system A”, “very degraded”, “quickly reparable”).

In this paper we claim that contingency management Intelligent Decision Support Systems (I-DSS) can be quite useful to support decision makers in the management of contingency/crisis situations (e.g. fires, bomb threats, floods, explosions) (Gadomski et al 2001). Contigency/crises situations are serious concerns of any operational risk department in most companies, as for example manufacturing and chemical plants, refineries, maritime ports and airports. In a broader perspective operational risk is part of what is called EWRM- Entreprise Wide Risk Management (Lam and Litwin 2002), which deals with all types of risks in companies.

The envisaged objectives of an I-DSS for contingency management are: to support decisions under critical and stressful situations; to decrease global risk (e.g. prevention); to increase the level of response; and to ensure process description’s consistency analysis (what-if analysis). The main advantage of the tool developed, Contingency Management Tool (CMT) is the support to the I-DSS development process. The CMT offers decision makers a global, consistent and stress-free view of all assets, highlighting important situations. Furthermore, the CMT is a distributed, robust and fault tolerant tool that allows decision making even in the case of partial communication failures. It should be noted that the CMT system, discussed in this paper, is based on previous work by the authors (Sousa et al 2006).

The main motivation for this work is to discuss how a Contingency Management Tool (CMT) is able to provide intelligent decision support for managing any kind of contingency/crises situations. The expected contributions are: discuss the importance of understanding the context of operational risk in companies/organizations; to highlight why having a generic support tool like the CMT can be important for organizations; to show the usefulness of having a fuzzy multi-criteria model capable of handling imprecise information; to discuss the need for a distributed tool that ensures consistency of data; and finally to show how the determination of relevant actions are based on the specific operational context scenario and knowledge of the limited resources available.

This paper is organized as follows. In section 2, we provide the background of operational risk management, within Entreprise Wide Risk Management (EWRM), highlighting the organizations need for contingency management tools. In section 3, we provide a short background for Intelligent Decision Support Systems as well as describing important enabling technologies for building a successful contingency management tool. In section 4, we discuss the concepts behind the contingency management tool, highlighting the specific requirements for both data and knowledge management. In section 5, an overview of the potential application fields is given and a current application of a contingency management tool for Portuguese Navy's frigates is summarised. Section 6 presents the conclusions.

2. Operational Risk Management

Entreprise Wide Risk Management (EWRM) integrates credit, market and operational risk with effective organisation, reporting and other support functions into a single framework, to provide a complete picture of company-wide risks (Toevs, Zizka et al. 2003). During the past decade, technology suppliers have attempted to provide organisations with EWRM ' tools but they are still developing in both theory and practice (Lam and Litwin 2002) (Sternberg and Lee 2006) (Toevs, Zizka et al. 2003). Major improvements have been recently achieved in this area (Toevs, Zizka et al. 2003), and the practice of EWRM is now a universal concept adopted by several industries, in particular in the financial and energy sectors. The objective is to manage risks in an integrated fashion, across different business sectors and risk types and at both the operational and strategic levels.

Operational risk analysis is the less consolidated component of EWRM. The creation of a Comprehensive Emergency Management Program (CEMP) is the adequate approach to achieve a structured solution. CEMP (Sternberg 2006) considers all hazards and all phases of related planning including mitigation, preparedness, response and recovery. This includes business continuity, emergency and disaster planning, as well as all of the related specialty areas such as hazard identification and mitigation, emergency response, disaster recovery, crisis management, and continuity of operations. Furthermore, assets are subject to risks and therefore ISO's safety and security plans (ISO 9001, ISO 14001, ISO 18001) are mandatory to increase assets' global value. There are few proposals for operational risk management tools but two interesting ones are (Gadomski et al. 2001) that describes a CMT tool for an oil port and (Marques and Pires 2003) that describes an application for battleships under battle conditions.

In this work we focus on developing an holistic approach, integrating concepts and recommendations from CEMP, for operational risk management because this is a challenge to obtain higher assets safety. Within this context the construction of an I-DSS for contingency management is important and we will now discuss why organizations do need this type of contingency management tools.

2.1. Why do organisations need contingency management tools (CMT)?

In the field of Operational Risk Management, when presented with a CMT, organisations tend to argue that they already have gone through the process of performing knowledge elicitation in order to produce contingency plans; they already have experts capable to deal with crisis situations and teams trained to tackle incidents and to repair equipments.

Although it is possible to argue against the completeness of some, if not all, of these remarks, it is still possible to raise the following questions:

- What happens when experts are not available? (E.g. holidays, away from the premises).
- How many persons in the organization have a global perspective? Organizations are becoming more complex, composed by many different sub-systems and it is difficult to grasp all information available.
- How do people react under stress situations? In the face of actual danger, human reaction is unpredictable and it is impossible to assure their reactions (e.g. fire-fighters, doctors, nurses).
- Is a global control perspective available during the crisis? Information flow, during a crisis situation is critical. Experience shows that communication systems are the first to collapse (mainly due to overload of unnecessary communication). A good example was the failure of the communication systems among the police, firemen and rescue personnel prior to the Twin Tower collapse in New York. Although, when the usual or the alternative communication channels are available the most critical task is the capability to collect and integrate all the relevant information that flows continuously.
- If needed, where and how is the information available (e.g. location of spares, fire equipment...)? During crises there is neither time to consult other persons nor to consult lengthy documentation.
- Do we have complete and accurate records, history, consistence, training, and availability of contingency plans and related information? Efforts during crisis are always concentrated on fighting the incident (specially in real cases), although it is impossible to increase response levels without an accurate post-incident analysis reporting.

Answers to these questions usually make it clear that the need for an I-DSS for contingency management is essential within the context of incidents contingency management. Further, there is a lack of software tools that can adequately answer the questions posed. In our case we consider a Contingency Management Tool (CMT) that tries to answers the above questions by providing (HOLOS 2005):

- Real-time data necessary for contingency/crises management;
- Fast and efficient levels of response to help decision makers;
- A user-friendly interface to assist all levels of decision-making involved in the crisis management;
- Quality of information during critical situations in order to enable good decisions;
- Integration of several data sources from distributed workstations;
- Good instruction/training tool for personnel including “what-if” capabilities;

- Consistency and automatic recovery of data in case some workstations fail.

In this paper we also focus on discussing the core of the tool, the fuzzy inference model, to clarify its novelty, scope and functioning. Specifically we discuss the main concepts, the inference model and the respective architecture. Moreover, we present the main capabilities of the CMT that encompass all points above (see section 4.3).

3. Intelligent Decision Support Systems (I-DSS) for Contingency Management

Human understanding, decision, and action drive the operation of complex systems. The usage of automation, networking, systems integration and intelligent decision support systems (I-DSS) (Guerlain and Brown 2000) improve the ability of human operators and decision makers to better perform their duties and to work together.

In operational risky situations, particularly under contingency conditions, time is a critical factor and the inherent stress affects the capabilities of decision makers. On the other hand, the decision process is extremely complex due to the high number of parameters involved and the vague and uncertain concepts and relation between them, which are used in the characterization of the situations. Vague concepts, implicit in linguistic expressions such as “severe limitations”, “very degraded equipment”, “relevant system” are nevertheless essential for human assessment and intelligent systems should be able to handle this type of imprecise information.

Recently, many improvements have been witnessed in the DSS field, with the inclusion of artificial intelligence techniques and methods (Turban et al. 2004) (Dahr and Stein 1997) (Jackson 1999), as for example: knowledge bases, fuzzy logic, multi-agent systems, natural language, genetic algorithms, neural networks and so forth. The inclusion of AI cutting-edge technologies in DSS is an effort to develop systems that mimic certain human characteristics, such as approximate reasoning, intuition, and just plain common-sense (Jackson 1999). A common denomination for systems including AI techniques is Intelligent Decision Support Systems (I-DSS), (Gadomski et al. 1998; Guerlain, Brown et al. 2000), (Turban et al. 2004).

The aim of intelligent decision support systems (I-DSS) is to develop effective smart systems for problem solving and decision-making (Turban et al. 2004) (Dahr and Stein 1997). These systems can deal with complex, imprecise and ill structured situations. Intelligent decision support systems are dynamic in the sense that they develop and implement more effective and productive support systems, both for individual users as well as for groups of users. In general, the need for I-DSS derives from (Turban et al 2004): (i) the growing need for relevant and effective decision support to deal with a dynamic, uncertain and increasingly complex management environment, (ii) the need to build context-tailored, not general purpose systems;

(iii) increased acceptance that intelligent technologies can improve decision quality and work productivity.

In our case the I-DSS for contingency management, called CMT, is based upon concepts from Fuzzy Logic, Knowledge Based Systems and Distributed systems. The following sections provide a brief overview of each of these technologies and their relevance for the contingency management tool.

3.1. Fuzzy Logic

Fuzzy set theory (Zadeh 1965) is a generalization of classical set theory that provides a strict mathematical framework to deal with the uncertainty inherent to phenomena whose information is vague or imprecise and allows its study with some precision and accuracy.

Fuzzy logic is a powerful problem-solving methodology with a myriad of applications information processing (Ross 2004). It provides a simple way to draw definite conclusions from vague, ambiguous or imprecise information. Moreover, fuzzy logic allows expressing knowledge with linguistic concepts (Ross 2004) (Zimmermann 1996) such as “very important”, “bright red”, “very dangerous” and “long time”.

In terms of contingency management, since we are mainly dealing with on how to express relations between concepts with different degrees of relationship, using fuzzy relations (Ross 2004) is quite important, natural and effective. For instance, for expressing relations such as “which function lines are important for a particular task and to what degree,” or “which equipments are relevant for a certain system and to what degree”. Hence, we need a method that allows us to formulate these vague concepts and Fuzzy Logic provides a good way to express imprecision that is inherent in the vagueness of such concepts (Jackson 1999) (Ross 2004).

3.2 Knowledge Based Systems

Knowledge Based Systems (KBS) (Turban 2004) are able to execute knowledge intensive tasks (e.g.: diagnosis, assessment, planning). Usually the referred tasks are intended to support human activities by applying previously extracted expert knowledge. Knowledge based systems or expert systems (Turban 2000), typically include a knowledge base, an inference engine and a dialog module. The knowledge base stores facts and rules while the inference engine performs the reasoning process to achieve results.

In terms of a contingency management tool we need to perform inference for determining a priority list of which equipments or subsystems should be fixed and in what sequence. As mentioned before, in stressful situations it is difficult for a team of humans to decide which equipments should be fixed first. Moreover, KBS allow different reasoning processes such as the fuzzy multi-criteria discussed herein.

3.3 Distributed Systems

Distributed systems enable the global sharing of resources to solve complex problems through cooperation supported by communication networks. It is a widely used technology in the development of distributed databases (Schmidt and Pedone 2005), real time expert systems (Janssen 1989) and decision support systems (Yan et al. 2000) (Schwarz et al. 2001).

The underlying paradigm enables the separation of data, the transparent access (local and remote), the sharing of computational power, decentralized decision processes, thereby enabling the increase of robustness, redundancy and efficient resource usage.

The CMT is a distributed system that considers the replication of the Data Base Management System (DBMS) in each workstation to ensure consistency and failure recovery. The DBMS replication allows the maintenance of a global state in normal situations, or the fallback to subgroup or stand-alone operation, by maintaining locally all information needed for the decision-making process, whenever communications fail. When communication among workstations becomes available a distributed writing mechanism ensures consistent replication of information to maintain a global state, common in all workstations.

An illustrative application of a contingency management distributed system, which provided some background for the CMT development, is a fuzzy expert system to assist command and control activities in a Naval environment (Marques and Pires 2003).

4. Contingency Management Tool (CMT)

Here we outline the main characteristics of a fuzzy Contingency Management Tool (CMT) for dealing with operational risky situations, based in the modification of a tool developed by HOLOS (HOLOS 2005). As mentioned, in this paper we focus on the intelligent decision support aspects and do not address the problems of scarce resources management (e.g. incidents team assignment) or other CMT capabilities such as simulation/training.

Any I-DSS for contingency management should have a hierarchical and distributed decision-making process, simultaneously following the human organization hierarchy while providing the necessary autonomy for each workstation. The CMT supports the decision process by offering a specific framework (libraries, knowledge bases, databases, inference engine) and a set of generic templates that reduce the time to market a customized application (HOLOS, 2005).

4.1 General architecture

Figure 3 depicts the general architecture of the proposed CMT.

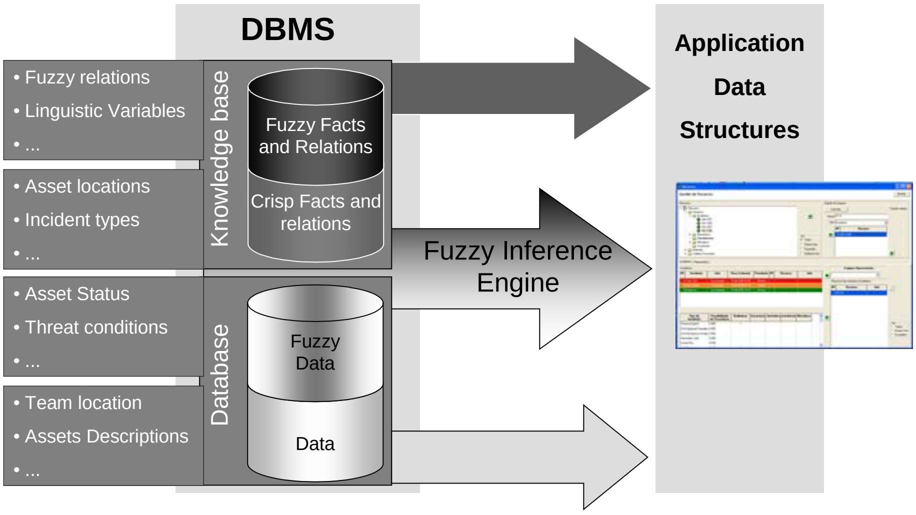

Figure 1. *General architecture of CMT*

The contingency management tool (CMT) collects and compiles input information on the status of assets under the current operational scenario and considering current risks (possibility of occurrence of threats and associated severity level). With this information the CMT is able to provide human decision makers with a global view of all assets and respective status, highlighting important situations.

The CMT includes both crisp data (e.g. compartment number, danger location of equipment) and fuzzy data (e.g. assests/equipments, list of possible threats and their possibilities). All this information should be previously stored in the Database and Knowledge Base through the help of appropriate templates provided by the CMT. The proper operation of the system relies heavily on already existing knowledge about the company assets and operational contexts, in both crisp and fuzzy formats. For example, the CMT needs to have stored the fuzzy relation expressing the importance/relevance of certain equipments for certain systems, as shown in Table 1.

A Fuzzy Inference Engine brings together Knowledge and Data producing information that drive the intelligent decision process. The inference engine model developed for the CMT is discussed in the next section (details can be found in (Sousa et al 2006)). All information (both fuzzy and crisp), stored in the Database and Knowledge Base, as well as the information derived by the Fuzzy Inference Engine are fed into a user-friendly interface, as depicted in Figure 2. As can be observed in Figure 2, there are 4 main panels. Number 1 panel shows the layout of the operational context and the location of the incident (represented by an E in the image- red for serious incident, green for partial failure); number 2 panel shows the zooming ability to see any incident in detail; number 3 panel shows the current status of the occurred incidents in terms of equipments malfunctions and already prioritized by a colour scheme (red- inoperational, orange- damaged, green-slight malfunction). The last panel, number 4, shows the active contexts, threats, tasks and special tasks that are affected by the incidents that occurred.

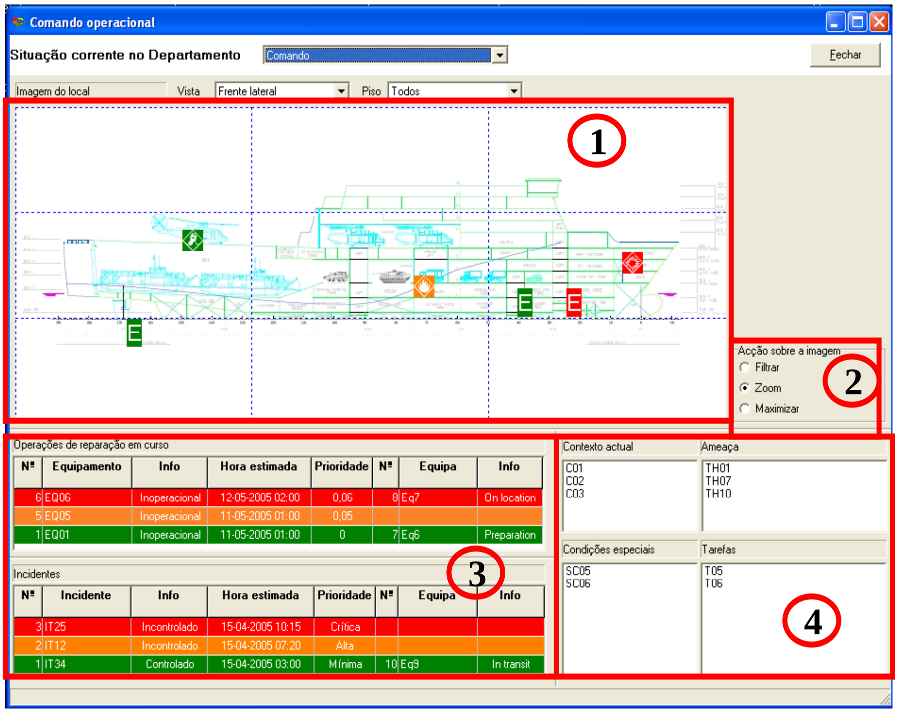

Figure 2. *Incidents Status Interface (command view)*

The Data Base Management System (DBMS) is replicated in several workstations to allow the maintenance of a global state in normal situations, or the fallback to subgroup or stand-alone operation, by maintaining locally all information needed for the decision-making process, whenever communications fail.

Moreover, whenever communication among workstations is available, a distributed writing mechanism ensures consistent replication of the information, thus maintaining a global state, common to all workstations. This mechanism provides the needed redundancy to allow each workstation to operate in the event of network partition, even in the limit situation of standalone operation, thus ensuring some degree of fault tolerance. As soon as communications are restored, a recovery mechanism supported by a high-speed, multi-agent based, negotiation protocol ensures that the overall state of the system becomes coherent, by combining the partial views available at each workstation, while maintaining full decision support availability.

4.2 Base concepts and inference engine

The base concepts within this tool are sub-divided into operational conditions and asset's description. The operational conditions include (Figure 3): contexts, tasks, special tasks and threats (classified with severity and possibility of occurrence). The assets description includes (Figure 3): function lines, systems, and equipments.

Since many concepts and relations are imprecise in operational contexts the CMT uses fuzzy formalizations to represent these vague concepts (Sousa et al 2006). For example, the possibility of occurrence of a given threat (e.g. terrorist attack in an airport) is expressed as a discrete fuzzy set within the range 0 ("low possibility") and 1 ("high possibility"). Other important concepts, which include linguistic terms (almost natural language), to classify fuzzy relations are (see Figure 3):

Risk ={almost_null, low, medium, high, extreme};
Relevance= {irrelevant, almost_irrelevant, desirable, important, critical};
Equipment_Status ={operational, almost_operational, almost_inoperational; inoperational, irreparable}.

The main fuzzy relations used in the CMT (Figure 3), which have to be pre-stored in the knowledge base, are:

A. *Operational context relations*:

CtxTsk – which tasks are available under each given context;
CtxSpT – which special tasks are available under each given context;
TskFLn – which function lines are important to a particular task;
SpTFLn – which function lines are important to a particular special task;
RiskThr – which function lines are relevant for a given threat.

B. *Infrastructure dependent relations:*

FLSys – which systems are important for a given function line;
SysSys – which systems are important to other systems;
SysEq – which equipments are important to a given system.

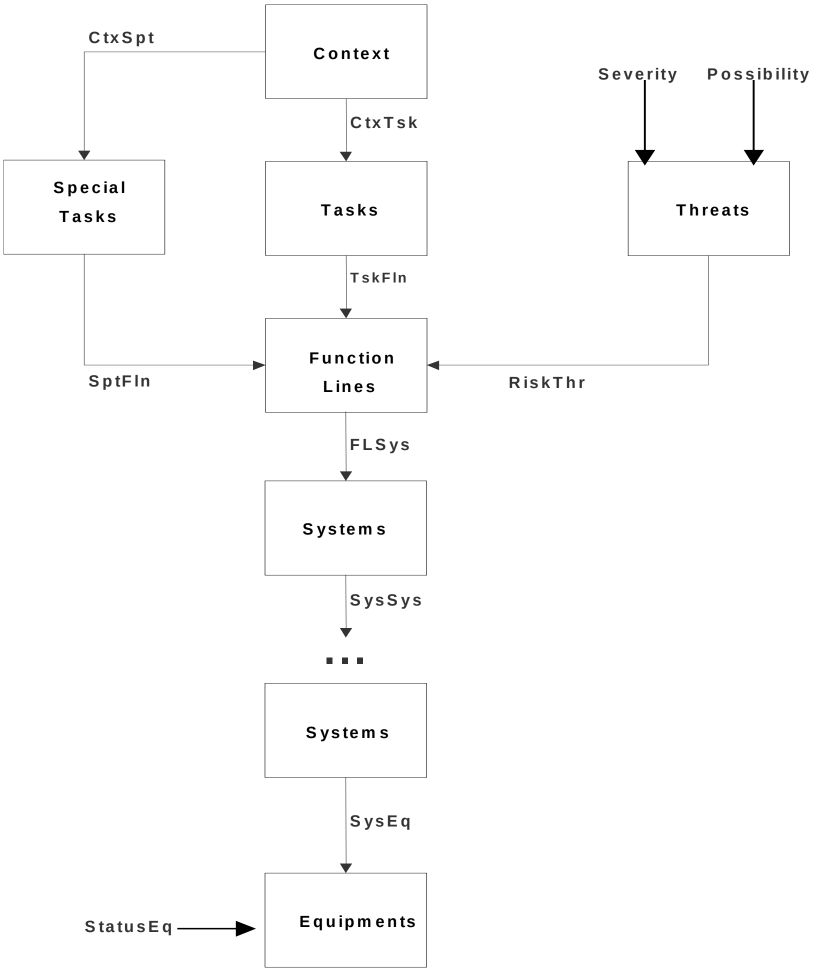

Figure 3. *Inference engine*

To clarify how a fuzzy relation is defined in the CMT, let us consider the relation SysEq (System-Equipment) with 4 systems and 3 equipments, which is represented in tabular form, as follows:

	Sys1	Sys2	Sys3	Sys4
Eq1	**important**	**irrelevant**	**desirable**	**irrelevant**
Eq2	**critical**	**important**	**irrelevant**	**desirable**
Eq3	**desirable**	**important**	**critical**	**irrelevant**

All relations described, and shown in Figure 3, use similar tabular formats to ensure usability and easiness of understanding by the users.

As mentioned, the CMT uses a fuzzy multi-criteria inference engine (Sousa et al 2006), whose decision model follows a hybrid approach:

- Top/Down aggregation. This aggregation is performed by considering the operational condition (e.g. tasks being performed under certain contexts, threats affecting operations) and its influence on specific function lines (e.g. propulsion system of a ship, refuelling in petrol companies, air traffic controller system in an airport);
- Bottom/Up synthesis considering the status of the equipments (e.g. inoperational, malfunction degree) and their relevance for each system (e.g. radar, fuel tanks, fire engines, etc.) towards the operation of each function line.
- The final result is a priority list of equipments to be repaired and information on how they affect other systems and function lines. This information is provided to all levels of decision makers involved in the contingency management to help them decide on actions to be taken.

In summary, the CMT model (see Figure 3) adapts itself, in real-time, to changes on operational scenarios driven by changes on the environment (contexts, tasks, risks) and by changes in the infrastructure complex system. The complete decision-making inference process is performed using fuzzy operators for the aggregation, selection and reduction of the fuzzy relations, in a hybrid top/down and bottom/up synthesis. A more detailed description of the fuzzy inference model can be found in (Sousa et al 2006).

4.3 Capabilities of CMT

As mentioned before, all I-DSS produced using CMT are real-time, distributed, robust and fault tolerant systems aimed to support decision-making processes. Assistance is provided to support decisions taking into consideration uncertain and vague information, under constantly changing dynamic and stochastic scenarios where operational priorities change according to the operational scenarios and/or the status of system.

The I-DSS developed with the CMT will have the following generic capabilities:

- Independence from specific Database Management Systems, allowing the selection between different Vendor Specific and Open Source solutions;
- Capability to integrate various data sources;
- Management of all resources (human and material);
- Graphical interface, where the current status of actions (e.g. equipment status, incidents types) are shown over the layouts. Information level of detail depends on the user’s desired focus;

- Explanation facility, allowing the user to see the inference that produces the advice suggestions;
- Detailed information of a specific elements allows access to pre-action activities checklist (e.g. “first - commute to auxiliary system B, second - switch off the equipment”) and post-action verification check-lists, as well as access to technical documentation and history;

The main advantages of using an intelligent decision support tool for contingency management, as the CMT, are:

- Reduction of operational risk, by providing recommendation of preventive actions when the operational context includes tasks and conditions that may present an increase of risk;
- An overall increase of efficiency and operational reliability, by decreasing the operational risk and providing advise on actions to perform;
- Global overview of assets’ status available on all workstations at any time;
- Better quality of information is provided during critical situations, minimizing communication errors and inconsistencies;
- Provide Decision Support to humans in critical and stressful situations, in real-time, enabling efficient reaction in crisis/disaster situations;
- Enable consistency analysis of emergency and contingency plans through “what-if processes”;
- Support training and instruction.

5. Potential Applications

In the operational risk domain, potential applications of the CMT are:

- Decision support for management of equipment repair priorities under disaster/emergency situations;
- Decision support for management of actions to take, based on the current operational context;
- Personnel training for contingency situations. The tool can be used as a simulator to train personnel and improve security of installations;
- Advice on the selection of resources for prevention of equipment malfunction, damage control, and prevention of incidents.

With this in mind any critical facility that can be subject to hazards such as fires, terrorist threats, floods, earthquakes, explosions, severe utility failures etc., are good candidates for using the CMT. It should be noted that here we consider facilities as large and complex human-occupied structures (Sternberg and Lee 2006). Examples of facilities that can be particularly affected by contingency/disaster situations are: power plants, airports, subway stations, oil refineries, manufacturing plants, chemical plants, maritime ports, homeland security and military facilities.

5.1. Application Example

One existing I-DSS, implemented as a contingency management tool, is the system “SINGRAR -Sistema Integrado para a Gestão de Prioridades de Reparação e Afectação de Recursos” (Integrated System for the management of repair priorities and resource assignment) which is currently installed on board of frigates Corte Real and Vasco da Gama of the Portuguese Navy (operated by approximately 180 sailors). The system, developed using ideas discussed in this paper, was tested under war exercises, and it proved to be useful to support the decision process within several levels of the hierarchy under stressful conditions. This particular I-DSS was also based on previous conceptual work (Marques et al 2000) (Marques and Pires 2003) and its decision-making model includes a hierarchical and distributed approach, following the military chain of command while providing the necessary autonomy and robustness.

The system adapts to operational scenarios and consequent context variations, depending on changes of threats types (e.g. “surface threat”, “air and surface treats”) redefines and determines repair priorities and repair resource assignment.

The fault tolerance and robustness is guaranteed trough distributed writing mechanisms that enable information refreshment, and consistence replication, assuring the necessary redundancy. Fault recovering is done in real time reassuring a global state, through the consolidation of partial contexts, potentially inconsistent, through an agent negotiation protocol (HOLOS 2005).

6. Conclusions

The lack of adequate tools in the market that could supply satisfactory answers to operational risk questions such as “what to do in crisis situations when experts are not available?”, “how can good decisions be made under stressful situations?”, or “is a global perspective available in real time during contingencies?” led us to the development of a tool to develop Intelligent Decision Support Systems (I-DSS) for contingency management of incidents.

An operational I-DSS must support decisions based on a high number of parameters and criteria, where knowledge is frequently expressed using vague and uncertain concepts, which are, nevertheless, essential for human assessment. Fuzzy logic is an appropriate framework to support this need.

Other technologies were also deemed necessary, considering the wide area o potential applications. Considering the need to represent human knowledge in both crisp and fuzzy formats, the contingency management tool (CMT) is considered a knowledge-based system. To cope with the need of decentralised decision-making it also requires the development of an inherently distributed system. Being a distributed system, that requires operation to be maintained even in the case of communication failure, imposed that the I-DSS' should use information redundancy, while assuring consistency and a coherent global state.

In short, the usage of I-DSS created with the CMT enable the following:

- The support decision under critical and stressful situations reducing the risk of bad judgement.
- Risk reduction through preventive actions.
- Increased level of response supported by better instruction and training.
- Process description's consistency analysis and validation through what-if analysis.
- Overcome critical situations even when experts are not available.
- Provide decision makers with a global perspective in real time.
- Enable 24x7x360º information availability depending on users profile.

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