Decision Support Through the Experience Feedback of Crisis Management

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***Abstract*—In a crisis situation, the ability of SAMU[1] to take reliable and quick decisions is the main element that defines the success or failure of this organization in its crisis management. Decision makers spend time to identify the decisions that will be taken in the time of crisis management, anticipate up to the preparation of these decisions, ensuring that they have time to properly prepare all decisions to be taken and, be able to implement this decision as fast as possible. However, the context and the characteristics of the crisis make the decision difficult because there is no specific methodology to anticipate these decisions and properly manage collaboration with the other stakeholders. There is also the pressure of the time, the big stress and, the emotional impact on the decision maker that lead to losing objectivity in decision making. We understand so that the right decision will be greatly facilitated and enhanced by the development of tool and process for decision making support. This tool must respect their methods in managing crisis, and highlight the importance of experience feedback referencing to the past cases, especially success and failures. We propose, in this paper a system in order to handle experience feedback as a support of decision making in crisis management "Crisis Clever System" (CCS). Several dimensions are considered in this study, from one side: organization, communication and problem solving activities and from the other side the presentation of experience feedback using GIS techniques in our CCS.**

Keywords-Knowledge Engineering and Management; Experience and situations representations; Emergency crisis management; scenarios; decision making under stress; time, space and task dependence

I. INTRODUCTION

SAMU is responsible for providing an appropriate response to urgent medical problems which are submitted by a hotline exclusively for medical purposes (15 in France) or through other hotlines: general European number 112, 17 police, 18 firefighters, or through the telecommunications network health.

Medical regulation can range from the simple emergency medical to the commitment of heavy mobile means of mobile intensive care unit through sending a single ambulance or rescue, adding to that the possibility of calling other means such as those of firefighters and private ambulance companies or even the Police and Army (helicopters Aircraft).

SAMU become a main actor in situations of acute health crisis and collective medical emergency. In France it is one of responsible for triggering disaster plans, manage mobile medical units (reinforcement material to equip hospitals in case of need, or the advanced medical posts), advanced command and mobile control station.

The emergency department of SAMU is one of responsible of decision and intervention strategy to face crisis situation. It should manage a lot of information and means in order to build the most appropriate decisions.

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To sum up, the main object of this work is identification of criteria in crisis situations (road accident, explosion, NRBC-E crisis, etc) and its structure, in order to provide models and methods handling experiences and problem solving during crisis management. This work focuses on medical intervention of emergency department and its work based on preserving human life. We use in this context the methods of knowledge management and engineering, also the case based reasoning which based on human analogy reasoning.

In this paper we begin by presenting several related work, in the next axe we introduce the crisis management field and its issues related to decision-making. Finally we will show our approach in analyzing crisis situation, used techniques, the base of our system and the specification of human-machine interface for CCS.

II. RELATED WORKS

Several propositions theories design decision support for crisis managers. The authors propose several psychological aspect of crisis managers and management organizational techniques of these situation. The evaluation of many proposals notes give rather inconclusive results. The approaches that attempt to design a perfect system can be found in the works of Turoff, French, Hale, Carver and Kim. Even if they are known works, they never became working software [26] [27] [28] [29] [30].

Other systems and models are proposed around this thematic [7] [2] [6] [22] [14]; they aim at representing the operational, organizational and communication level, these solutions offer generic treatments or rigorous techniques adapted to specific situations. The more used techniques and

[1] In the French language (Le Service d'Aide Médicale Urgente) is the medical emergency department

methods are based on workflow modeling, GIS, multi-agent and rule-based systems.

Other works more pointed use case-based reasoning and knowledge ontology are recently presented, its limit is that there is big restriction and definition of many concepts which are not shared between case and not adapted to the dynamic specificity of crisis situation [33][34][35].

The main contribution of our system is the use of actors experience feedback related to space and time dimensions, and the capacity of our system for adaptation and learning from future situations using techniques of tractability of the experience feedback. So, we develop techniques in order to handle the use of experience feedback [19] to promote decision-making. Our first attempt solutions are to represent the experience feedback using, on one hand, experience and situation representation based methods [1] [11] on the other hand, knowledge engineering approach [16] [18], in order to define a decision making environment.

III. THE CRISIS AND ITS MANAGEMENT

A. *The Crisis management*

Crisis management is a special type of collaborative approach in which actors are subject to an uninterrupted stress. It requires succeeding of actions because the consequences are important (human and economic losses). Crisis differs from an emergency situation by its destabilizing effects [20]. An emergency is an event for which intervention procedures are known, requirements are clearly identified, and roles and responsibilities are clearly assigned.

A variety of approaches has been identified to deal with a crisis and can be classified in three categories [7] [20]. In the first category, we can note the model presented by Ian Mitroff and Pauchan Thierry, it is a model of identification of crisis situations. One of their axes identifies characteristics "internal" or "external" while the other highlights the dimensions "Technical / Economic" or "Human / Social / Organizational." The second category focuses more on a set of points that characterize the crisis as a result of events and behaviors. The eventual effects caused by this situation in terms of pressure on people supposed to manage it, its consequences on the environment and the difficulty of adopting adequate responses to many persons concerned by the situations. The last category includes approaches, called synthetic. It aims to give general definitions for the crisis in terms of threats, of stakeholders and of critical choices facing events in the crisis situations.

Authors have identified a set of common phases in the management of crisis situations [14] [20] [2]; to summarize, we can identify three major phases that can occur cyclically (Figure 1):

- *Preparation:* through the classification of situations, training and exercises, scripting events, identification of critical sites, structuring and definition of library resources and of roles and tasks for structuring feedback.
- *Intervention / handling:* The phases from alert to system stabilization. It consists in four basic steps :
  - Identification of the situation.
  - Logistics and implementation of emergency on site.
  - The evacuation, reception and support of victims in institutional care.
  - The debriefing and review.
- *Analysis / Feedback:* learning from real-life situations. This assessment is critical to improve the response strategy. It will therefore help describe the types of situations more precisely and enrich the feedback structure.

Figure 1. phases of crisis management

Through these three phases, we found the relevance of experience feedback in order to deal with crisis situations. In our work, we use knowledge engineering and management to acquire and model experiences in order to propose answers for the problems of the three phases described above.

B. *decision makers dealing with crisis*

Dealing with crisis, decision makers attempt to identify or anticipate potential events that can occur, also the important moment, or incidents, that may trouble to develop actions and measures to avoid other incident into a current crisis [7]. These elements are attached to the crisis context that influences the initial followed reasoning and decision making strategies.

Until today, a lot of research work has been done about the influence of context during the reasoning and decision making process. A non-integral perception of the environment may lead to limited inferences. This process is strongly influenced by the information received through sensorial registers, as well as the memory capacity. In consequence, any useful information will interact with inferential processes during [13] premises processing. Tulving (1976) [24] was the first to draw attention to this phenomenon; he introduced the concept of specific encoding (the success of recovery depends on the proximity between encoding and recall context). An inefficiency context representation and perception may influence the actor's point of view and build inappropriate decisions. In an unknown situation the analogy is the natural reasoning process of human. A misinterpretation caused by an incomplete perception of a dynamic fuzzy context produces wrong result.

According to Gentner and Toupin (1986), the analogy [23], is based on a general and calculated similarity between a source and a target. There are three kinds of similarities: attribute similarities, similarities between low-order

relationships and between high-order relationships. To make the analogy, we need to match our current situation (called base) with another past situation (called target) based on the similarities of high rank. Commonly, in crisis situation the similarity among situations can be estimated using metrics and considering that cases are represented as attribute-value pairs (the number of victims, localization, accident type, homogeneity, etc). The other techniques can be used such as looking in semantic field of some indicators. Thus, we are interested in developing an algorithm that could provide results within a reasonable response time. It must also be suited to this kind of non-formal situations.

Moreover, the analogy reasoning is an essential activity in dealing with crisis situation. The term analogy [23][24] is used in expression "reasoning by analogy" that is a general heuristic for assumptions. It refers to the form of reasoning that is involved in a task, used extensively in the psychometric tests. It also means the transfer of meaning from one domain to another. Moreover, it consists in reusing a known situation from other similar situations [23].[24] The analogy is a central activity in the human life. We use it every day when faced with unknown situations. It allows dealing with the unknown from what is already known. Pedagogically, it is the most natural and the easiest way of reasoning. Thus we use the techniques defined by the CBR for recognition and representation of situations.

Finally, crisis management is a cooperative activity. Therefore, we also study Computer-Supported Cooperative Work to process communication and coordination [15] in such situations.

IV. OUR APPROACH AND CONSIDERED ASPECTS

To handle experience feedback in crisis management, case-based analysis [9] seems the best approach to be used; in fact the actors express their knowledge through a set of real-life situations. So, we use the techniques of case-based reasoning (CBR) [11] and especially the description of situations to define a structure of crisis representation taking into account the context of problem solving. Similarly, the type of underlying reasoning in CBR systems can be based on an analogy of situations [23] [1], very useful in the recognition of crisis situations.

Moreover, experience is owned by the actors of the emergency sector, as well as the documents and reports prepared or produced as a result of such intervention. Knowledge Engineering provides techniques to represent expertise in problem solving [23][24]. These techniques allow highlighting key points as objectives or reasons for such actions of the experts. Several techniques of interview issued from knowledge management and engineering are used to communicate with experts in order to understand and represent rules and concepts used in crisis management experiences.

The cooperative aspect must be considered including coordination, communication and cooperative problem solving in order to specify several actors with different objectives who are involved in crisis management [23][24][15]. In this project, we studied the dimensions of coordination and communication conducted by a single type of actor: the Emergency Department. Cooperative decision making in a crisis where other types of actors are involved (government officer, fire-fighters, police, etc.) is not studied in this work.

To summarize, the different aspects considered in this work are:

- Representation of the context of the situation: environmental information and available resources.
- Dynamic representation of the problem-solving considering the evolution of situation.
- Successes and failures pointed on each intervention as well as rules and concepts.
- Identification of the types of situations and criteria for recognition of these situations.
- Representation of the communication between the actors within the spatial dimension (various locations).
- Coordination in actions as well as human and material logistics.

Our results are based on several meetings with actors in the emergency department of the Troyes' hospital; the emergency doctors, assistants and the specialists who have experience in real crisis situation and training exercises. First interviews were general and helped to identify main problems of the domain, Next ones aimed at describing a specific situation like road accident, fire on on a nursery home and a nuclear accident exercise.

V. SPATIOTEMPORAL DIMENSION OF CRISIS SITUATION

A. *Space dimension*

The space (place) is a major dimension of crisis management; the representation of the organization of actors in relation to the space will help, in one hand, to clarify the type of existing communication and vision that each actor has of the situation. In the other hand it makes more clearly the manner in which we make sense of crisis events and issues around problems associated with managing the acute phases of a crisis, as well as dealing with its location, setting, victims destination and its aftermath. Three main places have been identified [16] [19]:

- *The Crisis unit:* the place of the control and the management of the intervention, its most important role is managing the material and human resources. The link with outside and the responsible of emergency department (the rear base) is done by the communication center.
- *Crisis site:* The area affected by the event, it includes actors such as the first medical team and advanced medical and other professionals.
- *Emergencies/hospitals:* These services receive victims and their families and ensure their follow-up. The emergency department, depending on the distance of crisis site and or available places and required specialties for each victim, achieves the choice of the transport of the victims.

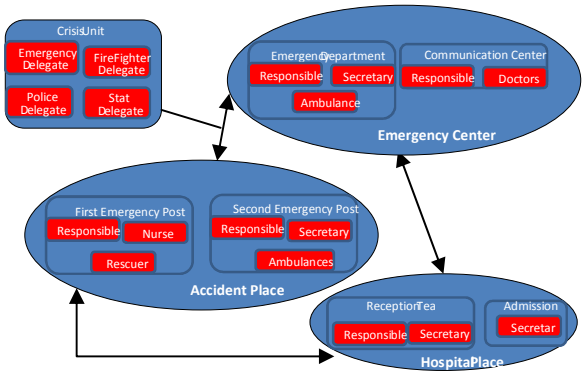

Figure 2. Actors organization seen from the space dimension

Several actors of emergency department are involved in crisis situation: doctors, first aids rescuers, assistants, secretaries etc. According to the work place and situation 's state, each actor is in contact with other professional of the domain such as police, state services, government delegates, etc (Figure 3). So, the communication and organization dimensions have to be considered to represent this type of situations.

B. *Time dimension*

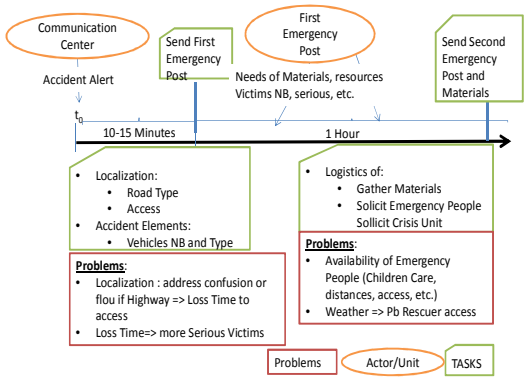

Figure 3. The responsible of emergency department tasks and faced problems on a timeline.

For better organization of the actor tasks, the time dimension is very important in crisis management not only in terms of life preserving as a final objective, but it has also a major importance on each step during the intervention. It must be considered so in order to provide [16] to decision makers an empirical and control environment in which they can have an overview of what happens in terms of tasks and actions duration, what must be done or what should be done immediately.

Experts identify different types of situations to represent. We work with them for acquiring experience and definition of common structures [16][19] to represent this experience. They are looking forward to promote the reuse of this experience and acquiring a future one. Thus, we propose a structure that include, chronologically, actor tasks and faced problems during an intervention (Figure 4). The aim of this structure is to represent the different communication links established during the crisis intervention and nature of its exchange. In addition we represent the experiences: by several tasks and associated problems as well as consequences of the non-respect tasks and experts' recommendations.

VI. SYSTEM SPECIFICATION

An efficient decision support environment has to take into consideration the characteristics of crisis situations [26], the status of people supposed using it and, space and time dimensions. To sum up, firstly the provided information has to be precise; the decision maker in crisis situation has no tolerance or time to spend for things unrelated to the management of crisis. Secondly, the context must be understood and the experience reused; learning and understanding what happened before, during, and after the crisis is extremely important for the improvement of the system capacities. Thirdly, everything in a crisis is an exception, thus less generalization is recommended. Finally, the information exchange and its validity in timeliness is required, in fact the crises require for many persons with different roles to be able to exchange information which is critical to those who may risk lives and resources, these information must the most up-to-date and notified by alerts.

A. *Decision support needs in our system*

In a clearly explained situation but not necessarily completely formalized, the decision support is an activity which helps to get some answers to the questions of an actor in a decision process [31][37]. Decision making covers two aspects [31]:

- Modeling formalized or non-formalized preferences of the decision maker.
- Analysis of the solution and evaluating their consequences.

To guide decision makers in crisis situations we can act at two levels. The first one concerns the perception of the context as an important element in reasoning process [13] by providing additional and useful data with less ambiguity about context using the quick and automatic research in GIS system and a situation base.. The second one concerns guiding the process of decision making [13] [23] [24] as a cognitive process. We aim at guiding the reasoning process during each phase of the crisis using available cases from the situation base.

Information processing in dynamic situations can be distinguished by a number of dimensions from decision making in the normally used static task environments. First, because the environment changes is an inherent dimension of the decision making process. Second, strategies can be used that benefit from feedback. Third, time pressure can be defined from the evolving situation itself rather than by some external criterion [25].

Cognitive psychology is assumed to contribute significantly to the improvement of analytical issues and the quality of solutions offered in decision support and problem solving. This could be achieved by methods and tools for

firstly making the analysis of decision maker's query; secondly, providing high quality methodologies and systems evaluations. It can thus define gaps to be narrowed. Finally, it provides the knowledge and methods needed to evaluate the proposed solutions.

Mental activities are a part of cognitive activities [13][23][24]. They are located between sensorial and action programming activities. It helps building an understanding of the situation, developing new knowledge and making decisions. Considering information processing types, we can distinguish three broad categories of mental activities [23]: The understanding which consists in constructing a situation interpretation, the reasoning that is looking for links between information collected via inferences using knowledge eventually stored in the memory, then finally all the control mechanisms of mental activity.

B. A system state through a crisis stage, base principle

Considering cognitive perception and dynamicity of crisis situations, we may represent emergency department crisis management as a set of couples of states and events (Figure 6) using a basic Petri network [1]. Each state of the system match a crisis stage, it is represented by a place of Petri network (Figure 5):

- Type: It's a sort of index referencing a complete or episode of a crisis situation. It indicates the main class (category) of current situation. (E.g. road-accident, fire, etc). Providing this index help the system to do research by keyword, it allows recognition and rebuilding of such situation through previous situations and keeping the link with central event of crisis.
- Actor/ role: is the concerned person or unit in each system state (crisis stage).
- Time: is the moment to do an action by the concerned actor according to place's type.
- Data: is the available data for concerned actor in each moment, this information are related to the characteristics of crisis situations, localization, weather and victims.
- Action: is the action to execute considering previous elements.
- Place: is the actor location.

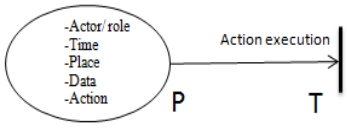

Figure 4. Petri network's State and transition of crisis situation.

The event (transition) is defined as the result of the action processing. It leads to a next state.

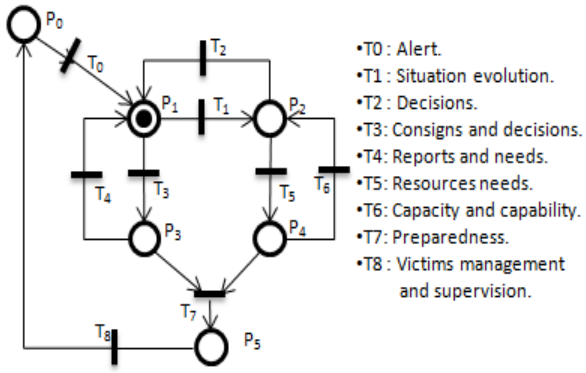

Figure 5. Petri network of crisis management -- P: Actors/unit – T: event/tasks/exchanges (P0: the stable system .-P1: Communication Center. -P2: Emergency department.-P3: Intervention Teams. P4: hospitals. -P5: Victims' evacuation)

The starting point of our proposition is based on the exchanges, the events and the tasks. All these elements are important to determine the following tasks to do or the decisions to make. Their definition on situation structure (Figure 4) helps to identify a set of system states, transitions and conditions between them. Representation of these elements in the same structure for all actors is difficult. Indeed, a concrete structure is relatively complex considering the time and the space dimensions (Figure 3 and Figure 4), it make its interpretation difficult. While the transcription of a Petri network allowed us to see these elements in the form of a state / transition graph (Figure 6) more simply and, respecting the dynamicity of crisis management. Transitions represent the interactions between actors and events that can change the system state and parts. This type of representation allows also flexibility in the representation structure, especially for making evolve the structure using traceability of new information from situations.

C. Specification of operating protocol of CCS

As first specifications of the system, we identify used scenarios related to each actor role. These scenarios respect time thread, communication and best practices guidelines. Otherwise, Departments Emergency use a lot department maps in their decision making. So, the main blocks of the system architecture will be:

- GIS system
- Situation Base
- Interface with Emergency communication and Information system
- Dedicated Human machine Interfaces related to actors' roles.
- Emergency actors, who will be guided by several information types:
  - Data to be completed: Localization of accident, number of victims, road schema,
  - Task to do: Send first aid post, ask for materials, ask for parents' victims welcome place, etc.

- Warning related to missed actions, dangerous events: risk places, evolution of the gravity of accident, if it is is not yet located in precision, etc.

The environments integrate multiple data sources (Figure 7); the main one is our situation databases which define the context of requested information. It allows the data processing to use efficiently other data sources. The emergency department database contains information about emergency department (human resources, equipments, procedures, hospitals, etc). The GIS database contains personalized geographical information about risks and vulnerable places and much other personalized information.

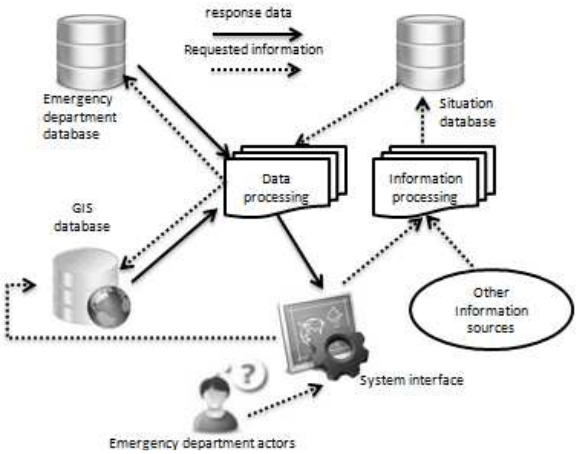

Figure 6. System data and information sources

1) the selection of maps system

The maps of emergency interventions represent an essential tool; they show main information such as the locations of crisis, the networks of streams and rivers, and the locations of man-made features such as trails, roads, towns, boundaries, and buildings. They also show what the crisis place is like and distances between useful crisis management stakeholders. All of these elements are important considerations in emergency planning. It make easier to decide where to go and where to place resources.

Therefore our system is fitted with interactive maps allowing actors to zoom to a custom scale for a detailed view of a specific area of interest associated to several information essentially related to localization of risk places, Human / materials resources, emergency, rescuers means and services information. So, we identified a number of risk places and their characteristics in the AUBE's State. Further, used GIS should allow defending more position and information on maps.

We identified that Google Maps is the most adapted GIS in terms of functionality and accuracy. But, the problem is that we cannot have maps locally. So we need a permanent Internet connection with the remote Google Maps API. As there is the risk of losing the connection in a crucial moment of the crisis, it is preferred to have as much as possible data and maps locally. The OSM then became our preferred choice; it is also a system under a GPL license and is supported by a large community.

2) Situations Base organization

A crisis situation can incorporate several elements and characteristics related to others crisis, for example, a road accident can generate a disaster situation, specially a chemical accident when a tanker transporting a chemical substance is implicated. Then, representing situation as a road accident is not enough. Thus respecting this classic classification will require each time to add related elements that emerge. So, the result is a few number of cluttered situations seen that there are elements to ignore or add during each uses.

Then our approach uses another alternative, the idea is to create a new index for each important event (indicator) in order to define a new case which is a complete or part of a situation. This representation will allow the CCS to rebuild such situations using many combination possibilities. The search within the cases is made using the perceived indicators. For the interests of speed and system efficiency the solution space (similar situations) must not be too large. Thus, the index corresponds to the most discriminating value as possible.

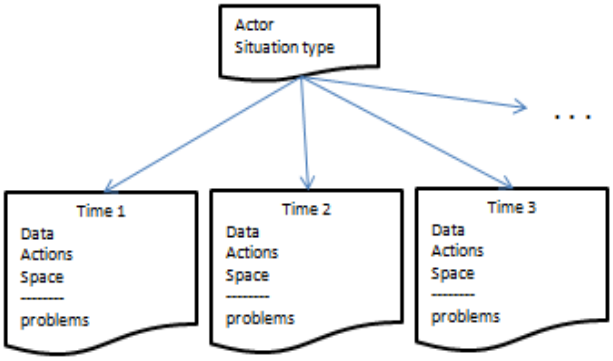

Figure 7. Situation base organization

The situation base is organized by actor. Each situation points for each actor on the important moments of the crisis in the form of time intervals (Figure 8). For each case we defined three parts; set of characteristics (data), set of tasks (actions) to do and the problems involved if the task is not completed.

3) Human-Machine Interface specification

A better human-machine interface must respect several criteria; among others we present most important [36]:

- Good guidance: facilitate learning and use of a system (users easily know at any time where she (he) is in a sequence of interactions and possible actions).
- Good prompting: avoid obliging the user to learn a series of commands and protecting him from errors.
- Grouping the similar items in the same place.

- Reply and quick reaction of the system. For the establishment of user confidence and satisfaction, the system must respond clearly if a command is treated or not.
- Content legibility to facilitate information reading.
- Respect the technical words and the terminology of the user and the system domain.
- Use shorter entries for better reminding.
- Required actions to accomplish tasks should be minimal.
- Insure the minimal density; Items that are not related to the current task should be removed.

The Figure 9 shows an overview of Human-machine specifications noted above. The following list describes the numbered items in Figure 9.

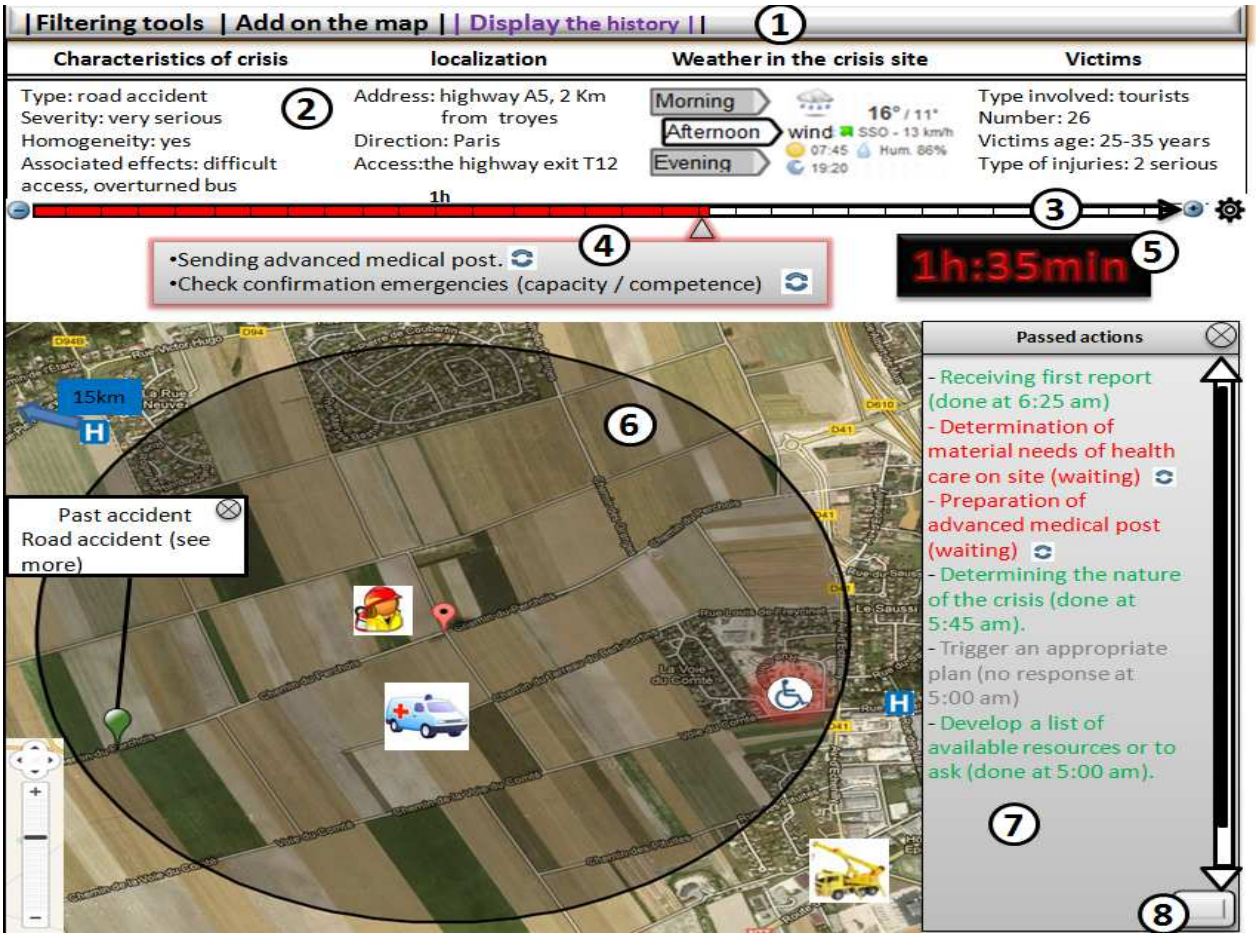

Figure 8. A view of the CCS interface

1. The horizontal menu: this menu allows the user to define the items to show or to hide on the map. These elements are generally emergency locations, risk sites and resources. It helps also to personalize the maps by changing or adding other items. The element of this menu is used to display the history of communications, problems or actions as shown (number 7).
2. The data to be provided on the crisis: this is a dynamic list data. it reminds the user data to be collected on the situation. These data refer to characteristics of the crisis, location of the crisis and the victims. The weather is updated automatically through the weather web service.
3. Timeline: it allows monitoring the state of actions and what is urgent. By double clicking on this line, the system provides also the possibility to add other data to be collected or actions to do for current situation. By clicking on the setting icon, we can also view on this line the communications as well as the problems of actions. The default value (5 min) of the time scale is changeable by a zoom presented at the beginning and the end of timeline.
4. Current actions to do: The content of this item present the action to do immediately. The existing icon in front of each action allows changing the state of the action

(waiting, done or no response). Once the time for action is expired an alert is triggered.

5. Timer: it displays elapsed time since the beginning of the crisis.
6. The site map of the crisis: it provides an overview on the site of the crisis, the user can easily see; deployed means, risk sites and the nearest resources.
7. History of actions: This item is displayable from horizontal menu (view history). It serves to review the history of actions and change their status. Displaying the history of communication and problems is also possible from the same menu.
8. Button to display user exchanges: this button allows showing the exchanges between the users and displaying new coming information.

In order to illustrate this type of interactions, we can show how to guide emergency department based on the experience presented in Figure 10.

VII. CONCLUSION

We show in this paper, our results on analyzing crisis management. Our approach aims mainly at identifying the experience feedback and representing it. The aim of this study is to define a decision-making environment for crisis management, related to emergency activity. Future work aim at developing the system to promote decision support for each role respecting the objectives of stakeholders in the main project.

Finally, we will focus on the definition of experience traceability module for our system. We use several approaches in order to represent this experience:

- We use GIS as base of the human machine interface, it's the main part system for emergency department..
- Situations have to be represented in this experience, so the dynamic dimension considering events has to be defined. We use time thread, which is an important aspect in crisis management for this purpose. We represent situations using basic petri network in order to respect this dynamicity.
- Experience feedback has to be shown, so we use knowledge engineering techniques (interviews based on tasks, concepts and problem solving) in order to represent at each step tasks, related problems, success/fails keys, and related consequences.
- Crisis situations are a collaborative activity, so organization, coordination and communication dimensions have to be described. These dimensions are under studies and future recommendations will be proposed.

In our specification, we work closely with Aube's Emergency department in order to answer real needs and to consider real crisis environment in our system. In future work, we aim at testing our system in Aube's Emergency department, firstly in crisis management exercises.

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