Supporting DSS Acceptability through a User-Centered Design Methodology: Experiences in Emergency Management

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Abstract. This paper presents a user-centered design methodology for Decision Support Systems (DSSs), which is specifically built to face the socio-technical gap that often impedes DSS acceptability by end users in real work environments. The methodology has been experimented in two case studies in the field of health-related emergencies, namely earthquake and pandemic flu management. Methodology application and results are described with specific focus on the phases of requirement analysis and system evaluation.

Keywords. User-centered design, decision support systems, requirement analysis, evaluation, socio-technical gap, emergency management.

Introduction

Health threats are events that may have serious adverse effects on human health such as epidemic or pandemic infections, biological or radiological terrorist attacks, earthquakes and other hazardous natural events. In such situations, formalizing well-defined emergency plans and establishing emergency management teams are crucial for assuring a coordinated and effective response to what could be a catastrophic event [1]. Members of emergency teams usually include several experts and operators from different fields and work contexts, from medical communities to public health and public safety agencies, organized at national, regional, and local levels. They have different roles and responsibilities in managing an emergency, as well as different perspectives on the emergency event itself and its possible effects.

In particular, in emergency management teams, *crisis managers* play an important role for effectively responding to emergency situations. They are not involved in operative tasks but are in charge of all the decisions necessary to select, prepare and carry out operative actions. They are typically active 24 hours a day even for rather long periods of time, and operate under pressure, stress, and responsibility overload. In their job, they have to apply stated emergency plans, comply with formal regulations, and promptly respond to several inputs arriving from the upper management at local,

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regional or national level. Their tasks are typically knowledge-intensive and require all their competence and experience in the field.

To face the complexity of this scenario, a decision support system (DSS) that can match the practical and social expectations of an emergency team can be of a great value. A DSS can proactively help crisis managers in making crucial decisions and assists the whole emergency team in its work [2].

However, in order to make a DSS a useful tool for decision makers, a socio-technical gap must be bridged. Emergency management teams, indeed, include high-level professionals who are generally not willing to be supported or driven by an artificial system. Four main issues impede DSS acceptance:

- Lack of trust: DSS users know that their actions, if wrong, will have a severe social impact: why should they trust a system they only partially know and that can be even perceived as intrusive and foreign?
- Lack of motivation: decision makers are expert professionals who know their job and have a wide experience in managing critical situations: why should they adopt the DSS, what benefits should they expect from its use?
- Fear to be diminished: decision makers may suspect that adopting a DSS might play down their role and make their job trivial.
- Fear to be replaced: decision makers may suspect that, in the long run, the DSS might even make them useless.

User acceptance is therefore a key issue in DSS design. To this purpose, we have developed a novel user-centered DSS design methodology specifically built to face the socio-technical gap that often impedes a good project to be effectively applied in the real work environment for which it has been conceived. This methodology has been experimented in two real-size case studies concerning emergency management: (i) an Italian project related to the management of emergency situations that arise after an earthquake event [3]; (ii) EU project HEALTHREATS [4], whose goal is to enhance the capability of European health institutions to respond efficiently and in a coordinated manner to health threats caused by pandemic influenza. The proposed methodology is focused on two phases of the whole DSS life cycle that play a key role for user acceptance, namely requirement analysis and system evaluation; the former is aimed at identifying DSS requirements and the latter at assessing the usefulness and usability of the implemented system. Putting the users in the center of these design steps may greatly help supporting their awareness and obtaining their confidence. Users feel like designers and realize the DSS as their own construction.

The paper is organized as follows. Section 1 presents the user-centered design methodology proposed to support DSS acceptability. Sections 2 and 3 describe how we have applied the methodology in two cases studies in the health domain. Section 4 discusses related work, while Section 5 concludes the paper.

1. A User-Centered Methodology to Support DSS Acceptability

Developing a decision support system that is accepted by crisis managers and all the members of an emergency team requires an approach that takes care of different aspects of the decision-making process, from individual and social dimensions to knowledge and activity-centered perspectives. In this work, we focus on user-centered design approaches [5], which deepen users' needs, goals and knowledge through several observation and interactive sessions. Particularly, our approach aims to ensure DSS acceptability by involving users in different aspects, steps and dimensions of DSS requirement analysis and evaluation phases, which are crucial in DSS design.

1.1. An Approach to User Acceptance

Lack of user acceptance is one of the most important aspects of the socio-technical gap between a DSS and its users.

To support user acceptance, the advantages provided by the DSS must be evident to users, otherwise the DSS will be eventually discarded. A crucial role is also played by system usability: if users find it difficult to perform their tasks with the DSS, there is the risk that they abandon the new tool and return to the old practices.

Another important obstacle to user acceptance is due to the fact that users' expectations are often not properly managed during system development. Members of an emergency management team are not experts in information technology, therefore they are not able to envisage how a DSS might support them: their expectations vary from trivial functions to very hard – if not impossible – tasks. Effective management of expectations means that no negative surprise arises when the system is delivered to the users. To this end, it is necessary to involve the users in the development process since the very beginning, in order to help them understand what the system will be able or not be able to do. Moreover, if users actively contribute to system specification, they will likely feel the DSS as their own creation, thus avoiding the 'not invented here' syndrome. They will understand its behavior and trust its suggestions since they correspond to their own design and expectations.

In order to cope with these issues, we have adopted a *user-centered methodology* to DSS design and development. The methodology iterates through three major steps: analysis, design and implementation, evaluation (see Figure 1). In the following, we focus our attention on the analysis and evaluation as user-centered phases of our methodology.

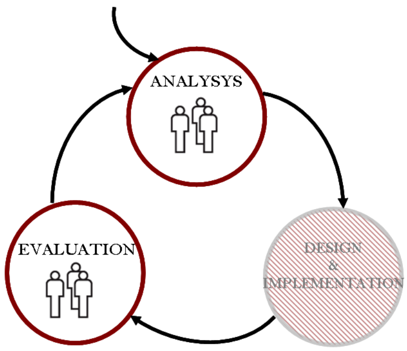

Figure 1. A user-centered design methodology supporting DSS acceptability.

1.2. User-Centered Analysis of DSS Requirements

The analysis phase, aimed at specifying DSS requirements, is carried out according to an iterative process centered on users (see Figure 2). At each iteration new aspects of the domain are taken into account, either in breadth (from a topic to another) or in depth (from a coarse view to a more detailed one).

Each iteration includes four sequential steps:

(i) *Elicitation* collects, as far as possible in objective terms, the original mind and point of view of the users with the aim of eliciting their explicit and implicit needs; elicitation is based on state-of-the-art techniques for knowledge acquisition, including interviews, questionnaires, naturalistic observation methods, and focus groups;

(ii) *Task analysis* examines and formalizes the tasks users commonly carry out in their work environment;

(iii) *Assessment* critically examines and scrutinizes the collected information from the points of view of consistency, completeness and complexity, and proposes a first statement of requirements; in this step it is necessary to balance between what users ask for and what is actually useful to support their tasks effectively and efficiently. Moreover, a trade-off has to be found between user needs and the potential of current technologies; while in general these represent a limit to user desires, they may also suggest unexpected solutions to tacit needs or unexpressed problems;

(iv) *Rehearsal* shows users the proposed requirements, stimulates their feedback, and refines the requirements until a clear and shared statement is achieved.

Each iteration step focuses on three dimensions:

- *User needs*, which reflect both explicit and implicit exigencies and concern what users feel to lack or would consider necessary; needs represent the deep motivation for requirements (no requirement without a need);
- *User goals*, which substantiate user expectations about the way a need might or should be satisfied (no requirement without a goal);
- *User knowledge*, which includes the background information, the experience and the know-how that are needed to specify in any detail how a goal might be attained (no requirement without knowledge).

At each iteration, tacit and conflicting needs have to be elicited and deepened. Also goals are more and more clarified and knowledge is extracted, formalized and validated with the users.

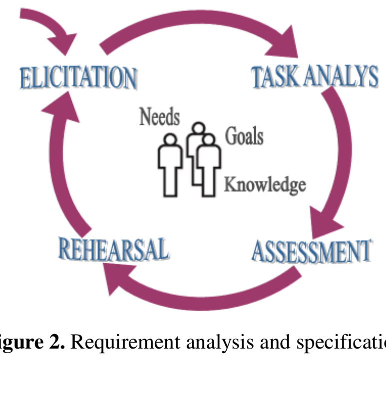

Figure 2. Requirement analysis and specification.

1.3. User-Centered DSS Evaluation

After DSS design and implementation, the evaluation phase takes place. It comprises four activities: verification, technical quality assessment, validation and usability assessment.

Verification and technical quality assessment aim at a systematic and objective verification of some internal system properties of the DSS. The former checks correctness by comparing the implemented system behavior against the *stated* requirement specification; the latter evaluates the DSS technical quality in terms of set attributes (architecture, modularity, programming style, documentation, etc.). Both these activities are carried out by software engineers.

Validation and usability assessment are, instead, user-centered activities that evaluate with real users whether the resulting DSS satisfies, to a certain degree, their needs. Both evaluation activities focus on the user-DSS interaction (see Figure 3), but explore different dimensions of system acceptability.

Validation checks DSS usefulness, that is, whether the system meets users' expectations. Specifically, it assesses implemented DSS functions against the *intended* requirements, that is the requirements seen from the point of view of the users. Indeed, an implementation that fully meets stated requirements might nevertheless only partially match user expectations and needs. Validation is carried out through an extended DSS experimentation with a set of representative users on the basis of a suitable collection of test cases. User judgments are rated and finally aggregated.

Usability assessment aims at evaluating whether the users can perform their tasks easily and effectively by exploiting the interaction tools offered by the DSS. More precisely, according to a widely shared definition [6][7], usability is assumed to include the following five attributes: learnability, efficiency, robustness, memorability, and satisfaction. Usability assessment is performed on the DSS through an experimental test with a set of key users representing the various user classes that have access to the system in the real work environment. Test participants are required to execute a suitable set of tasks with the DSS that allow analysts to assess usability attributes according to the usual metrics defined in human-computer interaction literature [7] (for example, time to complete a task, number of tasks completed in a given time slot, number of user errors during execution of a task, etc.). Indicators are then defined and rated on the basis of these measures.

In the following sections we discuss how the user-centered methodology described so far has been applied in the context of two case studies in the health domain, the management of earthquake events and pandemic flu emergencies.

Figure 3. Validation and usability assessment.

2. Applying the User-Centered Methodology: The Earthquake Management Experience

The first case study was explored in the frame of an Italian project carried out from 2004 to 2005 related to earthquake emergencies. In the following we first outline the project and the case study analyzed. We then describe how a DSS for managing earthquake emergencies was developed according to the proposed methodology.

2.1. The Earthquake Project

This project dealt with emergency situations arising after an earthquake event [3]. We focused our attention on the Italian scenario, given the large number of earthquake hazard zones in the country. We specifically considered as a case study the seismic event of Richter magnitude 5.5 occurred in the night of November 24, 2004 in the region around the west coast of Garda lake, near Brescia, a medium-size town in northern Italy.

In this emergency situation, the local institution in charge of public health – the *Azienda Sanitaria Locale di Brescia* (*ASL Brescia*) – was deeply involved. An emergency management team was established to identify and execute the most appropriate intervention plans and to allocate the necessary human and material resources to the actions prescribed by the selected plans in compliance with the current regulations. This case study offered a valuable source of information to identify the conceptual requirements of a DSS aimed at helping crisis managers effectively respond to an earthquake event [8].

In this context, five main issues make the crisis managers' job extremely complex:

- *Information overload*: crisis managers receive information from the field at a high rate and through various channels (telephone, fax, private communication networks, etc.); information arrives in an unstructured, uncontrolled, and unfiltered way. Consequently, crisis managers have to deal with too much, too frequent and too chaotic information.
- *Time pressure*: crisis managers must operate in real time: once they receive information about an event, they must react immediately. They are not allowed to spend all the necessary time to investigate the problem occurred, to examine the relevant regulations and intervention protocols, to analyze alternative solutions, to assess their feasibility, and eventually to launch the action they consider the most appropriate. In such a context, a primary need is to respond as soon as possible to any input received, since, generally, problems become more and more severe with time.
- *Uncertainty*: crisis managers are often unsure about the credibility of the information they receive. They have to check, compare and assess any information before accepting it as a valid input. Moreover, information arriving from the field is often incomplete and imprecise. Almost no information is definitively valid, as new information may complement or even contradict previous information. This situation is a source of complexity for crisis managers, who must rely on their personal experience to make decisions in an intrinsically uncertain situation.
- *Task overhead*: crisis managers are involved in many tasks at the same time. They have to take care of a very large number of aspects, which range from

very important issues to trivial details. It is difficult for them to separate easy decisions that can be made on the basis of known, simple rules, from complex decisions that require careful consideration and involve high responsibility. Paying due attention to all emerging tasks may be hard and it may happen that under the pressure of many, urgent, simple tasks, more complex and demanding ones are overlooked.

- *Task complexity*: some of the problems crisis managers need to solve are inherently complex and require a significant intellectual effort. For example, a key problem for crisis managers is allocating resources to the activities to be carried out: this might be a reasonably simple task if there were enough resources, but becomes a really serious problem if the available resources are insufficient to cover all the current exigencies, as it is generally the case.

2.2. The Methodology at Work

Before starting the analysis phase, the first challenge was creating a common background between knowledge engineers and domain experts. It was necessary to explain the general DSS concept to the experts, discuss with them the conceptual principles on which a DSS is based, the need for knowledge acquisition and the main techniques that would be used to elicit and represent knowledge. On the other hand, the knowledge engineers had to learn about the specific domain at hand.

After this preparatory activity carried out in an informal way through presentations and focus groups, the proper analysis phase was started and carried out during a couple of months with the support of a limited number of representative users. The identification and selection of key users to involve in this phase was a critical point, since it was necessary to balance among three contrasting exigencies: (i) avoiding to exclude any people interested and motivated in the project, (ii) taking into account the effective availability of domain experts involved in a hard routine activity, (iii) keeping the work group within a reasonable size in order to assure efficiency. This led to a selection of only five users, four with distinct specialized competences and one with an overall view on the domain. This has been a key decision for the success of the project. From a technical perspective, analysis focused on both elicitation and task analysis, according to our methodology. Elicitation was carried out using simple elicitation techniques, including tutorial, focused and structured interviews, scenario simulations and teach-back sessions. This experience pointed out the importance of these two steps: while elicitation brought to light several informal issues and implicit user expectations, task analysis did provide a more objective and pragmatic view on the domain and was greatly helpful to give rationality and concreteness to the final requirement specification. Rehearsal needed to be iterated several times, both with the entire work group and individually with the specialists of each area of the domain to reach a shared understanding of DSS requirements: the positive effect of this expensive activity was however appreciated in the evaluation phase. As final result of the analysis phase:

- 2 main user classes have been identified, namely: (i) information managers, in charge of collecting and validating information that arrives from the field, concerning events occurred, results of actions undertaken, availability of resources, etc., and (ii) decision makers, in charge of all the decisions necessary to manage the emergency in the most suitable and effective way, among others: selection of intervention plans, selection of alternative implementation, and allocation of resources;

- about 40 functional requirements have been defined, divided in 3 areas: (i) possible pollution in the aqueduct of a town due to damages to the spring or to the pipes, (ii) damages to a high-risk factory that might cause an environmental disaster, and (iii) unavailability of regular home assistance for patients requiring special care.

Evaluation was carried out after the DSS prototype was completed. Validation turned out to be fast and rather straightforward: the detailed and extensively tested stated requirements proved fully compliant with the intended requirements of the users in all three areas considered. Usability was tested extensively but with a small number of users: in-depth evaluation was preferred to a wider but shallower assessment. The tests carried out concerning all five characteristics of usability revealed several problems, especially concerning efficiency and memorability. The outcome of usability assessment was important to plan future developments of the DSS. This result demonstrated that it is always difficult to foresee user behavior with a DSS before the DSS can be actually experimented in the real work context. Even if several scenarios and use cases were developed and shown to the users during the design and implementation phase, users' expectations about user-system interaction were only partially met and a new design cycle turned out to be necessary.

3. Applying the User-Centered Methodology: The HEALTHREATS Experience

We are applying the user-centered methodology to HEALTHREATS, an ongoing project started in 2007 for supporting decision making in pandemic flu emergencies. The DSS is currently under development and the first prototype will be released by April 2010. In the following, we briefly describe the research project and present the requirement analysis we have executed so far.

3.1. The HEALTHREATS Project

The HEALTHREATS project [4] addresses the problem of pandemic flu emergency response and management, both at regional and local levels. It has a wider perspective than the previous one, since it includes 11 partners from 5 European countries, and in particular health institutions from Italy, Romania, Slovenia and Spain. The main goal of the project is to develop an innovative DSS able to assist health authorities in making strategic decisions underpinning the launch and management of operational interventions in response to pandemic flu.

As a starting point for DSS design, the relevant prescriptions of the World Health Organization (WHO) have been assumed, as specified in the "WHO global influenza preparedness plan", which provides national health authorities with priority goals and recommendations to develop national preparedness plans [9]. Of the six WHO pandemic phases, it has been decided to focus on phases 4, 5 and 6 concerning the pandemic alert period and the pandemic period (see [9] for more details). The informal analysis of this case study has revealed the following key characteristics:

- *Heterogeneous population*: members of an emergency team belong to a heterogeneous community; they have different roles and expertise in managing emergency situations, thus requiring different decision support.

- *Distributed knowledge*: each member of the emergency team is expert of specific aspects of emergency management and has a different perspective on the emergency event and its possible effects.
- *Tacit knowledge*: members of an emergency team usually know more than they can tell; their knowledge about emergency management is to a large extent tacit; they use such knowledge to carry out tasks and solve problems, but they may be unable to express it in verbal terms or even unaware of it.
- *Integration issues*: different departments involved in managing an emergency usually adopt different and heterogeneous information systems that need to be considered and integrated to yield a global view of the emergency situation.

3.2. The Methodology at Work

The requirement analysis has been carried out with a group of selected key users as much as possible representative of the heterogeneous community of experts involved in managing a pandemic flu emergency. With reference to the Italian scenario, nine domain experts have been involved, seven from ASL Brescia (the local authority in charge of public health), one from Spedali Civili (a public hospital), and one from ACB (an association of local municipalities in the Brescia region). They have different expertise and specializations in emergency management, from veterinary and medical prevention, to primary health care and emergency assistance, home care and nursing service, socio-sanitary activities and public safety management. Two knowledge engineers have been involved in preparing and conducting the analysis phase.

Different elicitation techniques have been combined and iterated to progressively elicit and formalize users' tacit knowledge and to coherently integrate different user views on the emergency management task.

Two questionnaires have been submitted to domain experts; one allowed experts to carry out individual reflections on their needs and goals, and to precisely identify the classes of the intended DSS users; the other was aimed at collecting basic information on existing data bases that experts usually exploit during a pandemic emergency, to which the DSS should have access.

Two focus groups have been performed to elicit expert knowledge about pandemic flu emergencies and their management, as well as general expectations about the DSS in terms of goals to be achieved and activities to be performed. Focus groups allowed knowledge engineers to identify and solve substantial or apparent divergences among users, and to integrate different user perspectives.

Finally, individual interviews have been carried out with the purpose of expanding the requirements analysis both in breadth and in depth by stimulating domain experts to make their mind explicit, deepen and justify their expectations and points of view.

As to task analysis, knowledge engineers focused their attention on established procedures relevant to decision making in case of pandemic emergencies, with the aim of understanding the tasks an emergency management team has to carry out during a health emergency caused by a pandemic flu. Domain experts have been involved, through individual and group interviews, to identify, for each pandemic phase, the actors involved in responding to the emergency, their roles and responsibilities, as well as the procedures and organizational methods to coordinate and manage the emergency. For each *event* that may happen during a pandemic emergency (e.g., "Human case exposed to risk of contagion"), the relevant *intervention plans* necessary to effectively respond to the event (e.g. "Plan for the surveillance of human subject exposed to risk of pandemic virus”) have been identified. Therefore, starting from the critical assessment of current work procedures, the task analysis was able to define improved intervention plans incorporating all available best practices and experience.

All the information collected during elicitation and task analysis has been critically assessed and integrated by the knowledge engineers, leading to a partial and semi-formal representation of DSS requirements, in terms of conceptual diagrams and use cases [10]. Furthermore, all the intervention plans emerged from the task analysis have been represented through a semi-formal graphical language compliant with the Business Process Modeling Notation (BPMN) [11]. Figure 4 shows the BPMN diagram representing an example of an intervention plan.

A rehearsal phase has been carried out through a focus group to discuss with the key users the first statement of requirements and the task model derived. Specifications have been checked for completeness and correctness and critically reviewed to produce a complete and shared specification of the DSS requirements and the supported tasks.

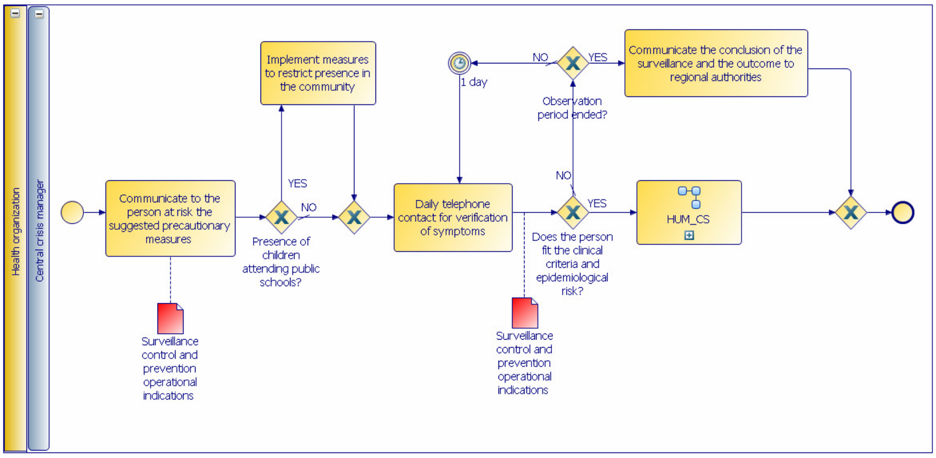

Figure 4. BPMN intervention plan for the surveillance of human subject exposed to risk of pandemic virus.

A second iteration has been performed to refine DSS requirements and understand their priority. In particular, a third questionnaire has been submitted to domain experts to elicit the expected requirement priorities, divided into three classes: ‘mandatory’, ‘advanced’, and ‘nice to have’. Then, a final focus group has been carried out to discuss the responses to the third questionnaire, thus validating the final statement of DSS requirements. As final result of the analysis phase:

- 6 main user classes have been identified: event managers, central and local crisis managers, field operators, observers, and resource allocation managers;
- 77 functional requirements have been defined, divided in 8 areas: (i) management of events, plans, and actions; (ii) information about the emergency situation; (iii) management of material resources; (iv) management of human resources; (v) geographical mapping; (vi) knowledge management; (vii) document management; (viii) user administration.

As to DSS evaluation, proper indicators and metrics have been defined for validation and usability assessment. They will be applied after the completion of the design and implementation phase.

4. Related Work

The experience reported in this paper focuses on a user-centered design methodology for supporting acceptability of DSSs. Although the emergency management domain considered in the two case studies has been the starting point and the test bench for our methodology, it is not essential for our proposal, which features a high level of generality and can be applied to a variety of application contexts.

Scientific literature about DSSs for emergency management – consider, for example, among many others, RODOS [12], ARGOS [13], CAMEO [14], RiskWare-Hiterm [15] and DMT [16] – does not generally focus on methodology. Moving to other application domains, two works are particularly worth mentioning.

The work described in [17] discusses the adoption of user-centered design techniques in the development of ADVISE, an antibiotic DSS to be used in an intensive care unit. Ethnographic approaches, contextual inquiry modeling notation and paper prototyping have been adopted to investigate the work environment and design a software application capable of addressing users' needs. The impact of ADVISE on work organization has been positively evaluated, the clinicians declared to be satisfied with the suggestions provided by the system and reported increased confidence in prescribing or ceasing antibiotic therapy. With respect to our case studies, the problem addressed in [17] is however more limited and better defined; therefore, the adoption of user-centered design techniques was in some sense easier and did not require a highly structured methodology to be effectively applied. In any case, the ADVISE project demonstrates the validity of a user-centered approach in the DSS context.

A user-centered methodology has also been applied in the design and evaluation of a DSS in a railway network context [18]. The methodology proposed is based on the U-model of software development [19], which, on the descending phase, starts from task analysis and arrives at the human-computer interface generation, and, on the ascending phase, focuses on different evaluation steps by distinguishing between usefulness and usability properties. This methodology is very similar to ours in the idea of involving users in various stages of system specification and evaluation and in the suggested user-centered techniques. However, its basic structure (the U-model) seems to limit iteration possibilities, which, based on our observations, are crucial both in the overall system design and individually in requirement analysis, validation and usability assessment phases.

5. Conclusion

This paper describes a user-centered methodology for DSS design and development whose goal is to support DSS acceptability by increasing users' motivations and confidence in DSS usefulness and effectiveness. The methodology has been applied in the context of two research projects in the domain of health emergencies.

As future work we are going to complete the evaluation activities on the HEALTHREATS DSS prototype according to the methodology proposed, by applying the indicators and metrics we have properly defined for DSS evaluation. Furthermore, we plan to apply the methodology to further application domains requiring strategic decision making, such as business and financial domains. Finally, we intend to explore participatory design approaches and end-user development techniques [20] to involve DSS users also in the design and implementation phase of the system life cycle.

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