A decision and reconstruction support framework: elaborating on web technology

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Abstract—In earlier research, we focused on the development of information models for distributed GDSS (Group Decision Support Systems), closing the gap between the study of concurrency control mechanisms, document structuring and decision tracking. The properties of the developed information model (implemented into a GDSS software tool) not only achieved the proposed goals, but allowed to support the reconstruction of past decision-making processes. Decision reconstruction is the process that allows an individual or group of individuals to understand how a GDSS supported group has reached a previous decision in the context of an organization. We believe that by fostering the decision reconstruction ability, we promote their capability for information retrieval, while fostering knowledge acquisition. In this paper we present a framework for developing decision and reconstruction support systems. With this framework a GDSS encompass not only quantitative analysis and deliberative support, but also decision reconstruction or traceability support. The building blocks of the framework are: Contribution support; Preservation of the information; Structure building support; Decision making and reporting; and Visual representation. Instead of advocate the development of systems from scratch, we posit their development by using the common functionalities of Web 2.0/3.0 tools.

Keywords— Decision, Framework, Group, Reconstruction, Support, System.

I. INTRODUCTION

THE aim of group decision support systems (GDSSs) was (and still is) to help rising rationality in decision making processes, seeking to counterbalance the intuition of decision makers, to reduce time of analysis, ultimately contributing to improve the overall quality of decision making.

This approach derives from the 80's of the XX century, when software started to look like the contemporary one, though placing major challenges, due to limitations of memory management and processing capacity. Only two decades after, we observe a completely different paradigm in software development and management. Current developers do not have crucial worries in saving disk space nor do normal users take great care in efficiently manage the use of their disk space, by searching and deleting obsolete, outdated and useless files, for example. The current trend, that could be called "save it all", is present in any sort of devices (computers, mobile phones, etc.), as people tend to store every e-mail message, document or even hundreds of photos of past holidays (whether well framed/focused or not).

In parallel, the main idea in GDSSs development is still the cumulative (sequential) support for the decision-making phases (as defined by [1]) and so, it is not always easy to understand the earlier stages of a discussion. This is particularly evident at the end of discussions when records, which were created to encompass the discussion elements and some of the details, are "flattened" and only the final solution is stored. Only now, the idea of 'save it all' begin to be considered and brought into GDSSs [2, 3, 4, 5], in order to record the entire decision process from its inception to its conclusion, making the in-between steps available for decision reconstruction (or traceability).

Although the traditional focus of GDSSs is quantitative-oriented (mainly through multi-criteria decision-making support), it is known that GDSSs supply a collaborative learning context where people can interact, create and obtain knowledge, acquired and shared by groups [6], while providing structured opportunities to engage in the deliberative exploration of ideas and evidences [7]. Therefore,

current GDSS development should encompass not only quantitative analysis and deliberative support, but also decision reconstruction (or traceability) support, by capturing the history of decision-making and connecting underlying assumptions. This can provide a dynamic validation of the decisions under varied contexts [4]. Moreover, when combined with the traditional decision-making support, decision reconstruction can enhance transparency (as stated in [8, 9]), and empower GDSSs as tools for public consultation and the external scrutiny of decisions.

To address these issues, we present in this paper an outline of the building blocks of a decision support and reconstruction framework for GDSS development. The remainder of this paper is as follows: motivation and the used methodology are explained in section two, while the building blocks of the decision and reconstruction framework are detailed in section three. Section four presents some issues on implementing such framework, with Web 2.0 tools and Semantic Web concepts. In the final section, we present conclusions and future research considerations.

II. MOTIVATION AND METHODOLOGY

In earlier research [10, 11, 12, 13, 14], we focused on supporting the development of distributed GDSSs, closing the gap between the study of concurrency control mechanisms, document structuring and decision tracking. Knowing that the simultaneous manipulation of shared information resources is likely to enhance information inconsistencies, we developed an information model to avoid such situation, as well as to capture and manage divergent (conflicting) contributions from a distributed group, thus eliminating restrictive strategies for distributed information manipulation (like data-locking strategies). This approach moved away from traditional divergence management (a technological approach, quite focused on managing competing and divergent information flows) and incorporated divergence as something natural within group processes. This view was sustained by GSS (group support systems) literature, where the convergence/divergence concepts were used to indicate the existence of conflicting contributions, which may or not result in converged solutions or consensus (expressed, for instance, in [15, 16, 17, 18], among many others).

The properties of the developed model (implemented into a GDSS software tool) not only achieved the proposed goals, but allowed to support processes of reconstructing past decision-making processes. To evaluate this capability we emulated the extreme case in which recalling the reasons for a past resolution was only dependent of previous GDSS records, seeing that no decision reviewer was involved in the decision [2, 19]. The evaluation regarded the examination of the correctness of a decision process, performed in a public company, regarding the acquisition of external auditing services, according to existing legislation requirements. Senior technicians – the subject group – were invited to review the decision process using our GDSS. The reviews were made in independent sessions (meaning that the reviewers had no contact amongst them). Although being experienced with both

management and group decision support systems usage, the subject group had no practice in using our GDSS and only had a basic written tutorial on how to operate the system.

The presented model proved adequate to deal with decision reconstruction, but requiring extended features in order to lower the cognitive effort of decision reviewers and additional properties to support processes that are more flexible. Evidencing the used argumentation schemes in the reconstruction process, and building re-structuring tools, based on the transition between such argumentation models, was also found very important in order to decrease the cognitive load of the decision reconstruction process.

Another aspect was that the subject group experienced a great deal of effort in understanding that different representation schemes (argumentation models) were involved in the decision process, as they expected an athwart representation for the whole discussion, as in usual GDSS tools. The model/prototype were found to be excellent in supporting several ways of conducting a decision process, as they made possible the use of different types of argumentation models and representation styles within a decision process. However, such freedom of style was also pointed out to be a problem for the decision reconstruction.

These findings ratified our earlier expectations, as we had anticipated that using a GDSS without any knowledge on how the discussion was organized or which were the used argumentation schemes at the different phases of the decision process, would increase the difficulty of the decision reconstruction. This situation seemed, however, more adequate to our goals in testing the model/system and more realistic in emulating the situation in which the decision reviewer is not part of the decision group.

Another limitation, derived from the earlier presented ones, was the lack of tools that would allow the decision reviewers to re-structure the represented information into another argumentation model or representation scheme.

Based on the referred limitations we decided to develop a framework to support both deliberative and quantitative decision support, but taking into account the desire to register the intermediate steps of the process.

The foundation of decision and reconstruction support lies within the scope of distributed cognition perspective, guiding the design of systems that support managers as interpreters and enactors of a stream of events in their organization [20], but also within the scope of design research. This option takes into consideration the creation, use, study and performance evaluation of artifacts in order to understand, explain and improve information systems [21, 22]. To provide substance to the theoretical background, we adopted the process defined by Peffers (explained in [23]) which uses an eclectic approach, combining the research steps of other authors and emphasizing knowledge use and development, throughout the research.

III. BUILDING THE FRAMEWORK

Decision reconstruction is the process that allows an individual or group of individuals (the decision reviewers), whether internal or external to the organization, to understand

how a GDSS supported group has reached a previous decision in the context of an organization. Understanding how the past decisions affect present ones fosters the relationships between information and facilitating the use of knowledge in mutually dependent contexts [24]. We believe that by fostering the decision reconstruction ability of GDSSs, we promote their capability for information retrieval, thus contributing to ease and deepen the comprehension of past decisions, while fostering knowledge acquisition. In addition, expanding GDSSs capabilities from the perspective of knowledge management can significantly improve the performance and satisfaction of group meeting participants [25]. We also stand that decision reconstruction can enhance transparency (as stated in [8, 9]), and will empower GSSs as tools for public consultation and the external scrutiny of decisions.

This retrospective knowledge addresses the information needs of an organization's internal and external users, as well as the ones of the usually independent examiners, normally known as auditors. The decision reconstruction concept seems preferable to a decision-auditing concept, as audits (whether internal or external) carry a connotation of mistrust.

From our research [2, 5, 26], we learned that a decision and reconstruction framework for GDSS needs to encompass some important building blocks, expressed in figure 1.

A. Contribution support

A contribution is every input provided by users of a GDSS solution and every solution proposal provided by the system to the users, within a GDSS meeting. Contributions are, therefore, human or system based, reflecting an expected interactivity with the system, though deliberative or quantitative (when the decision process requires discussion and debate or a quantitative analysis).

Contribution support needs to cover a multiplicity of approaches to support different ways of building a collaborative discourse (according to [27]). These ways range from a simple question-reply pattern to more elaborate argumentation models supported by argumentation theory (as seen, for instance in [28, 29, 30], among many others).

The main issue here is supporting both the decision process from phase one to phase three [1] and from phase three to phase one.

Although the quantitative support of GDSSs might impose the use of pre-established data formats, in general there is no "best" predetermined structure for supporting a group's deliberative process, in spite of the fact that literature shows that it is possible to use predefined templates to assist in facilitating group meetings [15]. Although traditional GDSSs usually embed a transversal discourse representation for the whole discussion, instead of implementing a distinct discourse for different discussions or discussion segments/phases within discussions, we posit that a general approach to the deliberative support should not be restricted to any pre-established discourse structure. The corollary of capturing the discussion elements and their relationships using a basic structure is that it might imply that only a restricted number of relationships can be represented (e.g. the basic sequential
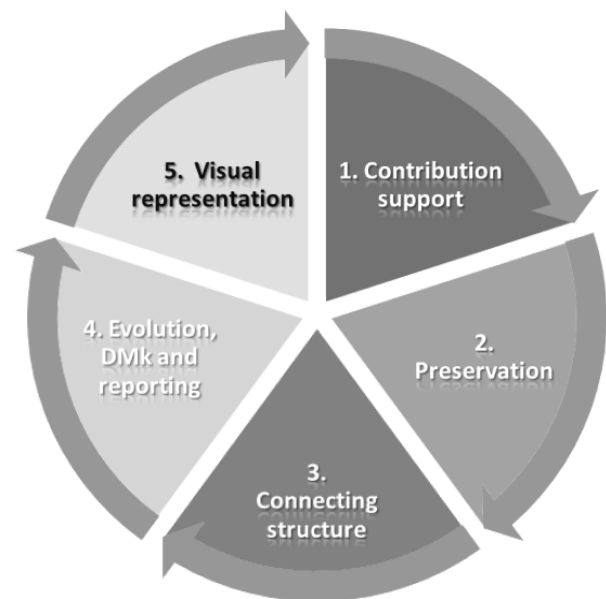

Fig. 1 framework building blocks

process of a simple question-reply thread pattern).

Expressing more complex argumentation models as simpler ones does not seem troublesome. The opposite, however, may not be accomplishable (at least automatically) due to the lack of associated information. Producing such information requires the establishment of new types of associations) beyond the ones established in the decision process.

The capture of the relationships between the discussion elements covered by the information model should also provide the necessary basis for its visual representation. In order to enhance its utility in decision reconstruction and especially to respond to different information needs and cognitive styles of decision reviewers, it requires, nevertheless, a combination with tools for filtering, sorting, selecting and displaying multiple relationships.

This situation might obstruct the decision reconstruction process, as it removes context information. Thus, choosing an argumentation model or discourse structure beforehand should not be taken lightly.

Unbinding GDSS development from any pre-established discourse structure, frees the developer to adopt existing structures, to develop new ones or even to build a transition support among different discourse structures. Nevertheless, in order to decrease the cognitive load of decision support and reconstruction, the explanation of an applied discourse structure (elements and relationships) should be made available to the final user.

B. Preserving the information

The essential goal in preserving records is to enable reconstruction of past events, activities, decisions, and states of affairs from recorded information accumulated in the course of the decision process. Information loss might constitute an important barrier to decision reconstruction, whether originated by information "flattening" to some

condensed form or actual deletion. To this matter, no records could mean the inability to retrieve past decisions.

Baring the intention to register all the steps in decision-making to foster decision reconstruction, instead of deleting information, while avoiding information overload, contributions should be marked as "active" or "inactive" (meaning that an inactive contribution represents a "deletion" but without actual information loss). These marks should be recorded with a time stamp. By doing so, it is always possible to re-visit the information and its connections, considering a past moment and rebuilding the state of the system at that moment. This strategy enables to consider the past, the present and the future, relatively to a predefined moment in time, helping the understanding of the evolution of the information of a decision process.

Although this option is memory consuming, it reflects the new paradigm referred in the introduction, having its counterbalance on the increment in storage capacity, variety and cost reduction in memory hardware, as well as on the enhancement of computational processing capabilities of ordinary computers.

C. Connecting contributions and structure building

Connections between contributions require: discourse relationships (e.g. support, response to, evidence for, etc.); structuring support (as one of the most common features in GDSS is their ability to separate contributions into meaningful categories or information containers, namely, discussions, topics, categories, information "buckets", documents, etc.); and time-span association (sequence, dependence, versioning, merging, etc.).

As already referred, decision-making might benefit from the use of formatted contributions or from predefined data-types used when inserting data, especially when quantitative data is under analysis (e.g., percentage numbers, weights, etc.). Therefore, the connection support should address data validation rules, over contributions, in order to ease or automatically support later convergence processes.

Linking also regards the interconnection of discussions, though this is not an always-present feature, as group discussions are usually independent in traditional GDSSs. The situation means that though group participants can retrieve information from other discussions and "copy/paste" the information between discussions, the traditional software support does not recognize that there are intertwined elements among discussions. The association to elements of earlier discussions (whether the final decision or some of the in-between steps) can be linked into a discussion in any stage and not just at its beginning, granting the possibility for deepening the decision reconstruction process whenever needed. This process allows adjusting the level of detail and time-span of the decision reconstruction analysis.

Without this explicit interconnection, traditional GDSSs often create the need for other systems (for instance, search engines using artificial intelligence techniques, based on natural language recognition) to generate ontologies, in order to perceive information connections.

D. Evolution, decision-making and reporting support

The necessary support to register (document) the in-between steps of the convergence/consensus-building during a decision discussion resembles the capabilities of entity-based versioning systems, which can create versions of packages, classes, and even individual methods of a complete system over its entire lifespan [31]. The association of entity-based versioning with granularity control, to version contributions (from coarse to fine-grained) while transparently maintaining and expanding their connection network, allows an in-depth registration procedure and grants the possibility to evidence their evolution over time [3].

When supporting groups, divergent contributions may exist. To deal with this situation a GDSS usually provides converging and decision-making techniques, knowing that the final decision might require more than one convergence process and more than just one convergence method (whether manual or computer-guided). Maintaining a record of the convergence process, as well as the used methods, contributes to ease the decision reconstruction processes by saving and linking the in-between steps of the decision process and still maintaining the traditional decision support of GDSSs. By doing so, it enhances the whole information retrieval process, fostering the ability to describe past discussions effectively, as well as the steps involved in them.

The in-between recording allows the production of better reports/documents, because usual reports only embed the latest result, especially when reporting is an automatic feature. For instance, in a GDSS voting environment, it is usual to expect changes in initial votes, as part of the group process. Even if people are allowed to review their votes (for instance, after discussing the results), when the decision is made and results are disclosed, the final report is poor when it comes to show discussion progresses, changes of opinions (and by who, if possible), convincing arguments, etc., which were involved from the start of the discussion to its end. In this case, a new group iteration (which could be the point when a vote changed) substitutes the earlier one, discarding the previous discussion scenario, without embedding it into the final report.

Any decision report should encompass the reasons that explain the decision outcome. However, the process that selects such reasons and its relevance is not a standard or an always-clear one. If decision-reviewers do not share the relevance pattern or judgment assessment expressed in the produced documentation, decision reconstruction might be hindered. Because of that, the parameterization of automatic recording procedures is needed (from coarse or fine grained as established for version control), in order to produce a final document or report, for instance, based on the performed convergence processes, which recorded the decision evolution within a certain time-span.

E. Visual representation support

Visual representation helps decision-makers and decision-reviewers to find the more innate and efficient discovery methods to perform their tasks.

The relationships between the discussion elements, covered

by the information model, also have to provide the necessary basis for its visual representation. In order to enhance the utility of the visual representation in decision reconstruction, and especially to respond to different information needs and cognitive styles of decision reviewers, a combination of tools for filtering, sorting, selecting and displaying multiple relationships becomes a need. Threaded structures, decision trees, hyperbolic graphs, knowledge maps or even plain reports and charts are just some of the most common representation schemes within GDSSs. The important point is that this type of functionality must be viewed as a toolkit that different types of groups with different applications can adjust to their needs [27].

As stated before, connections ensure structure, sequence, authoring details and all association between contributions, especially regarding discourse or argumentation attributes. All of that provide the basis for a "frame-to-frame animation" instead of a "final photo" representation, in spite of the fact that it is doubtful that a single way to visualize a GDSS discussion representation is attainable (or even desired).

IV. IMPLEMENTING

Instead of developing from scratch an application, we want to determine whether it is possible to implement the described framework, using the common functionalities of Web 2.0 tools, namely blogs and wikis, in conjunction with the available concepts of the so-called semantic web or Web 3.0.

Web 2.0 is considered a social revolution concerning the use of the network technologies, a different way to use the Web as a channel of publication. The Web 2.0 is the most common term for the movement of the Internet from "push" technology to interactive technology, and results in a massive collaborative model of interaction [32]. The information is no longer one sided, but instead results in a communal effort among different people who may never meet but may grow to know each other through Internet virtual identities. The fundamental passage is given by the tools offered to users to support the way they operate in the Web: from consultation, supported by efficient exploration tools, selection and aggregation, to the possibility of contributing with one's contents and the possibility of collaborating and social interacting through network computing.

The social and technological phenomenon called Web 3.0 has the aim of suggesting new concepts to tools, methods and models that can contest the information overload, offering the possibility to name "knowledge" the contents in the Web, even if it refers to "collective knowledge", resulting from social activities [33]. The Semantic Web is viewed as the symbiosis of web technologies and knowledge representation, which is a subfield of artificial intelligence, concerned with constructing and maintaining (potentially complex) models of the world that enable reasoning about themselves and their web-accessible physical objects represented via metadata [34].

A. Wikis and blogs

A blog is a journal or diary kept on a web site for people to view and comment on, but not change. By the time we wrote

these lines, Technorati, a well-known blog indexing company (http://technorati.com), indexed more than 1.250.000 active blogs.

Wikis are web applications, much like discussion forums, that allow users to add content using web browsers, but also present the ability for content editing. A wiki enables documents to be written collectively offering collaboration functionality for a relatively low cost. A single page in a wiki is a wiki page. The entire collection of wiki pages with hyperlinks is referred to as the wiki. As anyone can edit the content on a public wiki site it is easy for users to unintentionally or deliberately, add false or misleading information [35].

Wikis allow contribution structuring, using pages that are characterized by continuous modifications, i.e., while new pages can be created, existing pages can be read or updated. In this case, the pages embed individual contributions, though seamlessly, as contributions are mixed together into a "collective document". In a decision-making scenario, this procedure makes it harder to perceive the contributions of individual decision agents. On the other hand, blogs present a common thread scheme for individual posts commenting on contributions, which cannot be edited. This roughly means that while blogs offer the support for individual contribution, wikis present the combined outcome of collective editing. Neither wikis nor blogs provide, however, the needed flexibility to adapt the argumentation support and to offer a flexible contribution support, instead of the usual transversal representation for different discussions or discussion segments/phases within discussions [36].

Embedding a discourse template module (for different argumentation scheme selection and argumentation model building) into a wiki would allow users to interact using more efficient modes (from rigid rule-based to informal) according to the problem in hand, while making explicit that option, as well as its rules. This option would broaden wikis scope, while easing the decision reconstruction process.

Both wikis and blogs are able to prevent information loss (whether information is stored centrally or in distributed repositories) and to maintain adequate time-stamping procedures, helping the understanding of the evolution of the information of a decision process.

Although the update of a page in a wiki results in the creation of a new page, which never changes, it is possible to store the evolving versions of the page. Creating a history structure allows the tracking of changes [37], as needed in the decision reconstruction process. Wikis not only can provide general discourse evolution over time, but also, when combined with proper tagging for meta-information, can identify and evidence the evolution of the "need-to-track" granular entities determined within the document. This procedure requires, nevertheless, a proper interface to browse the "inactive" versions, as well as to perform change tracking and change awareness of the produced documents, as the "active" version corresponds to the page being displayed by the wiki.

Blogs simply are not suited for version management, as

blogs cannot be edited collectively.

Being able to cross-reference other pages, wikis can automatically build a tree-like content structure to allow basic navigation. In addition, meta-information can be automatically added, corresponding to authoring, discourse relationships and structuring support. In spite of the fact that linking to other pages (documents, discussions, subjects, etc.) is possible in wikis and in blogs (by common use of hyperlinks), the interconnection of subjects do not recognize that there are intertwined elements among discussions.

Regarding the need for formatted contributions or from predefined data-types used when inserting data, blogs seem more adequate for enforcing data rules on the of data-entry process. However, as contributions cannot be edited it would be difficult (if not impossible using the usual features of a blog) to implement a dynamic decision support, but rather a mere presentation of a sequence of alternatives, without the possibility for dynamic change. Wikis, is this case, would need specific decision support templates based on converging and decision-making techniques (whether manual or computer-guided), or the ability to create them, rather than the use of a "regular" blank page.

The existence of versioning capabilities within wikis not only solves the need for an automatic parameterization of recording procedures (as every update represents a new version), but also the reporting problem as the final document represents the evolution of the information. As the tagging of the constitutive elements of a report is made collectively, the final version of that report (which means the wiki page) embeds all the relevant entities (texts, polls, simulations, etc.) as perceived and selected by the group and not by a single decision agent. In this way a future decision reviewer will not only be able to recognize the evolution of the report, but also the evolution of its tagged elements.

Although the problem of future decision-reviewers that will not share the relevance pattern of the elements expressed in the produced documentation, when trying to reconstruct a decision, is not completely solved, the existence of a collective appraisal of the elements to embed in the final report seems to be a good way to mitigate it.

For the time being, neither blogs, nor wikis offer visual representation support beyond its own threaded structures or plain reports.

B. Semantic web

Even though it is arguable that "Web 3.0" (the so-called semantic web) is a reality, it rely on relationships' capture, usually built upon automatic document processing and natural language recognition, to achieve an ontology representation of the objects, concepts, and other entities that are presumed to exist in some area of interest and the relationships that hold among them [33]. To this matter, and to enhance information linking and refine its representation into a proper interface, that sort of technology can also incorporate the defined connections between contributions, and produce visualizations from its structure and meta-information analysis, which include data types, data validation rules, personal annotations,

argumentation role, search tags etc. [38].

Collaborative tagging offers an interesting alternative as it allows users to share their tags with other users. It allows users to publicly tag and share content, so that they can categorize information for themselves, and they can browse the information categorized by others. Tag classification, and the concept of connecting sets of tags between web/blog servers, has lead to the rise of *folksonomy* classification over the internet.

The term *folksonomy* means a classification performed by a group of people that may share a common interest over certain topic or information resource by adding metadata to publish information. All of the users repeat the process of adding metadata describing the content and the taxonomy involving meaning of a particular information resource evolves over time. By reviewing classified content, users develop a collective understanding of each term by examining the way other users use it. Larger-scale *folksomonies* have the benefit of using tagging, as astute users of tagging system will monitor/search the current use of "tag terms" within these systems. They tend to use existing tags in order to form connections to related items. In this way, evolving *folksomonies* define a set of tagging conventions through eventual group consensus [39].

A well-established *folksonomy* can increase the precision of information retrieval from the repository of information sources that are classified. The main characteristics of a *folksonomy* is that it is always created bottom-up, therefore lacking hierarchical structure, there is public availability of tags and metadata for each classified resource, and there is also social context. The advantages for information retrieval and information extraction relate primarily to the possibility of enhancing precision of search results that is achieved outside the retrieval process. This is because information sources are better described by metadata that is indexed through the collective intelligence of users. Also similar web services can be approached through same *folksonomy* so that the final results are more comparable than if they were not evaluated by overall users of the web service [40].

As the interconnection of discussions is not an always-present feature in traditional GDSSs, the process of collaborative tagging and the production of *folksonomies* would allow the association to elements of earlier discussions granting the possibility for deepening the decision reconstruction process whenever needed. In spite of the fact that linking is possible in wikis and in blogs (by common use of hyperlinks), the interconnection of subjects do not recognize that there are intertwined elements among discussions, as stated before. Adding semantic support for such tools would allow revealing the expressed entities in the text and automatically expose the intertwined connections among them, granting users the possibility for initializing different ways of exploring the information space around a particular entity.

V. CONCLUSIONS AND FUTURE RESEARCH

We presented a framework for developing decision and

reconstruction support systems. With this framework a GDSS encompass not only quantitative analysis and deliberative support, but also decision reconstruction or traceability support. The building blocks of the framework are: Contribution support; Preservation of the information; Structure building support; Decision making and reporting; and Visual representation.

Instead of advocate the development of systems from scratch, we posit their development by using the common functionalities of Web 2.0 tools, namely blogs and wikis, in conjunction with the available concepts of the so-called semantic web or Web 3.0. We discussed the use of blogs, wikis and *folksonomies* in order to implement the presented framework. Naturally, the next step in research will be to create a prototype with these tools and concepts and to test it both in lab and in field tests (case-studies).

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