Information Technologies for Environmental Decision-Making in Networked Societies [1]

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Abstract

Environmental decisions are difficult because of complex physical, technological components, economic and social influences and impacts. The complexity of the physical and technological aspect led to the development of many simulation models and decision support systems including spatial decision support and geographic information systems augmented with decision support components. Lack of mechanisms allowing social participation and conflict resolution during all stages of the decision-making often leads to undesired results including social unrest and rejections of good compromises. Assuming that (1) the public needs to actively participate in environmental conflict decision-making, and (2) the emerging networked society and its various organizations can gain access to highly sophisticated information technologies, we discuss the opportunity to construct and use electronic agora support systems. These systems utilize technologies embedded in e-business systems providing facilities for learning about environmental problems, sharing information and knowledge, engaging in disputes, creating alternative scenarios and assessing them, and making decisions in a collaborative framework.

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1. Introduction

Environmental decision-making processes are both complex and difficult. Environmental problems involve numerous interrelated biological, physical and chemical aspects, which are difficult to model and analyze. They are also social problems involving public and business organizations, and people who are directly and indirectly affected by the implemented solutions. Various groups have different, often contradictory, perceptions and understandings of the problems and their implications (Howard 1996). Many environmental conflicts are intractable (Burgess and Burgess 1995) and often those involved do not have sufficient knowledge of the environmental domain which results in the increase of the uncertainty of the decision and negotiation processes among the social groups involved. The difficulty in the identification of the affected groups, their roles and powers, and the possible and effective frameworks of problem formulation and conflict resolution increase this complexity.

Social awareness of the environmental problems and people's aspiration to participate in decisions that affect them increased over the years (NRC 1996; Beierle and Konisky 1999; Palerm 1999). Some socio-environmental decision processes are becoming unmanageable with more people willing to be directly involved in shaping decisions about the environment. Negative experiences, increasing threats of the adverse environmental impact, fear and lack of trust in the political mechanisms lead to the emergence of pressure groups, demonstrations, and other forms of social concern (Ecoplan 2001; Bay 2002).

Environmental decision and negotiation support systems require expert knowledge of the environmental problems, including their physical and chemical characteristics. Therefore, most of the existing models and systems have been designed to support environmental engineers, analysts and other experts. In effect, differing, often contradictory public opinions are not taken into account within existing models and systems thus hampering the participation of stakeholders. With the public not being involved in the construction and assessment of alternatives, the result of the decision process is often controversial from the social perspective with the proposed solution leading to opposition thus becoming less effective or rejected.

Policy makers and the public cannot be directly involved in the formulation of complex and hidden relationships between the assumptions, parameters, and decision variables. The question is about the feasibility of designing support systems that allow for active and direct public participation in the formulation of alternative scenarios, evaluation of their implications and the negotiation over issues that raise conflicts. We argue here that the new decision and software technologies can provide the no-experts with support so that they can acquire knowledge and information, and become participants during the early stages of the decision-making process. Public participation will not only increase the likelihood of making acceptable decisions but it will also bring in additional information during decision-making rather than during decision implementation. Positioning these technologies in a broader social context can change the nature of the processes and the roles of the stakeholders involved; from confrontational based on one-way flow of knowledge to collaborative based on knowledge exchange.

Social and economic importance of environmental decisions, and the difficulties in the construction of alternatives, determination of objectives and explicit formulation of preferences led to researchers' interest in building models and systems devoted to environmental decision making and negotiations. In a partial review of the field, over 400 different models and systems in the area of environmental decision and negotiation (environmental planning, impact assessment, water resource management, agriculture, forestry, and infrastructure) were reported (Kersten 1999). Simulation and visualization techniques, for example, contribute to the increased user friendliness of geographic information systems (GIS) and spatial decision support systems allowing for cooption of stakeholders into the decision process (Reitsma and Carron 1997; Simonovic 1997). Similarly, knowledge-based systems also facilitate the use of GIS in decisions involving complex environmental issues in providing context-dependent help and embedding local knowledge (Rais, Gameda et al. 1999).

The growing interest of governments at all levels in providing citizens with means for electronic participation will facilitate the citizens' direct involvement in public decision-making. However, extensive and expressive support is necessary so that the public is able to make informed decisions and to participate constructively in policy-making processes. Efforts are being made to provide Web-based decision-making environments and to enhance the flow of information between the public and governing organizations, and to aid the formation of a democratic consensus (Bridges 2001; Tiwana and Bush 2001). Most of these systems are used for information delivery rather than the facilitation of the users' participation, collaboration and negotiation. Technologies that can be employed for citizens' participation are discussed here.

Design of support systems that enable public involvement may be considered infeasible and controversial. Their use may lead to a misconception that their use is a replacement for expertise. They may lead to an increase in the number of contradicting viewpoints, explosion of the number of proposed solutions, and the demand for different and incompatible models. Noting these possible objections, we concentrate on the question of feasibility of constructing such systems that integrate the existing and emerging information technologies. The limitations of traditional approaches to decision-support and conflict management can be, we believe, relaxed with future generations of e-business systems (EBS)[2].

The main objective of this paper is to present several complementary information technologies and systems, and discuss the possibility of designing *electronic agora support* (EAS) systems within the framework provided by e-business. EAS extends the concept of a virtual agora as a meeting place (Sadagopan 2000; Kaempf 2001) to a forum equipped with numerous systems, tools, mechanisms and knowledge bases that allow for broad public participation in managing conflicts in environmental decision-making.

Several systems for environmental impact assessment and decision-making have already been deployed on the Web; three such systems are presented in Section 2. Two systems have been designed for analysts and experts and, although now every person can access them, for most they would be unusable. The third system utilizes experts' knowledge to provide effective support to every person who faces a particular environmental problem.

EBSs have led to a significant change in the targeted group of end-users; they are developed for a large number of consumers who have different cultural and educational backgrounds. In Section 3 we discuss three systems that utilize methods and technologies used for collaboration and negotiation support. These systems have been designed for those who understand the decision problem but do not need to know the methods used in problem structuring and solving; the complexities are hidden from the users.

Providing citizens with information, knowledge, expertise and tools for formulating and testing their hypotheses can be compared with the production and sales of personalized digital products and services on the Internet. EBSs used for this purpose are flexible, highly scalable, and accessible due to the tiered network-centric architecture, which is presented in Section 4.

Characteristics of the EAS' users and the resulting design requirements are discussed in Section 5. In Section 6 we discuss critical aspects of the systems, the need for providing extensive analytical support, in addition to holistic support proposed in Web-based GIS (Shiffer 1995), and directions for further research.

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[2] The term "e-business systems" encompasses all types of Web-based information systems that are used by an organization, both public and private, to link their partners, customers, suppliers and external members, and provide them with access to the organization's services and products.

2. Environmental decision support

2.1 RAINS

One of the few successful systems used in complex environmental negotiations is the RAINS system developed at IIASA (http://www.iiasa.ac.at/~rains/). The system has been used to construct and analyze strategies to reduce acidification, eutrophication and ground-level ozone in Europe (Hordijk 1991). It combines a variety of data relevant for the development of cost-effective emission control strategies in Europe. This includes the formulation of projections of future economic, agricultural and energy development in 38 European countries, the specification of the present and future emissions resulting from these activities, and the provision of the options for reducing emissions and the costs of these measures.

RAINS was designed to provide a consistent framework for the analysis of abatement strategies. It integrates latest scientific findings in the various fields relevant to scenario construction (economy, technology, atmospheric and ecological sciences) with regional databases and advanced optimization models (TAP 2001).

The system comprises three modules: (1) EMCO, the emission-cost module for the estimation of current and future levels of emissions based on national statistics and projections of economic activities; (2) DEP, the deposition and critical loads assessment module for the calculation of depositions and the manipulation of geographical data; and (3) OPT, the optimization module for the cost-minimal allocation emission reduction over Europe (TAP 2001). The EMCO and DEP modules are used to construct and analyze scenarios for one or more countries. The OPT module modifies the scenario by the redistribution of expenditures on pollution reduction among countries in order to achieve the pollution levels at the minimum total cost.

There are two versions of the RAINS system. One version that has been used in actual negotiations allows for the construction of new scenarios, complete analysis of the scenario impact on different industries and geographical regions, and the modification of model assumption. Web-RAINS is a scaled down version deployed on the Web with very limited capabilities that allow for either selection of one of the predefined scenarios or modification of the scenario.

It is quite easy to construct an alternative scenario of emission reductions with Web-RAINS. The system is deployed on the Web. To obtain a scenario the user needs to define emission levels of one of the four pollutants for selected countries in Europe. In Figure 1a data used to formulate one such scenario, called Reference_J is presented.

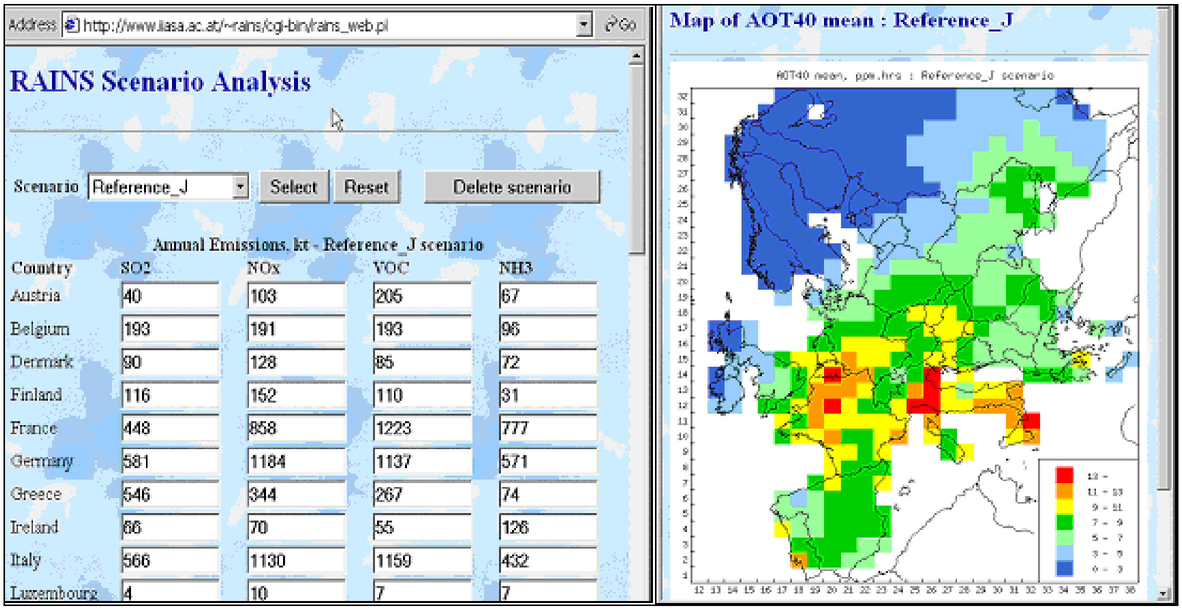

Figure 1. (a) Web-RAINS input for Reference_J scenario, and (b) The resulting scenario.

Based on the input pollutant levels and assumed levels of agricultural and industrial activities, a scenario of pollution for countries and regions is constructed. The scenario takes into account movement of pollutants between the regions displayed as grids in a map. The map constructed for Reference_J scenario is shown in Figure 1b.

The RAINS system may be compared with an e-business system. In e-business three types of entities can be distinguished: producers, customers and products. Producers and customers use virtual market to exchange information about products, possibly leading to a purchase. The product in the case of environmental negotiations is a scenario or decision alternative that a party (country, organization, group) is considering to accept and present to other parties. The customers are negotiators and their representatives (analysts, experts). The producer is an independent organization that owns a system capable of generating scenarios; in the case of RAINS this organization is IIASA (http://www.iiasa.ac.at). The services and customer support are provided by the TAP Group comprising researchers and the system's developers who are based at IIASA. A schematic representation of the interactions between the three entities is depicted in Figure 2.

The distribution of responsibilities between decision makers (negotiators), their experts and the system users (chauffeurs), is illustrated in Figure 2. It is typical for many traditional decision support systems and it is one of the key differences between earlier generations of information systems and

EBSs in which users are the decision makers themselves.

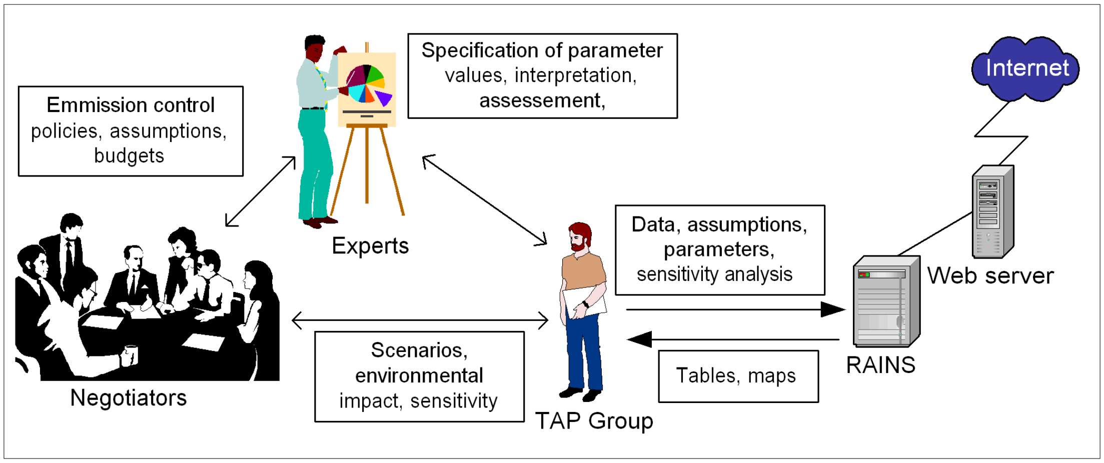

Figure 2. The TAP Group and its RAINS system

3. Web-HIPRE

The RAINS system cannot be used by decision makers directly. In contrast, the Web-HIPRE system provides user-oriented support. It is an experimental decision support system used for research and training purposes (Mustajoki and R.P.Hämäläinen 2000). The system's focus is on the formulation and evaluation of the user's preference structure, construction of the utility function and ranking of decision alternatives. Users may employ several sensitivity analysis tools to assess the impact of their preference structure on the ranking of the alternatives.

Web-HIPRE requires that decision alternatives are either earlier specified or entered by the user. In addition, users need to specify criteria which are used to assess the alternatives and also their levels for each alternative. The difficulty of the problem is not in complex relationships between objective functions, constraints and variables, and interactions between models describing components of the overall problem, but in the subjective and unspecified preference structure and its impact on the choice of an alternative. Thus Web-HIPRE support may be seen as complementary to support provided by RAINS. The former focuses on the subjective needs of decision makers given for a given set of alternatives; the latter on the generation of alternatives for given set of objectives and preferences.

To illustrate some of the system's capabilities two screen-snapshots are presented in Figure 3. The hierarchical structure presented in Figure 3, represents the regulation policy problem for the Paijanne Kymijoki water system in Finland (Hämäläinen, Kettunen et al. 2001). The user specified several alternatives and two levels of criteria. Two alternatives: Current and Recreation can be seen in Figure 3; they describe respectively the current regulation policy and the recreation-oriented policy.

The first level criteria include floods, industry (i.e., implications for the industry), and agriculture (i.e., implication for the agriculture); in Figure 3 these criteria are listed under the column Criteria 1. Level criteria may be further decomposed into more detailed criteria. For example, the criterion “floods” is decomposed into sub-criteria “agriculture”, “recreation” and “industry”.

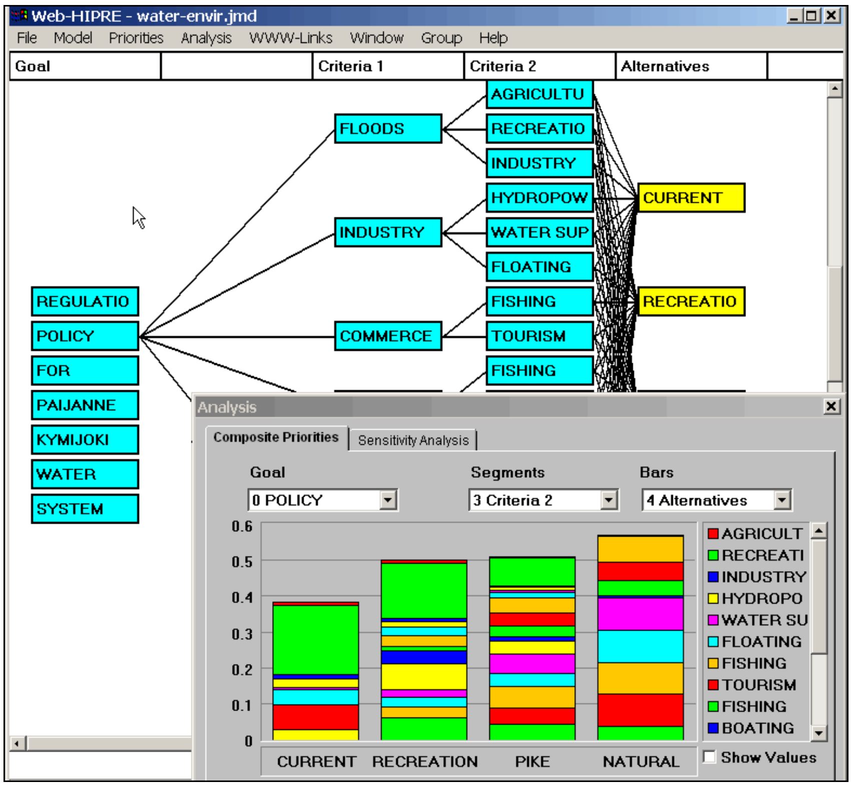

Figure 3. Formulating environmental policy with Web-HIPRE

An example of the analysis of the suggested solution is presented in Figure 3 as four stacked bars. The bars illustrate the contribution of each of the second level criteria to four decision alternatives (i.e., Current, Recreation, Pike and Natural) and the total rating of each alternative. The higher the bar the higher is the rating of the alternative; hence for the selected criteria and preferences the Natural alternative is most preferred.

Web-HIPRE is an example of an easy to use and expressive interface that can be integrated with a system which models and simulates an environmental activity. A system like RAINS has a model in which decision attributes, constraints and bounds are specified. It can provide attributes for the user to choose criteria and generate alternatives (scenarios). The interface-system is used to specify preferences and trade-offs, visualize and compare scenarios, conduct sensitivity analysis, modify constraints and bounds.

RAINS is an example of a system that has been used by its developers, it could be used by analysts but not decision makers. In contrast, the developers of Web-HIPRE aim at decision-maker as the system user. They also differ in that the former can generate decision alternatives based on a complex set of input assumptions and parameters, but has very limited capability to allow users easily manipulate input in order to assess the resulting output. The latter, on the other hand, provides easy to understand and use analytical interface but no capability for creating decision alternatives.

The underlying principle behind both systems is the following: *users need to have qualitative knowledge about the quantitative transformation undertaken by the system*. That is the user needs to understand the types of input and its roles in deriving output, and the general relationships between them. The system's role is mostly to calculate complex formulae; it has very limited structural capability in terms of the analysis of input and output. It has no contextual capabilities, it cannot interpret data, adjust models and provide context-dependent interpretations.

Decision support was directed to a particular type of user group whose knowledge of methods and models was known to designers. In situations where everybody may use a system and expects meaningful support the system has to be sufficiently rich in order to achieve easy to comprehend solutions of a complex problem. For this purpose the system needs not only to match the complexity of the problem but also be able to match the solutions to the user's cognitive capability. The latter postulate may greatly increase the system's initial complexity but is necessary from the system usability perspective. E-business systems are able to provide early examples in this direction.

2.2 SAGE

Decision support systems such as RAINS and HIPRE have limited ability to provide users with information regarding the nature of the decision problem and explain the relationship between the models and their components. They do not guide the user through the process and provide context-sensitive advice. This type of support is provided by knowledge-based systems and such systems are available on the Web. SAGE (http://www.clean.rti.org) is an example of a knowledge-based system used to determine a good solvent to clean a machine and some parts. The SAGE system uses backward chaining reasoning and suggests one or more solvents that are appropriate for cleaning. The number of alternative solvents is small and the user can review all of them.

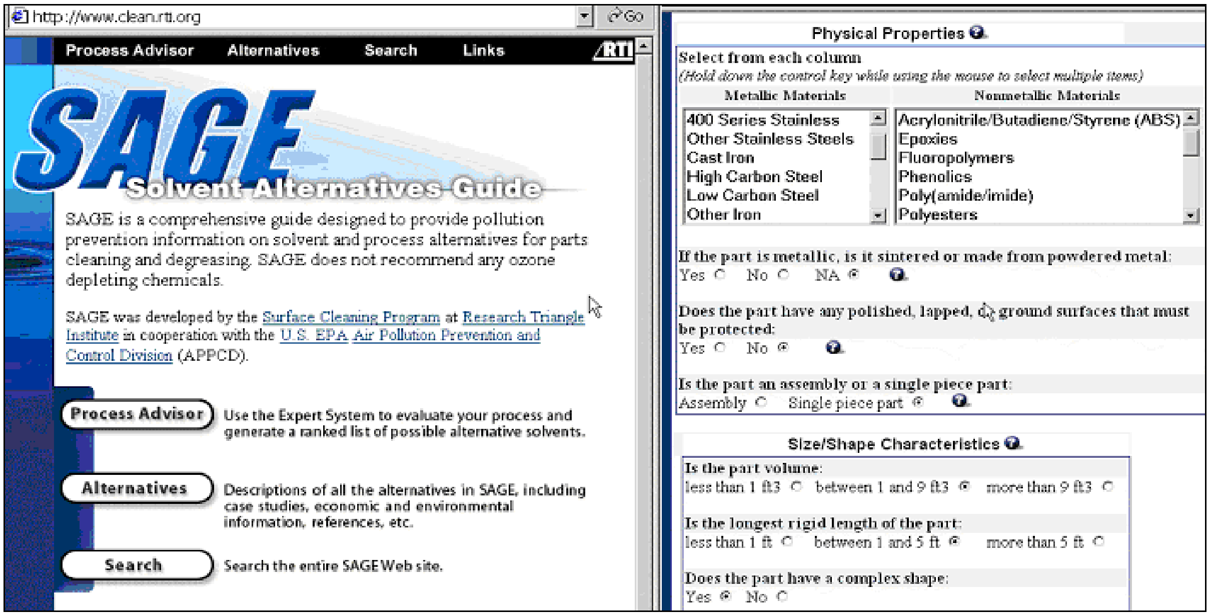

Figure 4. (a) The opening screen of SAGE, and (b) An example of the input form

The opening screen of the system is given in Figure 4a. Users access SAGE to obtain a ranked short-list of possible solvents to clean and degrease parts. They can also learn about alternative solvents and obtain information about their use in the past.

Users interact with SAGE by providing information about the characteristics and properties of parts' that need cleaning and degreasing. An example of the form that the user needs to fill in is given in Figure 4b. At the top of the screen there are two lists of different metallic and non-metallic materials followed by questions which the user needs to answer in order to obtain alternative solvents.

The three systems discussed above provide support to single users. Although the RAINS system has been used in negotiations and Web-HIPRE in group decision making, they do not support activities that are specific to the negotiation, such as, exchange of offers, discussion and argumentation, concession-making, and the negotiation process assessment. The also do not support activities that are typical to collaboration such as: joint construction and evaluation of alternatives, and maintenance of a process memory. The next section presents three systems that provide this type of support.

4. Collaboration and negotiation support

4.1 Negotiation support

Web-based negotiation support systems are already available in business and training. There is no reason to assume that they will not enter other domains, including environmental decisions. Kappeler observes that Internet offers the possibility of direct contacts of a sophisticated nature among governments and between governments and international institutions (Kappeler 1996). He notes that already in the mid-nineties Internet was used in economic negotiations between governments.

Some systems have been designed for training and research purposes and are available to everybody. Inspire (http://interneg.org/inspire) and Mediator (http://mcn.org/c/rsuratt/conflict.html) are some of the examples of systems designed for research and training. INSS and Mediator can be used in real bilateral negotiations as they allow users to specify negotiation issues and options. These systems are based on the negotiation analysis and help the users to negotiate an efficient compromise.

The Inspire system supports bilateral negotiations conducted on the Web (Kersten and Noronha 1999a; Kersten and Noronha 1999b); it was developed in 1995 as a part of the InterNeg project (http://interneg.org). The system has been used in teaching several thousands of students, engineers, lawyers, and managers.

The support functions implemented in Inspire include preference elicitation, construction of the utility function, quantitative evaluation of offers, maintenance of the negotiation history, and graphical representation of the negotiation dynamics. The communication support functions include the exchange of structured offers with accompanying arguments, free-text messages and automatic email notification of the counterpart's activity. An important feature of the Inspire negotiations is the structure of the process; the main steps of the process are given in Figure 5. The negotiation progresses through three distinct phases: pre-negotiation analysis, conduct of the negotiation, and post-settlement.

The Aspire system is an integration of Inspire, an existing negotiation support system, and Atin, a software agent (Kersten and Lo 2001, 2002). The main reason for linking Atin with the Inspire system is to provide users with context-dependent support about the use of the system and advice regarding the negotiation process, and the user's and his/her counter-part's tactics and strategies. In Figure 5 the opening windows of Inspire and Atin are shown. The figure with a sign is present in each Inspire window and it indicates Atin's suggestions: the green sign is used to indicate that the negotiation is proceeding according to the user's strategy and that there are no contradictions; the yellow sign indicates a warning; and the red sign – a contradiction or a mistake in the user's input.

Inspire's emphasis is on negotiation analysis and quantitative support. The system interacts with the user and it is under the user's full control. The main role of Atin is to continuously monitor the negotiation process so that it can provide qualitative support, including the assessment of the user's activity, suggestion of possible strategies, tactics and offers, assessment of the counter-part's actions, and context-dependent answers to the user's questions.

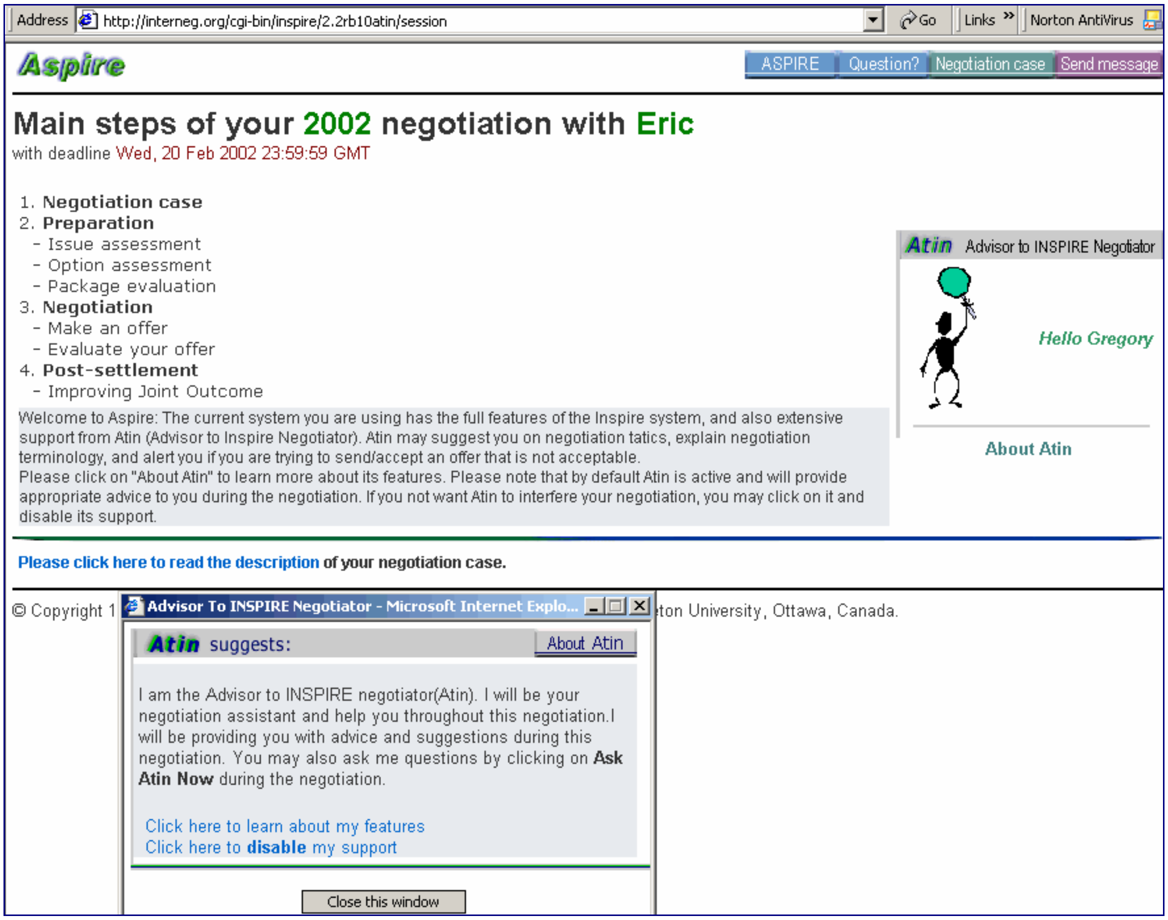

Figure 5. Aspire: Integration of Inspire negotiation support system and Atin agent

Recently, several Web-based systems have been deployed with the specific purpose of providing negotiation support to business organizations. Tradeaccess is an example of a domain specific and process-oriented support system [Ozro, 2001 #74]. Tradeaccess provides users with databases of potential clients (buyers and sellers) and with information about products.

The process-oriented support allows for secure exchange of information between the parties, logs of the exchanges, exchange of attachments, generation of orders and forms, and legal support. An example of the activities completing the Tradeaccess negotiations is given in Figure 6.

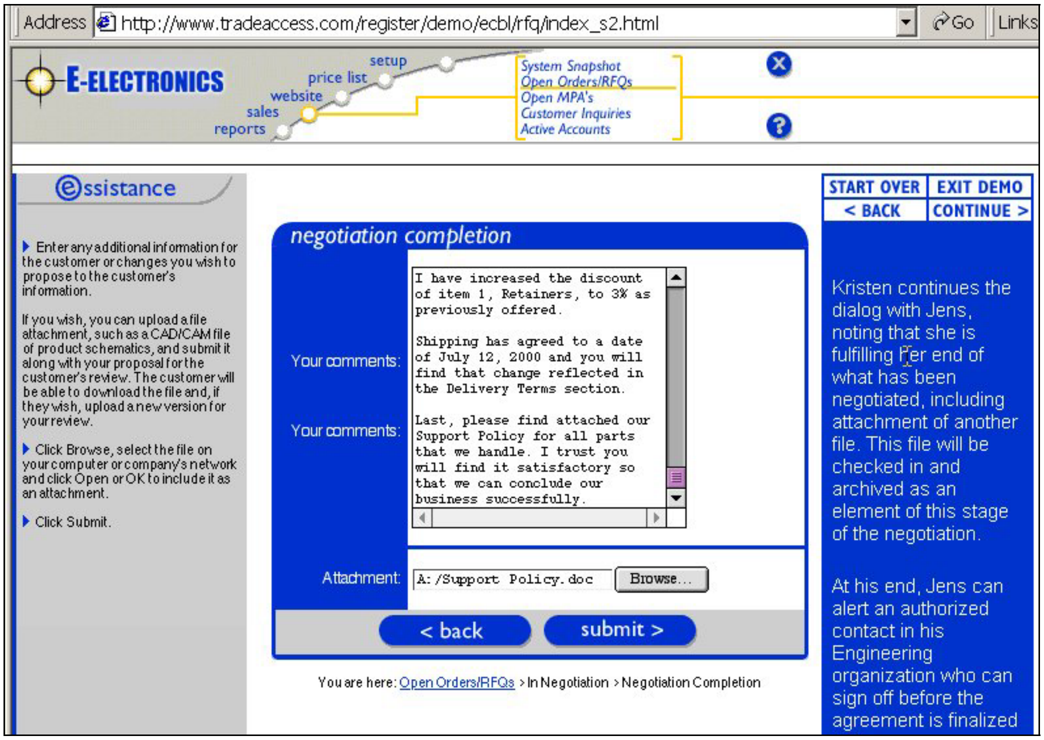

Figure 6. Offer exchange with Tradeaccess

4.2 Collaborative technologies

Computers as media allow for new forms of support and social interaction. Computer-mediated collaboration is growing and constantly evolving; as a subject of inquiry it encompasses the individual, group, organizational, social, and cultural levels of analysis (Greenberg and Cockburn 1999; Mühlenbrock and Hoppe 1999). Collaborative work of groups of individuals represents the main goal of many electronic group interaction systems used to support meetings, idea generation, scenario building, alternative assessment, and provide information reference, transfer and organization. They represent an answer to the growing requirements for in-group communication and collaboration support. In these systems, communication is mainly supported through synchronous (chat, audio- and video-conferencing, streaming), or asynchronous tools (e.g., email, mail list, newsgroups, conferencing).

An example of a collaborative support system is the In-Team software environment (Blenks 2002); it is a collection of systems and tools which users can access in order to conduct various tasks related to teamwork and electronic meetings. The decision support tools include facilities for parallel and anonymous input, generation of, and commenting on ideas, and meeting support.

In-Team project support tools include structuring of the history of collaboration, controlled access to work of team members, several levels of information clustering, knowledge creation and sharing, meeting support, collaborative writing and design, management of the organizational memory and knowledge. In Figure 7 two windows of the knowledge management tool are presented: Figure 7a shows how information and knowledge can be added to a particular knowledge base; and Figure 7b illustrates search through the knowledge library.

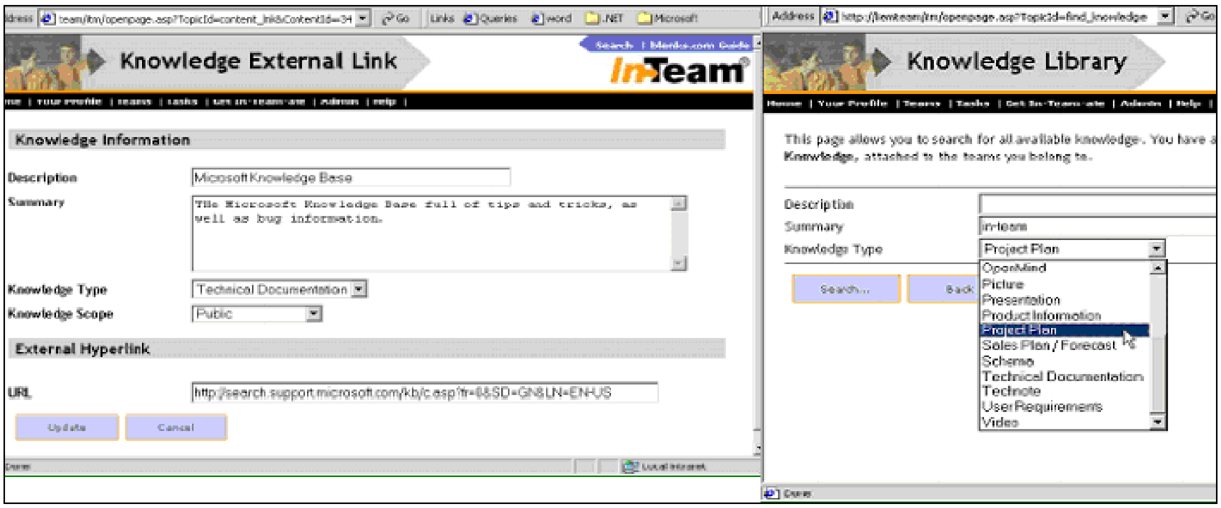

Figure 7. (a) Adding knowledge in In-Team, and (b) Searching the knowledge library

4.3 Multicriteria decision support

Multicriteria decision-making is a complex process that requires the specification of criteria, preferences, and alternatives. Analysts have used systems such as Expert Choice and Analytica to support decision makers in their complex tasks (Analytica, 2002; Expert Choice 2002). In contrast, the AOL Personalogic support system does not require any specialized knowledge about the decision process. [3]

The system provides a list of products and services from which users can select. A set of attributes is available for each product and service. The system guides the user through the selection of criteria and the specification of constraints. An example of using Personalogic for a diamond shopping decision is given in Figure 8.

An example of specification of constraints is given in Figure 8a; the user specifies the required shape of the diamond. The user's input in this and subsequent screens allows to narrow down the initial set

[3] Although Personalogic is no more available, this system illustrates other systems embedded in large-scale EBSs, such as SAP and IBM WebSphere, but for which the interface is designed by the system adopters.

of 6,680 available alternatives to 6 (see Figure 8b, the left-hand side bar). The final ranking of the six feasible alternatives is on the relative importance of the criteria given in Figure 8b.

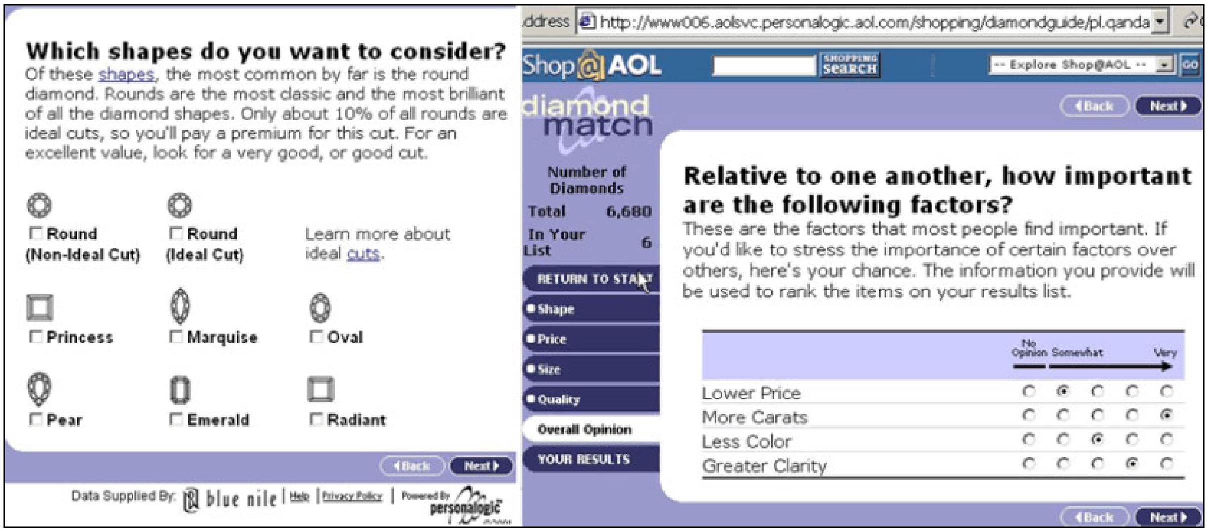

Figure 8. (a) Selection of diamond shapes, and (b) Comparison of decision criteria.

Web-based systems must be easy to use and should contain domain-specific information. This is because they need to provide computational type of support as well as support regarding possible criteria and constraints a user may be interested in. Personalogic, for example, has been designed to support the choice of a particular type of a product and/or a service described in detail in its database. The list of available products and services is provided by the associated vendors.

5. EBSs services and architectures

5.1 Comprehensiveness

E-business systems are used to conduct transactions and interactions between organizations and individuals on the Internet. EBSs are the latest generation of information systems that extend beyond the enterprise allowing interaction among organizations and between companies and consumers. The enterprise may be a business or any other organization that is involved in activities such as producing goods, providing services, and exchanging information. EBSs differ from other information systems in the following key aspects:

1. Network-centric character and reliance on ever-present Internet connectivity.
2. Support for tight integration of intra-and inter-organizational activities.
3. Provision of access for a very large number of users from outside of the organization who can

use the organization's resources.

4. The Web browsers provide the user interface which is familiar, easy to understand, and common to many different applications.

Persistent and ubiquitous communication between organizations and between producers and customers characterizes EBSs. This includes e-commerce which is buying and selling on the Internet but also such business functions as marketing, production and distribution of electronic goods (e.g., software, music, knowledge); information, training and financial services; and other interactions among businesses, governments and other organizations.

IT changes the way producers and consumers make decisions. Increasingly the producers, sellers and consumers engage in direct interactions, provide and use technology to market products, inform about, and search for products, determine the required product characteristics, and engage in negotiations. This is especially true for digital products or those that can be digitized. The production, customization, evaluation, trial use, sales and all other seller-buyer interactions can now be conducted via the Internet.

To see how e-commerce affects all the participants in the production-sales-use process, a process model is presented in Figure 9. The model is extended with the addition of interaction typical for e-business activities including those between the front-office (for example, marketing and sales) and the back-office (for example, design and inventory management). Three main entities are distinguished in Figure 9: producer, market and customer.

The process model depicted in Figure 9 presents main activities and interactions of producers and customers. Producers and customers interact on the market, which may be the producer's store or supplier's warehouse. The market may also be an intermediary that provides virtual market space. Some of the activities are conducted outside of the market. For the producer they include product design, production, inventory management, supply, customer support, management of product information and systems for back-end integration. The key customer activities outside of the market are needs analysis and specification, and product use (in consumption or production).

E-business requires changes in the front-office as well as in the back-office. The front-office deals with sales and services; the back-office deals with production, inventory and suppliers. Systems with which customers interact have to be integrated with the back-end systems.

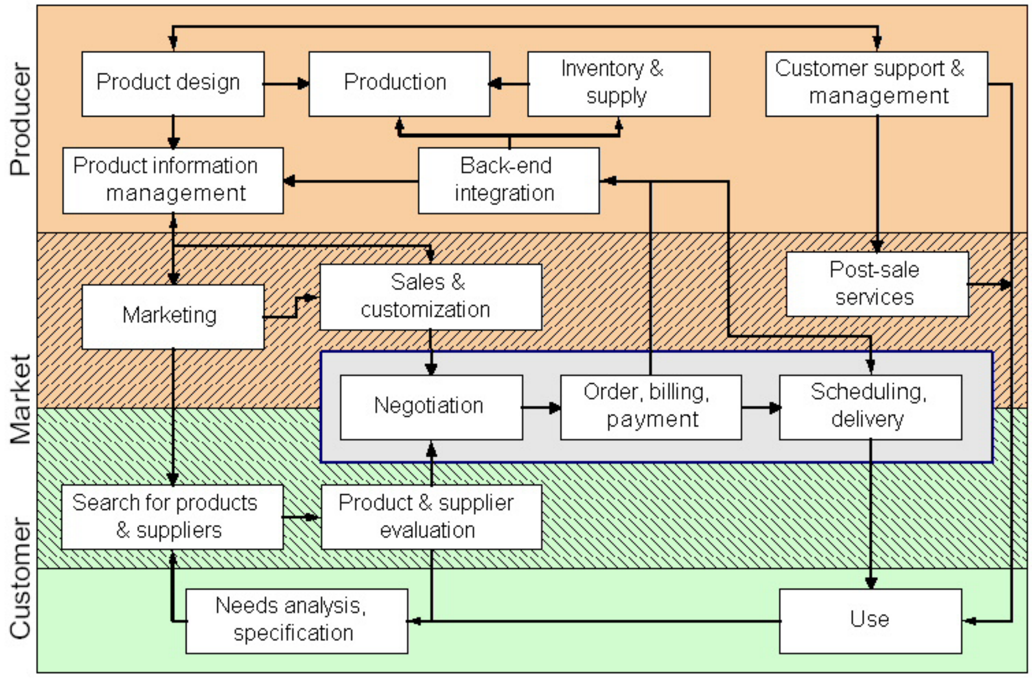

Figure 9. E-business process model

EBSs provide services that help their users to make informed decisions about activities that involve organizations and customers throughout the value-chain process. The systems are *comprehensive* in that there is a wide range of services used by both the organization itself, and by its customers, suppliers and intermediaries. Some of the services are listed in Figure 9, including product customization, personalization of interaction for an individual customer or a group, transaction processing, support for decision making, and the maintenance of product and customer databases.

5.2 Scalability and flexibility

Many systems for individual, group, team and negotiation support, including those discussed in Sections 2 and 3, have been deployed on the Web. They are oriented towards a specific type of a problem and implemented to provide a particular product or service and targeted at a specific group of users. EBSs, in contrast, provide a wide range of services for a wide range of users. From the perspective of their users the request for a service must be simple and the services themselves need to be easy to use. This can be achieved by following three important guidelines:

1. Hide all the complexities of digital production from the user.
2. Build highly scalable systems which can also be easily modified and adapted
3. Learn about the user as much as possible and adapt the system to the user's requirements.

Management scientists and operation researchers have often been concerned with the relationship between the model and the problem, and the model and the decision maker. Their focus was on the construction of formal and sound models that represent reality with a required degree of accuracy. With respect to the model of a decision maker, efforts have been made to construct a utility function that precisely represents her/his choice. Computer scientists, on the other hand, have often used simple procedures to construct systems capable to provide interesting solutions or undertake a variety of actions (e.g., the game of life, case-based reasoning systems and collaborative filtering). In order to provide comprehensive and expressive service that would satisfy users expectations and needs, they were less concerned with the relationship between the model and reality than between solution and the requirements of the user or problem. They often use simple value functions or comparisons with choices made by others so that the user's effort is minimized (Guttman, Moukas et al. 1998; Sandholm 1999).

EBSs require integration of complex models that are used for operation and inventory management, logistics, marketing with models that allow for effective use of the available resources and make satisficing decisions. The complexity of the resulting systems, the requirement that different models be linked together, multiple data sources used, and the representations presented in a meaningful yet intuitively obvious manner led to search for system architectures that meet these requirements and conform to the three above mentioned guidelines. An early approach to achieve these objectives together with the requirement of high level of security and system integrity database management systems have been proposed. The separation of data from applications and encapsulation of data in a dedicated system that is used to manage data allows easy and effective access to data with the minimum requirement of knowledge of the database and data access programs.

The concept of separation and encapsulation was expanded with the dedicated software servers for information resources (for example, a database server). With the requirements of EBSs this led to *n*-tier architecture (Chaffee 2000). An example of a tiered EBS architecture is presented in Figure 10. This type of architecture has been used in large-scale software environments for the development of EBS, for example, IBM WebSphere (http://www.ibm.com) and iPlanet (http://www.iplanet.com).

The *n*-tier architecture facilitates system *scalability* and *flexibility*. Addition of new elements, including applications, is done in a similar way as in the databases. Selection of applications which should be used for a particular problem, e.g. production of a digital product customized to a particular specification, is done in a similar way as in database management systems. Applications are stored in the application server, shown in Figure 10, they are modular and configurable. The dependencies between applications and rules of configuring them, known as *business logic*, are also part of the application server. Business logic allows to define different processes of production, determine different alternative products and services, customize the processes and personalize interactions.

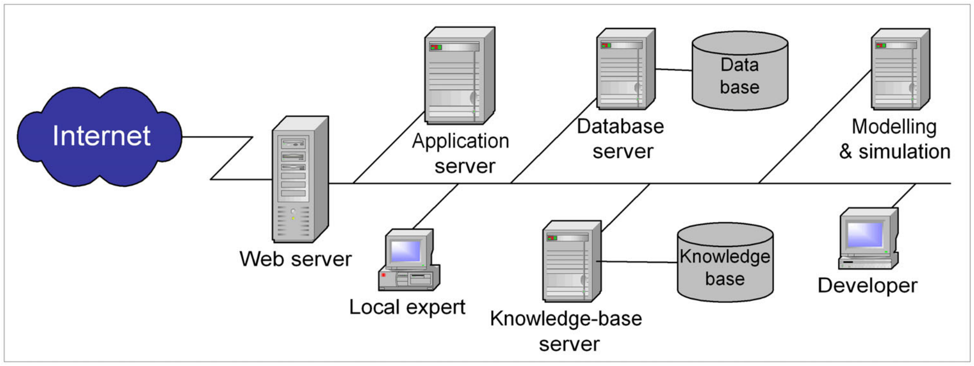

Figure 10. The *n*-tier architecture for e-business systems

Other servers are used to gather and use knowledge about customers, processes, products, services, etc. The knowledge base server, for example, can be used to control the customization and personalization, and to provide customer support (in a similar manner as the SAGE system, discussed in Section 3, does). The server-based approach allows for specialization: each server is used for one type of system's activities; and for scalability: servers with databases, knowledge bases, applications and other elements that can be added as they are required.

Another important characteristic of the server-based *n*-tier architecture is its ability to separate main functions of the system allowing for the integration of different components and technologies. The addition of a server used for modelling and generation of scenarios like, for example, the RAINS system, does not require modification of all other systems and servers, rather extending the communication between them. The assumptions and scenario can be then stored in the database and retrieved by applications when they are needed.

6. Users, experts and decision-makers

6.1 Decision quality

The architecture of EBSs and the tools discussed above allow construction of systems that are highly scalable, flexible, and capable of providing a large range of services to many users with very different cognitive frames and levels of expertise. These characteristics are also required for the *electronic agora systems* (EAS); they need to hide the complexities of the embedded models and be capable of adapting to the user's requirements. Therefore, the development, deployment and use of e-business systems can provide valuable insights in the similar activities associated with EASs. There are, however, several significant differences including the user population, users' requirements and needs. Together, they make the goals of an EAS developed for environmental conflict management different than those of an EBS.

We have already mentioned that users of DSSs, NSSs and other similar systems, whether or not these systems are deployed on the Internet, are typically analysts. These systems are rooted in the tradition of MS/OR where models are constructed, analyzed and solved by the OR/MS specialists. Finlay and Martin (1988, p. 530) noted in their extensive review that "chauffeured use of a DSS is the one and only feasible way forward for most organizations" because decision makers are unable to communicate their needs to the computer. This statement, although somewhat dated, is also applicable today especially to systems that deal with complex problems characterised by many constraints, variables, criteria.

EBSs users are customers who cannot know or learn all the intricacies of the systems they use to obtain digital products and services. Therefore, the designers follow the three guidelines formulated in Section 4. They implement as much as possible, models and methods which do not impose strong informational requirements on the user and which are strongly convergent. In e-business the quality of the solution or recommendation is often considered less important than the ability to obtain the solution fast and with minimal user input requirement. EBSs need to be sufficiently expressive and meet the users' needs even at the expense of the solution quality. It is important to satisfy users' expectations and provide them with satisficing services rather than searching for optimal bundles of services and expecting that users follow a rigorous and inflexible input process.

There is a trade-off between rigour and validity of problem specification and quality of the obtained solution measured by its optimality or efficiency. Although many efforts have been made to formulate methods and models that can accurately represent problems and preferences, experimental research shows that decision makers often select an alternative, knowing that it is dominated; and are not interested in the continuation of the process even when presented with better alternatives (see, e.g., (Kersten and Mallory 1999).

It is sufficient for an EBS to indicate a Pareto-improvement; ultimately it is the user who is responsible for the decision and its implementation. A user who is an employee of an organization, which owns the system, is responsible to this organization. Customers are either responsible to themselves or to the organization they represent. This is not the case with an EAS because:

1. The responsibility cannot be allocated to one individual or one organization; and
2. The implications of the environmental decision involve both those who are involved in the process and those who are not, and both present and future generations.

In effect, the decision quality is an issue that cannot be delegated to one or more participants neither it can be reduced to discussion on the weighting of the participants' objectives, as Kaempf suggests (2001).

Decision quality may be considered from the point of view of the achieved objective levels and, if applicable, utility function. Another consideration is the accuracy of the models that describe a given problem, their constraints and parameters. While we assume here that such models can be constructed, we also note that discussions about environmental problems involve objectives as constraints and parameters. Often constraints reflect the scope and breadth of social, economic and biological processes and expectations. Such constraints may be closely related to objectives but they are based on the assumptions underlying the required process levels. Groups and organizations may formulate different and contradictory constraints leading to an empty set of feasible alternatives. Therefore, an EAS need to facilitate discussions and negotiations about the assumptions, constraints and bounds, and guide its users in formulating and reformulating of problem representations.

EASs need to provide their users with tools for problem restructuring at different levels, including non-technical assumptions and constraints, that is, those that do not describe "objective" biological, economical and technological processes but describe their assumed scopes, levels and thresholds of these processes.[4] These systems need also to provide comprehensive and customized explanations and justifications about models and their components and provide support for problem reformulation. Furthermore, and in contrast with EBS, they need to facilitate reconciliation of the representations that different participants may construct.

Geographic information systems and spatial DSSs embedded in the EAS-type of systems may facilitate problem restructuring. Supported with simulation methods, knowledge bases, and personalization

[4] We realize that in effect nothing may be considered as objective, however, we propose to distinguish here between constraints and models that describe the inner workings of the economic, biological and technical system for which there is a general agreement, and those that describe tentative, perhaps controversial theories that themselves may be subject to discussion, and the assumptions that are made by groups and individuals (including experts) and which reflect their position regarding the problem representation and its acceptable solutions.

and visualization techniques the users' difficult task of analysis and assessment of the problem formulation, its reformulation and comparison may be tailored to their knowledge and cognitive capabilities.

6.2 Users communities

The user population of an EAS developed for environmental conflict management includes inhabitants, officials, environmental activists, and stakeholders of the region which future state they wish to influence. Some of these users may have hostile attitudes, preconceptions, and biased opinions. Other users, representing different interest groups, may have different and incompatible norm and value systems and well-defined agendas. The result is that environmental discussions often concern positions taken by different participants and proposed solutions rather than specific issues, constraints and parameters (Blackburn and W.M. 1995).

Holistic approach is often preferred in environmental problems because it does not necessitate justification all of the assumptions, and the resulting constraints, bounds and variables thus making the discussion on the problem representation and the identification of the specific differences in the understanding of the problem very difficult. Moreover, the problem's complexity on one hand and the attitude of the participants towards the preferred and often only partial solutions on the other, may make effective conflict management and resolution impossible. Therefore EASs needs to provide support for the analytical perspective, seeking specific and detailed points of contention. This is not to say that the holistic perspective is not required, but that it is complementary to the analytic perspective in the users' discussion. The more so that the users may already have strong opinions about the "best" solutions. Keeping the discussion only at a holistic-level may reinforce the already present opinions making the identification of issues causing conflicts impossible.

An EAS needs to provide services that allow users to move from general to specific, from holistic to analytic viewpoints. The specific and analytic is needed to determine and possibly enlarge the decision space; the general and holistic is needed to determine the relationship between the problem and social values, and the solution acceptability in political terms. Ideally, it should have an intelligence that would indicate a direction that is different from the one the participants may be anchored in.

EASs, similarly as EBSs need to accommodate users' interests, tastes, and objectives. Because participants of the environmental decision making need to discuss and reconcile their divergent opinions and interests, EASs need also to provide an *electronic agora* where the opinions and differences may be discussed. The complexity and difficulty of the problems require for the agora to be equipped with tools that facilitate and support information exchange, assess suggestions and solutions, and give access to past practices and various knowledge bases.

Knowledge bases in EBSs are constructed on the basis of the knowledge of product developers and of the experiences of past users. They are used then for system personalization and product/service customization. With the use of machine-learning and knowledge discovery methods these services are increasingly automated. The situation of the construction of knowledge bases for EASs users is more difficult although these users need access to expertise no less than consumers. This is because the "environmental encounters" are not only complex but they are often ill-structured, and involve more interactions than business transactions.

Typically EASs users have many conflicting objectives both at the individual and the community levels. Environmental decisions involve many stakeholders who have different understanding of the problem, its importance, structure, and implications. These differences may lead to separate requirements for the construction of different versions of the model, in addition to different objective hierarchies and preferences. Therefore, the resulting scenarios may not be compatible and not easily reconciled. This is in contrast with the digital goods and services obtained from e-business systems, which, due to customization, may be very different but each designed to serve the singular customer for whom it was generated.

The above leads to another difference between the communities of e-business customers and the users of EASs, namely that there is very little conflict among the customers. However, often there are very strong conflicts within wide communities affected by environmental decisions (including citizens, businesses and public institutions). Since the communities of customers share many similarities regarding their attitude and approach, the differences among them may often be ignored [5]. In contrast, the EASs designed to support wide participation in environmental decisions have to be designed so that that differences emerge however in a way which is constructive in terms of decision-making process (Burgess and Burgess 1995). This aspect becomes more and more relevant, if we consider the increasing impact of the environmental changes on even remote communities and places.

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[5] We refer here to the differences at the deep level (e.g., norms of behaviour, values and traditions) as opposed to the surface level (e.g., language, meaning of colours, format of dates, currency). The surface level differences are effectively addressed with software localization that affects only the user interface. The deeper level differences require the modification of the software core, which is software "culturalization" as opposed to its internationalization. The relationships between the surface culture, deep culture and software, and the issues of software culturalization architecture are discussed in Kersten (2002) and Kersten et al. (2002).

6.3 Producers and developers

The communities of the users of the EASs often differ in their cultural, educational, professional, and other key characteristics. Recognition of these differences requires both expanded and enhanced approach to the design of the EASs. This is perhaps even more important because of the possible deep differences between the community of users and of the EAS producers and developers.

E-business redefines the interactions between producers and customers. The customer becomes a participant in the production process and, as Daly (Daly 2000) observes:

> "The customers provide information as to what they want. Without that information, producers create a product that they can't sell and no one wants. So in more and more complex technological industries, you have the joint teams working together–customer and supplier. The relationship between the customer and the producer is radically changed and enhanced by the Internet."

This perspective is no less important for direct and active participation of the public in political decisions with the environmental decisions being one of the more difficult ones. However, values and decision-making practices of those who currently use EBS for financial, business and consumer decisions are similar to the values and practices of systems' developers. The situation of EASs users is significantly different because: (1) the user culture is not homogenous; groups and communities have dissimilar cultures; and (2) the public cultures are different from the technocratic culture of the EAS developers (Kelly 1998; Kersten 2002).

The ownership of the EAS is also an important issue. One would expect neutrality of the owners but this requirement may be difficult to achieve in local environmental problems. Such problems are managed by the public institutions that may own an EAS and be also involved in the environmental decision process. A possible solution here may be the location of EASs in universities and research organizations, in a similar manner as the location of the RAINS system at IIASA (see Section 2.1).

7. Conclusions

The public has largely been ignored or neglected by professional decision makers. Domain experts have been influencing environmental policies; lobbyists and special interest groups has been exerting various forms of pressures. The public, however, did not and could not participate in shaping these policies and be actively involved in decision-making. The reasons include lack of expertise and domain knowledge, inability to organize and manage decision processes involving large number of participants, problems' complexity requiring effective integration of many disciplines, and finally conflicting values, attitudes and emotions that are often associated with environmental decision problems making them intractable and hard to manage. We propose here technological solutions, that is electronic agora systems as a collaborative framework and a discussion space where individuals, groups and institutions can learn about the environmental problem, inform themselves, engage in disputes, and contribute to the decision making process.

Electronic agora has been earlier promoted; Rheingold believes that the technology, "If properly understood and defended by enough citizens, does have democratising potential in the way that alphabets and printing presses had democratising potential." [, 1993 #78, p. 279]; Gaynor notes that "Citizens can even converse with their political representatives about legislation on which they have an opinion." (Gaynor 1996). New communications technologies bring with them, among other things, the promise of increased citizen involvement. This was the case with the telephone, radio and television but it is not with the Internet and related technologies. Information and communication technologies can weaken public policy if they allow only to access and disseminate data but not to process data using systems comparable with those used by the experts and decision makers. While citizens are more educated and informed, they feel less capable of influencing decisions of elected officials. This may be behind the continuing fall of the voter turnout continues.

Business organizations have realized that access and information is not sufficient to attract and keep customers. They use EBS to provide numerous services and resources, personalize these services, and allow users to customize products. The more information is available and product complex, the more there is need for service that is easy to use but meets needs and expectations. If this is the case in business, then it is even more in environmental decision-making. E-business technologies provide a wide range of resources that can facilitate effective communication and support various forms of planning and decision-making activities.

The requirements for the design of EASs which we have identified include: (1) generation of alternative scenarios; (2) simulation and analysis of the scenario environmental, economic and social impacts; (3) specification of preferences and the subjective scenario assessment; (4) access and use of expert knowledge; and (5) visualization of alternatives, preferences, analyses and comparisons. Because environmental decisions involve also non experts who have competing points of views and different cognitive and communication skills EASs also need to support: (6) creation of interest communities, (7) representation and integration of expert and lay knowledge, and (8) group decision-making and negotiation. If EASs are to be used by people with different cultural, educational and professional backgrounds then they must be: (9) component-based, highly flexible and reconfigurable, and (10) easily tailored to the requirements of particular group of users. While no currently available software platform has all these characteristics, EBSs provide many directions for the development of such EASs.

Creating electronic agora support systems for wide participation in environmental conflicts also introduces some further challenges related to the cognitive dimension of the environmental conflicts. These conflicts often arise due to the incompatibility of objectives and goals (Libiszewski 1992), and from different possible interpretations of events, each being valid but partial (Fiske 2000). These issues, together with considerations of the variety of possible participants, make the cognitive dimension difficult to deal with. Knowledge management, sharing, use and production in a collaborative environment can also be difficult because of differences in languages, perceptions, cognitive frames, and power distribution among the users.

The cognitive dimension becomes a problematic aspect also in terms of the framework for the decision-making. EASs' users (participants) are often very different and their objectives may not be clear at the beginning. Situation reframing represents an important goal in environmental conflicts management (Gregory, McDaniels et al. 2001) mainly because of the need to involve most of the affected communities without knowing who is going to participate, the need to make differences among participants explicit, the need for objectives to be constructed rather than revealed (Payne, J.R. et al. 1999). Different approaches to the decision-making (strongly deliberative or mainly consultation, for example), differences in negotiation styles, opportunities for leaderships in the process, etc. are all relevant features of such decision processes. Therefore, what information is needed, how decision should be reached, and what (if anything) should be done represent basic issues of the decision process itself (Fiske 2000). What knowledge should be used to support decisions on decision-making procedure? Should this knowledge be given to the system or should it be acquired from users?

The design, implementation and use of electronic agora systems for decision-making in environmental conflicts need a deep reflection on the possible effects induced in individual/organisational growth and transformation. As never before, the opportunity for wide public participation is offered by developments in technological resources being integrated within web environments: management and organisational issues have to be explored.

Virtual participation and decision-making may have potential drawbacks (Sadagopan 2000). Community life can be harmed by the concern that electronic communication may replace face-to-face contact. Different groups and individuals may not be able to use the electronic agora leading to information gaps and creating “information urderclass”. There is also an issue of the EAS owner organization who should see themselves as custodians of the information they hold and collect and make every attempt to design EASs’ applications in a way that enhances public’s access rights without loosing privacy of information protection; Another possible drawback is the risk of trivialization of the decision-making process and the replacement of the real interest with strategic objectives hampering effective communication and problem solving.

The risk for trivializing the decision process is also due to our inability to manage and support collaborative work of large groups as those possibly enabled by EASs. Bazaar or fair discussion environments can hardly be transformed in focus-converging wide groups working collaboratively around a complex problem. New forms of governance and organization will be necessary to enable wide interactive and collaborative communication and decision-making (Prigogine 2000).

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