J.T. Yao, V.V. Raghvan, G.Y. Wang (Eds.): WSS'04, pp. 102-110, 2004.

Web-based Support Systems for Sustainable Communities

W.N. Liu J.T. Yao L. Fan Y.Y. Yao X.D. Yang

Department of Computer Science
University of Regina
Saskatchewan, Canada S4S 0A2
{liuwe200,jtyao,fan,yyao,yang}@cs.uregina.ca

ABSTRACT

This paper studies Web-based support systems for sustainable communities. A sustainable community is a community that respects the needs of both nature and future generations. A sustainable community activity is a collaborative process of solving environmental, economic and societal problems. We present an architecture of Web-based support systems for sustainable communities. The architecture is based on multi-tier, component-based structure. Each component provides distinct information services to support sustainable community activities. Users can access these services through standard Web browsers anytime, anywhere. It is argued that a Web-based support system can provide comprehensive and extensible services for diversified sustainable community activities.

1 INTRODUCTION

The notion of sustainable development emerged in 1987 as the overriding goal for human activities [23]. Sustainable communities seek well-balanced social, economic and environmental development strategies based on human responsibility to respect the needs of both nature and future generations [8]. Sustainable communities are also about the participation of all community members in sustainable community activities. A sustainable community activity is a collaborative process of solving environmental, economic and societal problems [9].

Public-led sustainable community activities must be managed to secure the transition to sustainable development [15]. Management support systems facilitate the management of sustainable community activities. The term of management support systems refers to the application of information technologies to support various management tasks [21]. For the diversity of sustainable community activities and participants, we use a more general term, computerized support systems, to replace the notion of management support systems. Computerized support systems for sustainable communities are used to facilitate the creation, discovery, management, distribution, exchange and presentation of sustainable community information. However, most of computerized support systems for sustainable community activities are devoted to individual activity, such as decision support systems [2, 5, 8, 22]. Due to the overlap between sustainable community activities in the content, different computerized support systems may overlap each other with respect to the services that they provide.

Sustainability issues are of multi-disciplinary, multi-agency, and multi-sector in nature [15]. The collaboration between community members is usually accomplished through classical media, such as print, audio, video and face-to-face contact, etc. The interaction between community members often suffers from financial, spacial and temporal constrains. In addition, policies do not always meet the needs of all community members.

The information technologies behind various computerized support systems for sustainable communities are well suited to take the advantage of the World Wide Web. The software architecture of Web-based applications is an essential shift of classical thick client/server architecture. A typical Web-based application consists of a Web site, application servers and data management servers. The Web site works as a presentation service provider. The data management servers store and supply the data needed by the Web site and the application servers. Information technology instruments work as application service providers. They are independent and reusable functional components. Users can access these application services through standard Web browsers anytime, anywhere. A Web-based support system for sustainable communities is an integration of relevant information technology instruments in the software architecture of Web-based applications, which provides comprehensive and extensible services for various sustainable community activities.

In addition, the Web has stimulated many communication tools for worldwide problem-solving collaboration and sustainable knowledge transmission. Web-based communication tools are user-friendly and multi-styles. They are less spacial-, temporal- and financial-restricted than classical media. Web-based communication tools play key roles in attracting community members to participate in sustainable community activities through the Internet. It is easier for community members to be involved in sustainable community activities by choosing preferable Web-based communication tools. As particular information instruments, these communication tools can be integrated into Web-based sup-

port systems for sustainable communities.

The organization of this paper is as follows: we first study sustainable community activities in the section 2. The participants of sustainable communities and the information technology instruments supporting sustainable communities are identified in the section 3. We outline an architecture of Web-based support systems for sustainable communities in the section 4. The functional modules of Web-based support systems for sustainable communities are elaborated in the section 5.

2 SUSTAINABLE COMMUNITY ACTIVITIES

Essential sustainable community activities include forecasting, public consultation, planning, decision making, implementation, and measuring progress. Each activity consists of some sub-activities or a series of procedural steps. These activities may overlap each other in the content. For example, both forecasting and decision making involve simulation activities. Sustainable community activities can occur individually, but they usually interact with each other to form more complex activities. The interaction between sustainable community activities is shown in the Figure 1 which is adapted from [10].

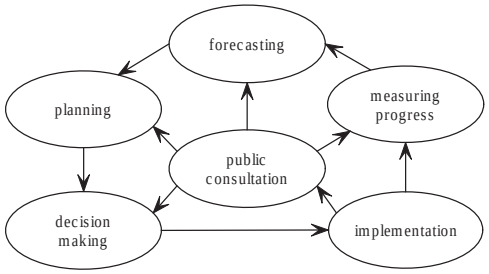

Figure 1: The interaction between essential sustainable community activities.

2.1 Forecasting

Forecasting activities are to identify the socioeconomic values that a community seeks to attain [6]. Sustainable development strategies often derive from forecasting activities. In a forecasting process, mathematical and physical models may be used to simulate the future environmental and socioeconomic situations. At the end of a forecasting activity, a clear view about the future community development is formed as the overall goal which may be impacted by the public consensus.

2.2 Public Consultation

Public consultation activities are the prevalent form of public participation in sustainable community activities. They usually involve the following sub-activities: public education, provision of background information, recruitment of participants, establishment of communication channels, coordination of consultation activities, recommendation and negotiation [19]. The first four activities are the preparations for the public recommendation and negotiation. The recommendation and negotiation are the core of public consultation activities.

2.3 Planning

Planning activities identify community problems and creates solution variants. A planning activity involves the following procedural steps: project preparation, problem identification, solution identification, and plan assessment. In the project preparation phase, the social, economic and environmental information of a community is collected. The problem identification is to find out issues from the collected community information. The identification of solutions to above community issues relies on the cooperation of stakeholders and the public consultation. The community background information, community problems and the corresponding solutions constitute a strategic plan.

Project preparation

The detailed planning procedure is formulated. A training program for planning and decision-making is given. Planners gather as much community information as possible, and compile it into a background information document [17]. Planners also need to identify who can influence the planning and to what extent [10]. Several advisory panels are established. The members are elected from stakeholders. The background information document are distributed to the stakeholder representatives for comment [17].

Problem identification

The overall goal is decomposed into subgoals [6]. Each subgoal is about a specific sustainability theme. Subgoals are highlighted as issues which may hinder the development from meeting the overall goal.

Solution identification

The planners and stakeholder representatives cooperate to create plausible solution alternatives for every identified problem. A solution is an ordered set of actions. Each solution is associated with necessary indicators. These indicators indicate what has been done, and how affected objects are responding. All issues associated with a specific subgoal, and their solution variants are assembled into a modal plan [6]. All modal plans constitute a strategic plan.

Plan assessment

The strategic plan is reviewed by the stakeholder representatives, and then revised based on the suggestions from the review processes [17]. At the end of this phrase, the strategic plan is submitted to the decision makers.

2.4 Decision Making

The decision making lays a practical scheme as the policy with legal validity. A decision making activity involves the following procedural steps: barrier and conflict identification, strategy formulation, strategy assessment and strategy judgement. The barrier and conflict identification examines the feasibility of above strategic plan. The strategy formu-

lation and judgement are the key steps towards a sustainable policy. In a decision making process, simulation instruments may be used to forecast the impact of the policy on the community and neighboring regions.

Barrier and conflict identification
Decision makers identify barriers to the implementation of the strategic plan. These barriers involve legal, institutional, financial, political, cultural and technological obstacles. Decision-makers also need to examine potential conflicts hiding in the strategy plan. Both barriers and conflicts are called constraints of the strategic plan. Within a given set of constraints, decision-makers establish a priority of solving identified problems.

Strategy formulation
Decision makers find out compatible sets of solutions in which solutions can reinforce or compensate each other in meeting their respective objectives. In every compatible set, solutions are arranged in a order by which more desirable overall performance can be achieved. The integration of solution helps to reducing barriers to implementation, and it is likely to be more effective than selecting any one solution on its own [10]. An integrated package of solutions is called a strategy. A strategy is a approach to achieve the overall goal. Usually, the range of solutions and the of ways in which they are combined can lead to more than one strategy.

Strategy assessment
Since the evidence available on the effects of introducing a new strategy is often incomplete, a number of scenarios or mathematical models are developed by experts to simulate the potential impact of individual strategy variants [10]. Stakeholder representatives also assess the strategy variants against the full set of overall goal and subgoals.

Strategy judgement
A priority list of selected strategy alternatives feasible to meet the overall goal is generated. The authorities choose one as the policy with legal validity.

2.5 Implementation and Measuring Progress

Community members also become involved in the implementation of policies. The implementation is usually monitored within a specified time frame [6]. Based on a set of accepted performance indicators, regular assessment reports indicate whether identified problems are being overcome or whether new issues are emerging. Revisions of the policies are made regularly according to the effect, the experience and the public consensus.

A forecasting activity, a strategic planning activity, a decision making activity and public consultation activities make up a sustainable community policy-making activity. A sustainable policy starts from a forecasting activity. Based on the overall goal formed in forecasting activities, planning activities identify community problems and alternative solutions to produce a community strategic plan. Decision making activities make critical judgements on the strategic plan to formulate the policy with legal validity. All sustainable community activities may be impacted by consensus. The effect or outcome of sustainable development affects public opinion in turn.

3 THE SUPPORT ENVIRONMENT OF SUSTAINABLE COMMUNITIES

The support environment of sustainable communities consists of human participants and information technology instruments. Human participants are the main body of sustainable community activities. Information instruments are specific software programs, such as database search engines and data ming tools, etc. They provide information and communication services for human participants of sustainable communities.

3.1 Human Participants

Participants of sustainable communities can be classified into coordinator, planning body, advisory body, decision making body, implementing body, and monitoring body as shown in the Figure 2. The coordinator is responsible for supervising

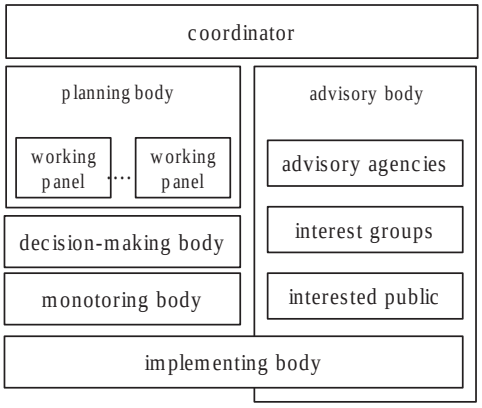

Figure 2: The human participants of sustainable communities.

sustainable community activities. The planning body usually consists of several mixed working panels. Each panel works on a specific aspect of community issues, but it should make its interest match to the overall goal. The decision making body may be governmental authorities or legislatures [12, 16]. The implementing body takes charge of implementing community development strategies.

The advisory body involves stakeholder representatives of a wide range of interests. The advisory body can be further divided into advisory agencies, interest groups and interested public. Advisory agencies include management branches in all governmental levels. Interest groups include public sector, private sector, aboriginal people and local residents. Their interests are likely to be affected by sustainable community activities. The implementing body is also an interest group. The interested public refers to the general public who

shows a high degree of interest and willingness to participate in sustainable community activities. The monitoring body works as a permanent management structure to oversee the result or outcome of sustainable community activities.

3.2 Information Instruments

The information technology instruments supporting sustainable communities can be roughly classified into computer-mediated communication tools, data management tools, as well as knowledge acquisition and presentation tools.

Computer-mediated communication tools
Computer-mediated communication tools run over the Internet. They provide synchronous and asynchronous communication services for community members.

Data management tools
Part of sustainable community information comes from increasing electronic data sources over the Internet. The electronic data is managed by either file management systems or database management systems. These management tools provide basic data storage service and data retrieve service. However, data management tools can not interpret data or discover knowledge behind data.

Knowledge acquisition and presentation tools
Information-theoretic tools and geographical information systems (GIS) can help users discover potentially useful information, identify problems, create solutions and make decisions. Information-theoretic tools include data mining tools, reasoning tools and expert systems, etc.

Information instruments used to work as either command line applications or thick client/server applications. Unfortunately unfriendly interfaces and complex software/hardware deployment of these applications may prevent ordinary community members from participating in sustainable community activities. Web-based support systems can fill the gap between human participants and information instruments.

4 THE ARCHITECTURE OF THE WEB-BASED SUPPORT SYSTEMS FOR SUSTAINABLE COMMUNITIES

A Web-based support system for sustainable community can be depicted according to its software architecture and application architecture, respectively.

4.1 Software Architecture

The software architecture of a Web-based support system for sustainable communities is a multi-tier, component-based structure. The structure can decrease system complexity and enhance extensibility. There are technical specifications on the software architecture, such as Sun J2EE [20] and Microsoft Dot-NET [13]. The multi-tier, component-based structure is shown in the Figure 3 which is adopted from [20].

The software architecture is divided into four tiers: Web client tier, Web service tier, application service tier and information service tier. A Web client is a standard Web browser. The Web browser renders the Web pages published by the front-end Web server in the Web service tier. Users access back-end application services through the Web pages.

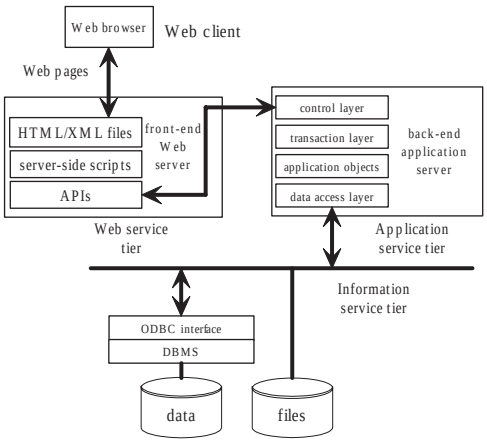

Figure 3: The software architecture of the Web-based support system for sustainable communities.

The application service tier can be further divided into control layer, transaction layer, application object layer and data access layer [20]. The control layer takes charge of the access control of application services. The transaction layer manages user inputs and sends them to the application object layer for processing. The application object layer contains a set of independent and reusable application components. Each component provides a specific application service. The data access layer is responsible for handling the data stored in the information service tier. The information service tier consists of database servers and file servers. It manages the raw data needed by the Web-based support system.

4.2 Application Architecture

The application architecture of Web-based support systems for sustainable communities defines functional modules. Information instruments are integrated into relevant functional modules to support specific sustainable community activities. Each information instrument works as an application service bundled with Web service. Therefore users can access it through standard Web browsers. The combination of functional modules can be used to support complex sustainable community activities, such as planning and decision making activities. In the section 5, we will elaborate these functional modules.

All modules are also organized into several subsystems with respect to their duties. Therefore the application architecture can be depicted according to these subsystems shown in the Figure 4. An Internet portal is the interface or entrance to a Web-based support system. The management subsystem provides management services for sustainable community activities. The communication subsystem mediates the

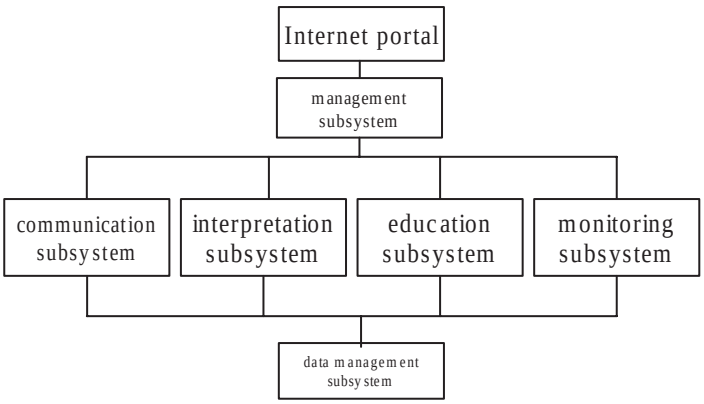

Figure 4: The application architecture of Web-based support systems for sustainable communities.

communication and collaboration between participants. The interpretation subsystem is dedicated to explaining and presenting sustainable community information for participants. The education subsystem is used to enhance the public participation consciousness and to transmit sustainable community information. The data management subsystem manages sustainable community information. The monitoring subsystem takes charge of measuring sustainable community progress.

The application architecture is mapped into the software architecture. The Internet portal is in the Web service tier; the data management subsystem is in the information service tier; the other subsystems are in the application service tier.

4.3 Web-based Resource Sharing

From the aspect of resource utilization, a Web-based support system possesses local human resource, local application resources and remote resources. The local human resource consists of participants in a specific sustainable community activity. The local application resources include sustainable community information and application services. They are usually located in a local-area network (LAN) and connected to the Internet through the front-end Web server. A Web-based support system can fully utilize remote resources over the Internet to compensate local resource shortage. The Web-based distributed resource utilization is shown in the Figure 5.

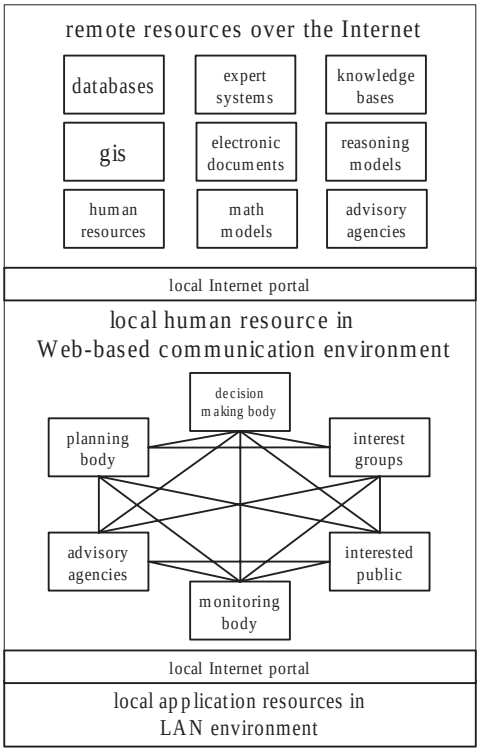

Figure 5: Web-based distributed resource utilization of sustainable communities.

Correspondingly a Web-based support system for sustainable communities can be divided into human resource layer, local application resource layer and remote resource layer. The resource sharing can be implemented by the access to remote application service providers as well as the communication between participants and remote experts through the Web. If necessary, sustainable community information is translated into meaningful and easy-understood forms by either intellectualized application services or professionals who handle the interpretation of questions and computer output.

4.4 The Impact of Web-based Support Systems on Sustainable Communities

Web-based support systems for sustainable communities take full advantages of the Web and Web-based distributed computing pattern. Their characteristics can be summarized as: ubiquitous and user-friendly access, integrated and extensible application services, worldwide resource sharing, and less cost of deployment.

- *Ubiquitous and user-friendly access*. The biggest benefit of Web-based support systems might be their Web interfaces [18]. Web interfaces are actually interconnected Web pages which are accessible for any device with a Web browser almost anywhere in the world. Web interfaces can be presented in multimedia style; hence they make users easily understand the content of a support system and use it without training.

- *Integrated and extensible application services*. In a Web-based support system, an information instrument works as an independent application service. These application services have distinct characteristics in function and style. They can reinforce each other to accomplish greater benefits. For instance, two planners can cooperate to prepare a plan draft through electronic white-board, meanwhile they can exchange their ideas through audio service. All application services can be flexibly uploaded to or offloaded from application servers to adapt to different sustainable community activities.

- *Worldwide resource sharing*. Through Web links embedded in Web interfaces, a Web-based support system can be seamlessly integrated with other Web-based support systems to provide more support services for local sustainable community activities.

- *Less cost of deployment*. Since Web-based support systems distribute information and deliver application services through the Web, and Web browsers are freely available for every major computer platform, few client software needs to be distributed [4].

Web-based support systems for sustainable communities can convert sustainable community activities into online community activities to some extent. Since online community activities can occur at less cost, Web-based support systems may therefore stimulate more community members to participate in sustainable community activities. Community members can freely choose preferable application services provided by Web-based support systems to accomplish their participation in a personal style. We may say that a Web-based support system for sustainable communities lays the foundation of online democracy. On the other hand, reusable application services and Web-based resource sharing maximize the availability and utilization of community resources, so the development of a Web-based support system for sustainable communities is also a sustainable community activity.

5 FUNCTIONAL MODULES

The functional modules making up a Web-based support system for sustainable communities are defined in this section.

5.1 Internet Portal

An Internet portal hosts a hierarchy of static and dynamic Web pages through which users can access application services. It is embedded with inner and external search engines. The inner search engine takes charge of retrieving local resources. The external one takes charge of retrieving remote resources. The external searching service may be provided by Internet service providers. For instance, with the Google Web APIs service, software developers can query more than four billion Web pages directly from their own computer program.

5.2 Management Subsystem

The subsystem includes project management module, stakeholder management module and access control module.

Project management

The module is used to help coordinators to manage sustainable community activities. Its functions may include creating project plans, scheduling tasks, tracking progress, managing cost as well as assigning and levelling hardware resources. By regularly pushing community activity progress reports to the Web, the module allow stakeholders to trace how their critiques are used.

Stakeholder management

The module is used to facilitate the recruitment of participants in a sustainable community activity. It maintains a database of stakeholder information. Initiators or organizers of the community activity evaluate stakeholder information to identify who can influence the community activity, and to what extent. The stakeholder database can help participants to rapidly find out proper advisory agencies and professionals against a specific problem. The stakeholder database may be accessed by remote Web-based support systems to accomplish human resources sharing. The module may also include a Web-based classroom for training participants.

Access control

The module provides integrated security administration services for the Web-based support system.

5.3 Communication Subsystem

The communication subsystem includes computer conferencing module and electronic polling module.

Computer conferencing

The module mediates users across the Internet to hold a teleconference, access a common database, or work on a common application process by using a series of Web-based communication tools. These communication tools may involve Email service, mailing list, chat room, audio/video-conference, electronic white board and asynchronous discussion board. Email is used to support personal communication. Mailing lists are used to support group discussion among stakeholders who share a common interest.

Planners, decision makers or experts can initiate a chat or audio/video meeting. However, the remote synchronous meeting preparation is not piece of cake. Initiators first use Email to schedule participants. And then they use Email to distribute meeting materials. They also need to check the status of each material submitted at the start of meeting. Finally,

some speaking protocols and facilitation may need to be established to insure the smooth implementation of the synchronous meeting.

As a particular teleconferencing application, electronic white boarding is used to support the cooperative research between experts on a specific topic. Web-based asynchronous discussion board is becoming a prevalent communication platform, which allows all stakeholders to participate in consensus forming processes without spacial and temporal limits. In Web-based discussion board, users can express their views through text, audio, video, flash, or their combination. The Web-based discussion board uses a matrix to manage topics [14], where one dimension is specific sustainable themes, and another dimension is interest groups. For each of the topic cells, there is a separate mailing list.

Electronic polling
Electronic polling is database-oriented Web application. It is used to collect public opinion on a specific topic or problem. Any authorized stakeholder can create a poll or topic. Anyone can view the subject and the statistical result for the poll, but initiators can determine who can be entitled to vote. The presentation of voting results only comes true after the expiration date in order not to affect public opinion.

5.4 Interpretation Subsystem

The interpretation subsystem includes spatial modelling module, data presentation module and intelligent reasoning module.

Spatial modelling
The module may be used to predict the effect of a policy or understand the dynamics behind community changes. It consists of model constructor, model repository and simulation driver. Its duty may include unit model development, model archiving and reuse, integration of multiple spatial representations, simulation, data access and visualization, and visualization of remote simulation [11].

Data presentation
The module is used to help users better understand sustainable community information. It involves two groups of tools. The first group consists of data warehousing tools, OLAP tools, data ming tools and data visualization tools. Its function may involve:

- cleaning and repairing noisy, erroneous, missing and irrelevant data,
- selecting data relevant to analysis task,
- transforming selected data into forms appropriate for mining,
- integrating relevant heterogenous data into a data file,
- extracting data patterns, associations, changes, anomalies and significant structures from the consolidated data,
- identifying the truly interesting knowledge based on interest measures,
- and presenting the mined knowledge to the user by graph or animation.

The second group of tools are GIS toolkit which is used to geoprocess geography-oriented data and render the results in the form of dynamic charts and maps. Geography-oriented data comes in three basic forms: spatial data, tabular data and image data. These data can be uniformly managed by advanced object-relational database systems.

Intelligent reasoning
The module generates explanations on how and why particular conclusions have been drawn from sustainable community information. It consists of knowledge bases, information theoretic-based reasoning tools, and communication tools. Knowledge bases store the domain expert knowledge captured by knowledge engineers. Reasoning tools may include rule-based reasoning, fuzzy logic, Bayesian networks, case-based reasoning, connexionist reasoning, evolutionary computing, qualitative reasoning, constraint satisfaction, and model-based reasoning [2], etc.

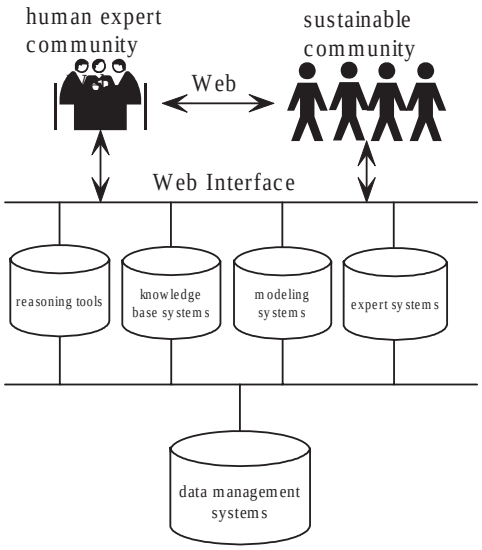

Figure 6: The combination of machine intelligence and human intelligence.

However, the inherent complexity and inflexibility of intelligent tools need a human expert community to work as a key element in the support system. The expert community consists of experts on various fields related to sustainable development. Depending on what users want, they convert question into a suitable form for a computer system and interpret the generated data in a meaningful way for users. These experts need to be enough flexible to distinguish different aims and requirements of various persons. The module provides communication tools or call the computer con-

ferencing module to facilitate the interaction between experts and users. The combination of computer output and human judgement can shorten the time in which decisions can be made and improve the consistency and the quality of the decisions. The combination of human intelligence and machine intelligence is shown in the Figure 6.

5.5 Public Education Subsystem

The subsystem is used to enhance public participation consciousness by deepening public understanding of sustainable development. A virtual library archives electronic educational materials on sustainable development. It also maintains Web links to other sustainable Web sites. The subsystem may include Web-based instruction (WBI) or distance learning application, which can deliver online personalized tutoring via the Web. The application dynamically generates learning materials based on students' past performance.

5.6 Data Management Subsystem

The subsystem is responsible for the storage, retrieve, exchange and dissemination of electronic data. The data needed by sustainable community activities can be classified into structured data and unstructured data. Structured data are well formed and fit into relational rows and columns. Structured data is managed by relational database systems. Unstructured data does not necessarily following any format or sequence. Unstructured data is managed by file management systems. Unstructured data can also be organized into self-describing terms called semistructured data [1].

5.7 Monitoring Subsystem

The subsystem is used to collect sustainable development indicators. It regularly or real time receives data from remote data sources. The collected data is verified and stored in database. The module may periodically analyze accumulated data and produce monitoring reports. If some pre-established critical level is reached, the module will sound a warning.

6 CONCLUSIONS

This paper studies Web-based support systems for sustainable communities. Essential sustainable community activities are studied. Computerized support systems can facilitate sustainable community activities, however, these support systems are hardly extensible with respect to the diversity of sustainable community activities. On the other hand, human participants are the main body in sustainable community activities. Information technology instruments provide information services for human participants, but the complexity of these tools may frustrate public participation. Web-based support systems are a feasible solution to above problems.

We outline an architecture of Web-based support systems for sustainable communities. The architecture is based on multitier, component-based structure. Information technology instruments are integrated into relevant functional modules. Each information instrument works as an independent application service. Users can access it through standard Web browsers anytime, anywhere. A Web-based support system can combine various application services to support diversified sustainable community activities. Community members can choose preferable application services to accomplish their participation in sustainable community activities.

ACKNOWLEDGEMENTS

Funding for this research is partially provided by Centre for Sustainable Communities of the University of Regina.

REFERENCES

[1] Abiteboul, S., Buneman, P., Suciu, D., "Data on the Web: From Relations to Semistructured Data and XML", Morgan Kaufmann Publishers, USA, 2000.

[2] Cortés, U., Sànchez-Marrè, M., Ceccaroni, L., R-Roda, I., Poch, M., "Artificial Intelligence and Environmental Decision Support Systems", *Applied Intelligence*, 13:77-91, 2000.

[3] Deshpande, Y., Murugesan, S., Ginige, A., Hansen, S., Schwabe, D., Gaedke, M., White, B., "Web Engineering", *Journal of Web Engineering*, 1(1):3-17, 2002.

[4] Ginige, A., "Web Engineering: Managing the Complexity of Web Systems development", *Workshop on web engineering*, Proceedings of the 14th international conference on Software engineering and knowledge engineering, 721-729, 2002.

[5] Haagsma, I.G., Johanns, R.D, "Decision Support Systems: An Integrated Approach", *Environmental Systems*, 2:20-34, 1994.

[6] Idaho Transportation Department (ITD), "Decision Process", *Idaho Transportation Plan (ITP)*, 1995.

[7] Yao, J.T., Yao, Y.Y., "Web-based Support Systems", *WI/IAT 2003 Workshop on Applications, Products and Services of Web-based Support Systems*, 1-7, 2003.

[8] Kaempf, C., "Decision Support Systems (DSSs) for Environmental management: Web-based Communication Modules to Enhance Public Participation", Society for Technical Communication (STC) Proceedings, 1-6, 2001.

[9] Lachman, B.E., "Linking Sustainable Community Activities to Pollution Prevention: A Sourcebook", Critical Technologies Institute, RAND, 5-11, 1997.

[10] May, A.D., "Developing Sustainable Urban Land Use and Transport Strategies: A Decision Makers' Guidebook", Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems (PROSPECTS), European Commission, 7-37, 2003.

[11] Maxwell, T., Costanza, R., "Developing Understanding of Ecological Economic Systems", RAND Workshop on Complexity and Public Policy, 14-15, 2000.

[12] Metro Regional Center, "Transportation planning decision-making process", http://www.metro-region.org/library_docs/trans/trans_process.pdf, 2001.

[13] Microsoft, "Application Architecture for .NET: Designing Applications and Services", Microsoft Corporation, 2002.

[14] Moor, A.D., "Information Tools for Susainable Development: Enabling Distributed Human Intelligence", *Journal of Failure & Lessons Learned in Information Technology Management*, 2(1):21-31, 1998.

[15] National Round Table on the Environment and the Economy (NRTEE), "Environmental Quality in Canandian Cities: The Federal Role", National Library of Canada Cataloguing in Publication, 2003.

[16] San Diego City Hall, "Land Development Procedures", *San Diego Municipal Code*, Chapter 11, http://clerkdoc.sannet.gov/Website/mc/mc.html, 2000.

[17] Saskatchewan Environment, "Forest Land Use Planning", http://www.se.gov.sk.ca/forests/landuse, 2000.

[18] Shim, J.P., Warkentin M., Courtney J.F., Power D.J., Sharda R., and Carlsson C., "Past, Present, and Future of Decision Support Technology", *Decision Support Systems*, 33:111-126, 2002.

[19] Sinclair, A.J., "Public Consultation for Sustainable Development Policy Initiatives: Manitoba Approaches", *Policy Studies Journal*, 30(4):423-443, 2002.

[20] Sun microsystems, $Java^{TM}$2 Platform Enterprise Edition Specification v1.4, 2003.

[21] Turban, E., Aronson, J.E., Bolloju, N., Decision Support Systems and Intelligent Systems, Prentice Hall, 2001.

[22] United Nations University International Institute for Software Technology(UNU-IIST), "Decision Support systems for Sustainable Development Experience and Potential: A Position paper", UNU-IIST Macau Workshop, 1996.

[23] World Commission on Environment and Development (WCED), "Our Common Future", Oxdord University Press, 1987.