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Supporting Sustainable Communities with Web-Based Information Systems

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

Department of Computer Science, University of Regina, Saskatchewan S4S 0A2, Canada

ABSTRACT. Computer and information technologies have been used to support human activities towards sustainable development. Sustainable community activities are multi-disciplinary and multi-sectoral collaboration for solving environmental, economical and social problems in sustainable ways. However, the current supporting tools are independent and optimized to perform specific functions. This situation limits adaptability with respect to diversity and situational adaptation of sustainable community activities. The Web provides a foundation for supporting human activities and it helps users focus on the work they are trying to accomplish. This paper studies sustainable community activities and their relationships. Based on possible support to various activities, we propose a web-based support system for sustainable communities. It is hoped that the new system will satisfy the needs of sustainable communities.

Keywords: Semantic web, sustainable communities, web-based support systems, web services

1. Introduction

The notion of sustainable development emerged in 1987 as the overriding goal for human activities (WCED, 1987). 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 (Kaempf, 2001). Sustainable community activities are about the long-term collaboration of people working at different disciplines, organizations, institutes, and regions. We have been striving to use information technologies for supporting complex environmental, economical and social problem solving (Kaempf, 2001).

However, informal and complex social interactions in sustainable community activities are challenging the adaptability and usability of traditional computerized support systems. For example, the individual computer tools are independent, run on isolated specific platforms, and are optimized to specific functions. Users have to devise practices to coordinate individual tools for addressing requirements of sustainable community activities. Such human coordination practices might both be inefficient and error-prone. On the other hand, available computerized support systems are organized around tools for communicating and for sharing information (Moran, 2005). When some tools get out of date, these systems may not be able to satisfy the ever-changing needs of sustainable communities. In addition, computerized support systems are often domain-specific and proprietary. They may not adapt to the multi-disciplinary, multi-agency and multi-sector nature of sustainable community activities.

The Web brings new opportunities for supporting sustainable community activities. It can also be viewed as a global repository of human knowledge and experience (Liu et al., 2004). In addition, we are moving from a human-centric Web to an application-centric Web with Web services (Cerami, 2002). The World Wide Web Consortium (W3C) (http:// www.w3c.org) is forming standards to promote interoperability and reusability of applications in heterogeneous environments. In industrial field, the frameworks for web-based applications are blossoming (Walls and Breidenbach, 2005). Web-based systems make applications easily extendible and highly adaptable (Yao and Yao, 2003). The web-based applications are considered as the essential ingredients of enterprise application, e-commerce, e-education, and e-science (Monson-Haefel, 2003). The study of the web-based support systems (WSS) aims to provide support to all kinds of human activities in a standard Web platform. WSS will provide distributed support with no restrictions on geography location or time (Yao and Yao, 2003). The goal of this research is to propose a type of web-based support systems that could provide support to the geographically distributed, long-term, and highly collaborative sustainable community activities.

The organization of this paper is as follows. The characteristics of sustainable community activities are reviewed in Section 2. Common support functions needed by sustainable communities are discussed in Section 3. We propose the architecture of the web-based support systems for the sustainable communities in Section 4. A demonstrative example is given in Section 5 followed by a conclusion section.

2. Sustainable Community Activities

In order to provide support to a sustainable community, the first task should be to understand sustainable community activities. There are some studies on sustainable community

* Corresponding author: jtyao@cs.uregina.ca

activities in the specific areas such as the work presented in (Lachman, 1997). However, there is lack of analysis and formalization for sustainable community activities from an information technology point of view. We will mainly focus on sustainable community activities that are supportable by computerized systems.

2.1. Sustainable Community Activities Classification

We identify and classify sustainable community activities into five basic types by investigating sustainable practices of some communities in North America and Europe (Idaho, 1995; May, 2003; San Diego, 2006; Sask, 2006). These five types of activities are: forecasting activities, planning activities, decision-making activities, implementing activities, measuring activities, and public consultation. Forecasting activities identify socioeconomic values that a community seeks to attain (Idaho, 1995). The planning activities identify the concrete community problems and create solution variants (Sask, 2006). The decision-making activities normally formulate policies with legal validity (San Diego, 2006). A public consultation is a prevalent form of participating in sustainable community activities. The community members are involved in the implementation of policies. The implementation of policies is usually monitored within a specified time frame (Idaho, 1995). Based on a set of accepted performance indicators, the regular assessment reports that indicate whether identified problems are being overcome. They may also provide indication if new issues are encountered.

The five types of activities are often related to each other by exchanging information as depicted in Figure 1 for a typical sustainability project. There are iterative cycles of forecastting activities, planning activities, decision-making activities, implementing activities, and measuring activities. These activities might be public consultation-based. In this case, public opinions have a great impact on community activities.

A typical process can be described as follows. Forecasting forms an overall development goal. Based on the overall goal, planning identifies concrete problems and produces a strategic plan. The decision-making makes judgments on the strategic plan to formulate a policy with legal validity. The implementation of the policy is evaluated based on a set of performance indicators. Revisions of policies are made regularly according to the evaluation. In addition, the above activities must take into full consideration of the public opinions. The general public may share relevant information with the participants of sustainable community activities.

2.2. The Structures of Activities

The sustainable community activities are preplanned and could usually be represented in a flow structure. For instance, Saskatchewan Environment proposed a planning process of land utilization (Sask, 2006). Each step of an activity is called a sub-activity of the activity if it can be represented in a flow structure.

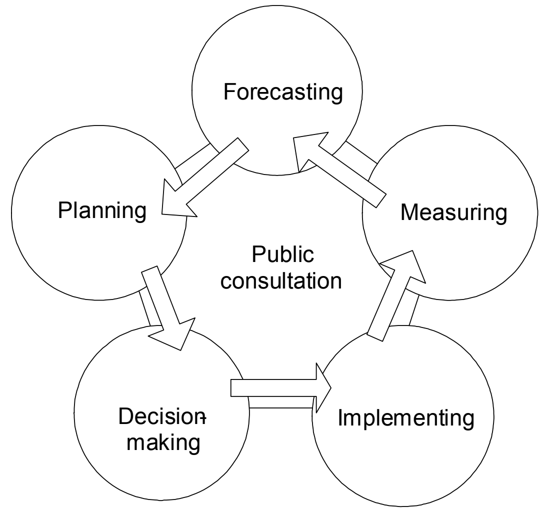

Figure 1. The life cycle of a sustainable project.

Each step of an activity may also be an action. An action is defined as the work that cannot be explicitly represented in a flow structure in this paper. A flow chart is a tool, popularly used in quality control and programming, that visualizes a process in a schematic way. It can be used to represent the temporal structure of a land planning activity that is depicted in Figure 3. The actions are considered to be atomic and indecomposable. For example, writing a document with a word processor can be considered a simple and well-defined action. However, some other actions may be complex and ill-defined, such as solution conceiving, creative thinking and face-to-face contact. They are non-routine and unstructured. It is observed that people tend to use flexible ways to deal with non-routine and informal tasks (Moran et al., 2005).

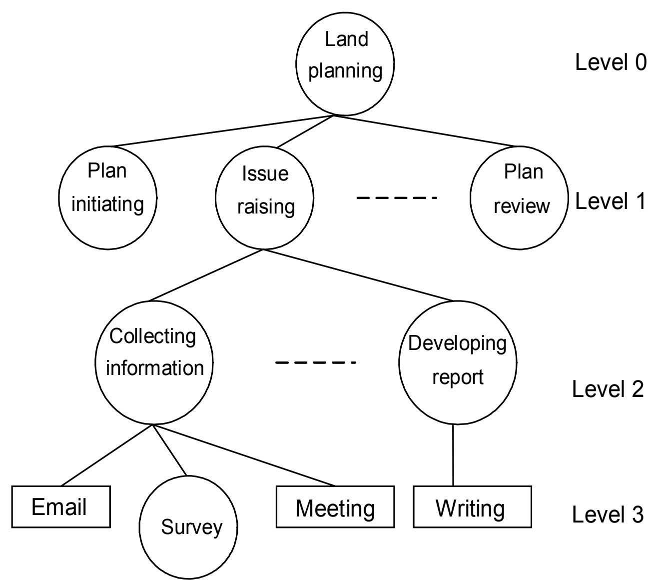

Figure 2. The hierarchical structure of a land planning activity.

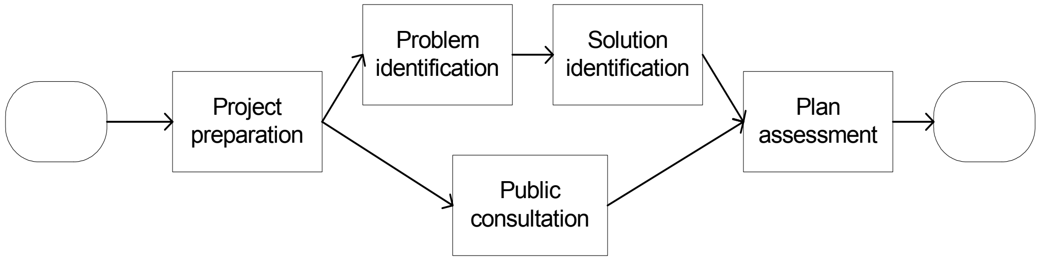

Figure 3. The temporal structure of a land planning activity at the 1st level.

Sustainable community activities can be depicted by a hierarchical structure. Figure 2 is an example of hierarchical representation of the land planning activity defined by (Sask, 2006). It implies that we can describe a sustainable community activity on different detail levels. The more detailed the activity is described, the more non-routine and unstructured aspects of the activity may emerge. Sustainable community activities can be depicted by a temporal structure based on a specific detail level. For example, the above land planning activity can be depicted in Figure 3 in the form of a flow chart. Project preparation and plan assessment are considered as the first and last step of a land planning activity respectively in temporal order. It is obvious that a problem should be first identified in order to seek for possible solutions. However, both problem identification and solution identification should be based on consultation with the public.

2.3. The Relation Graph for Sustainable Activities

Besides the hierarchical representations of the sustainable community activities, a sustainable community activity can be also characterized by the relationships with other activities as well as entities. Figure 4 depicts the relation factors associated with a sustainable community activity. As discussed above, together with principles of granular computing (Yao, 2005), an activity may be viewed as a sub-activity of another activity or as an example or prototype of another activity. In addition, it may provide some necessary information to another sustainable community activity. With this categorization, relationships between relevant sustainable community activities can be identified as subordinate relationships, prototype relationships, or dependent relationships respectively.

A sustainable community activity is related to many entities, such as events, patterns, tools, documents, and participants. The events are the dynamic factors that may impact the processes and results of activities. The relationship between an event and an activity is called a bound relation. Patterns predefine the procedures or workflows of sustainable community activities. The relation between a pattern and an activity is called an instance relation. The tools provide resources to activities. The participants play different roles in sustainable community activities. The document of an activity consists of activity description and audit trials. The activity description is the hierarchical representation of the sustainable community activity. The activity audit trials describe the agenda and responses.

As it was claimed by Morgan (2005), technology should support people focusing on to the work they are trying to accomplish and the foundation of activity support is an explicit representation of the activity. We mainly discuss sustainable community activities and relationships among them.

3. The Support Types of Sustainable Communities

Due to the fact that there are various levels of sustainable community activities, support may also arise on different levels. On the top-most level, there is a need for the workflow management support. On the bottom-most level, there is a need for individual action support. We study different support types for sub-activities in this section. In particular, we will investigate these activities from a management point of view, i.e., the possibility of being managed by information systems. Each activity or a group of activities will be supported by an information subsystem. These systems are project management, stakeholder management, cooperation management, polling management, modeling, data presentation, intelligent reasoning, public education, data management, and monitoring.

Project management is to assist people in managing the processes of sustainable community activities. It may include creating project plans, scheduling tasks, tracking progress, managing cost, assigning resources, etc.

Stakeholder management is to facilitate the recruitment of participants of sustainable community activities. It maintains a database of stakeholder information. The stakeholder information is used to identify who can influence the community activity and to what extent. The stakeholder database can also help participants to find out proper advisory agencies and professionals for a specific problem.

Cooperation management is to mediate users to hold a meeting, access a common database, or work on a common application process. For example, mailing lists support group discussion among stakeholders who share a common interest. Electronic white boarding supports the cooperative research between experts on a specific topic. Asynchronous discussion boards allow stakeholders to participate in consensus forming processes without spatial and temporal limits. In a web-based discussion board, users can express their views through text, audio, video, flash, blogs, or any combination thereof.

Polling management provides a platform or environment for collecting public opinion on a specific topic or problem. Any authorized stakeholder could create a poll. Anyone can view the subject and the statistical result for the poll, but only the initiator 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.

Modeling toolkit is used to predict the effectiveness 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 (Maxwell and Costanza, 2000).

Data presentation toolkits help people understand the sustainable community information. The data about sustainable development come from different institutions and disciplines. They should be filtered, consolidated, and associated before people can extract patterns and significant structures from the data. Information fusion techniques (Dasarathy, 1991) play an important role.

Data presentation toolkits may involve two groups of tools. The first group consists of data warehousing tools, OLAP tools, data mining tools, and data visualization tools. The second group of tools is the GIS tools that are used to geo-process geography-oriented data and render the results in the form of dynamic charts and maps.

Intelligent reasoning toolkits generate explanations on the particular conclusions drawn from sustainable community information. Reasoning tools may include rule-based reasoning, fuzzy logic, neural networks, Bayesian networks, case-based reasoning, connexionist reasoning, evolutionary computing, qualitative reasoning, constraint satisfaction, model-based reasoning (Cortes et al., 2000). However, due to the inherent complexity and inflexibility of the intelligent tools, human experts are still needed. Depending on what users want, experts convert questions into a suitable form for a computer system and interpret the generated data in a meaningful way for users. The combination of computer output and human judgments can shorten the time in which the decisions can be made and improve the consistency and the quality of the decisions.

Public education can enhance public participation consciousness by deepening public understanding of sustainable development. For example, the web-based instruction (WBI) or distance-learning applications deliver online, personalized tutoring via the Web (Fan, 2003).

Data management supports storage, retrieval, exchange and dissemination of data and information. The data can be classified into structured data and unstructured data. Structured data are well formed and fit into relational rows and columns. It can be managed by relational database systems. Unstructured data does not necessarily following any format or sequence. The unstructured data can also be organized into self-describing terms called semi-structured data (Abiteboul et al., 2000). The geography-oriented data comes in three basic

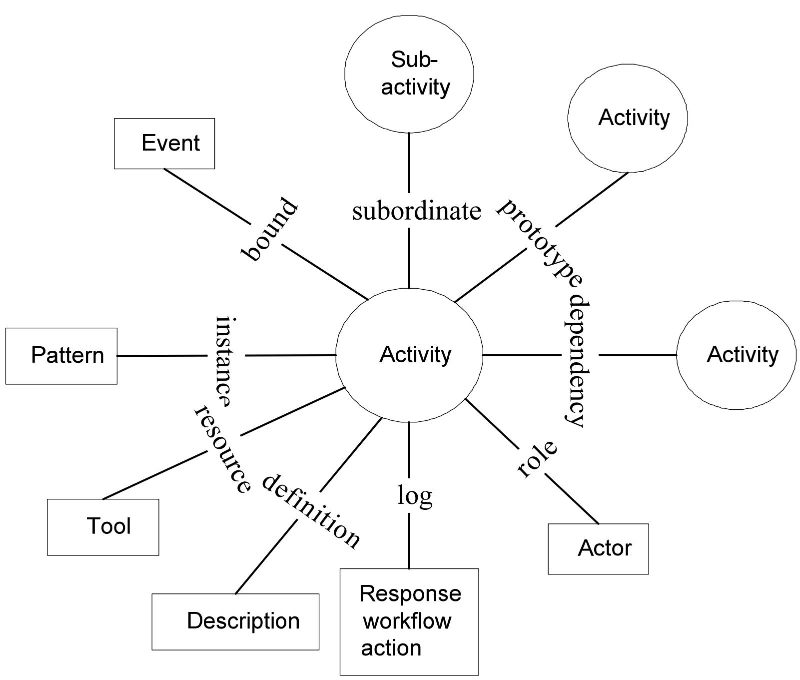

Figure 4. The relation graph of sustainable community activities.

forms: spatial data, tabular data, and image data.

Monitoring management is responsible for collecting and analyzing sustainable development indicators. The collected data is verified and stored in databases. The data also needs to be analyzed periodically. If some pre-established critical level is reached, a warning message as well as a report is submitted to the sustainable community.

It is believed that sustainable community activities can be supported by various support or sub-support systems. These support systems may involve diversified and distributed computer systems and information tools. The interconnected nature of sustainable community activities makes it crucial for tools to interoperate with each other in support systems. To take advantage of the emerging Internet and Web technology is a natural move for such systems.

4. A Solution by Web-Based Support Systems

The Web provides a common infrastructure on which the individual applications can work with each other (Linthicum, 2003). It also plays an important role for computerized support systems. As proposed in 2003, the notion of web-based support systems concerns multidisciplinary investigations that combine computer technologies with domain specific studies (Yao and Yao, 2003). The web-based support systems can be understood from the following specific aspects. The Web is viewed as a virtual machine running various operating systems. Web browsers play the role of the interface or window in which the Web application resides. This view makes it quite apparent that the Web is a global deployment environment (Cerami, 2002). The WSS is also about ubiquitous access to distributed applications and information. Since the Web provides a greater and greater capability of connecting people all over the world, WSS are about leveraging human cooperation by providing social interaction mechanisms and imposing only as much restraint as is needed.

Figure 5 outlines a model of WSS. The aim of a web-based support system is not to provide a set of individual tools, but to support its users to accomplish their goal for related activities. The bottom layer is called the online resource layer. It is comprised of legacy resources, web-based application resources, document resources, as well as other resources. The web-based applications refer to those information systems that can be accessed with Web browsers over the Internet or an Intranet. We have presented possible web-based applications needed by sustainable communities in the previous section. The legacy resources refer to existing non-Web applications, such as the expert systems, the enterprise resource planning (ERP) systems, and the aging database systems. The legacy applications and web-based applications are used to support complex activities such as the environment evaluation and the urban traffic planning. Document resources include HTML and XML files, Word files, PowerPoint slide shows, PDF files, photos, movies, Web links, etc. The other resources mainly include third-party toolkits that are used in supporting individual actions, such as the customized browser plug-ins and the open-source software.

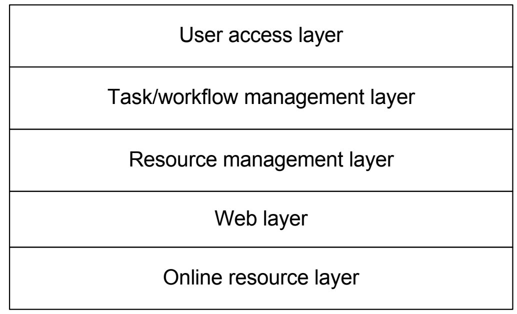

Figure 5. A multi-layer model of web-based support systems.

The access of the online resource layer is based on the following Web protocols: HTTP (Hyper Text Transfer Protocol), SOAP[1] (Simple Object Access Protocol), WSDL[2] (Web Services Description Language), UDDI[3] (Universal Description, Discovery, and Integration), and WS-I Basic Profile[4]. HTTP is designed for transporting HTML documents. It is the core foundation of the Web (Shklar and Rosen, 2003). XML is an Extensible Markup Language (HTML is the basic markup language) that is used to organize documents and data by tags. SOAP is a packaging and routing standard for exchanging XML-like information over the Internet. The WSDL is used to describe the types of XML documents and SOAP messages. UDDI is used to register Web services in a uniform manner within a common directory so that clients can locate their Web services and learn how to access them. WS-I Basic Profile defines a set of conformance rules that clear up ambiguities in the specifications of XML, WSDL, SOAP, and UDDI, and defines, in concrete terms, how to use these technologies to register, describe, and communicate with Web services. All these protocols constitute the foundation of the Web layer. Figure 6 presents a typical scenario of such activities. A user, the client, submits Web service requirements to the UDDI registry server. The UDDI registry searches relevant Web service and returns WSDL location that is normally the URL (Uniform Resource Locator) of the Web service. The user downloads the WSDL description of the Web service from the Web server identified by the URL. The WSDL tells the user how to invoke the Web service. The user then accesses the Web service with SAOP messages. The Web layer is built with the distributed computing architectures, such as J2EE[5] and .Net[6].

The resource management layer is characterized with two functions: resource location and resource integration. When a city looks for help about the decision-making on preventing urban sprawl, for example, the resource-locating agent may launch a search for the systems providing relevant services.

1 http://www.w3.org/TR/soap/
2 http://www.w3.org/TR/wsdl
3 http://www.uddi.org/
4 http://www.ws-i.org/
5 http://java.sun.com/j2ee/1.4/docs/tutorial/doc/index.html
6 http://www.microsoft.com/net/default.mspx

One or several candidates will be returned to the user. Once a user has decided to use the service offered by a specific system, the resource management layer will contact the service owner for a particular service contract. If it succeeds, the resource-integrating agent is then allowed to invoke the service under the service contract. Before the results are presented to the user, value-added processes with respect to the nature of the service and the particular application context may be needed. A more complex scenario is the service-oriented (Berman et al., 2003). Services can be traded and even resold in an Internet-based marketplace as depicted in Figure 7.

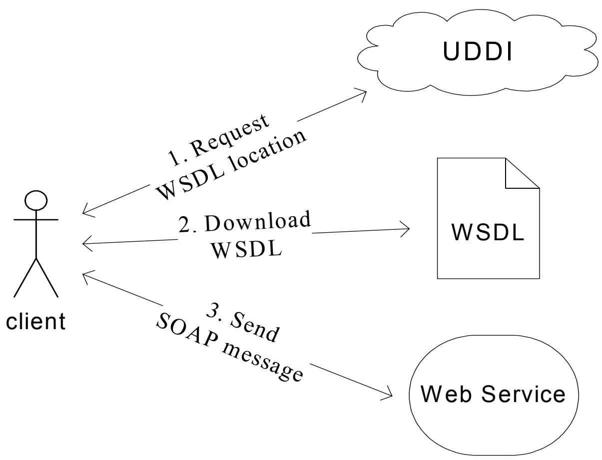

Figure 6. Web service interaction diagram.

The task/workflow management layer provides the main functionalities of a WSS for the sustainable communities. It mainly relies on social interaction mechanisms to control various activities. It is based on the hierarchical structure, the temporal structure and the relation graph of activities to integrate formal processes with informal collaborations needed by activities. A sustainable community activity can be decomposed into the lower-level activities or the atomic actions. The task/workflow management should be able to interpret the resource requirements of actions into query statements, and deliver the query statements to the resource management layer. For instance, the user developing a mathematical model for urban public traffic may look for materials about urban sprawl. In order to provide proper resources, the task/workflow management needs to understand the specific action context based on the hierarchical structure of activities. The above modeling action occurs in a traffic planning activity instead of a land planning activity.

On the other hand, each sustainable community activity or sub-activity is a workflow that is characterized with multi-disciplinary and multi-sector collaboration. In order to satisfy the compliance requirements, the task/workflow management should be able to support the process control of the activities based on their temporal structure. In order to support the multi-disciplinary and multi-sector collaborations, the task/workflow management also needs to support the flexible and open interactions between the people who are trying to accomplish the activity. Furthermore, the task/workflow management layer should be able to adapt to the dynamic changes of activities caused by the collaborative events. The relation graph provides a mechanism for integrating preplanned workflows and dynamic components (Figure 4).

The top layer, user access layer, comprises a set of Web components and Web clients, or application clients. A Web client consists of dynamic Web pages containing the markup languages that are generated by the Web components and a Web browser which renders such pages. An application client runs on a client machine and provides a channel for users to handle tasks that require a richer user interface. These types of interface can not normally be provided by markup languages.

In this section, we studied a model of web-based support systems for sustainable community activities. The main philosophy is that support systems should focus on helping people coordinating their work, collecting relevant resources, flexibly communicating with each other, and producing audit trails. The Web and Web technologies lay a foundation for realizing such an information system.

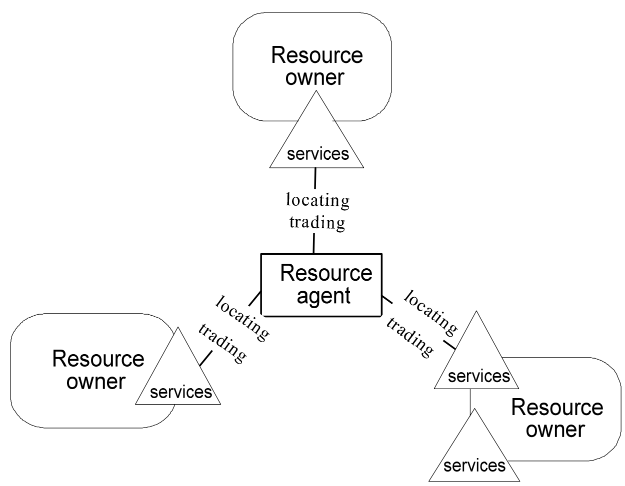

Figure 7. Locating and trading distributed resources.

5. XML-based Management of Delphi Survey

Forecasting, planning and decision making are three important sustainable community activities. Forecasting is a key to understand and plan for the future. Planning concerns what the world should look like and forecasting is about what it will look like (Armstrong, 2001). Forecasting may be either subjective or objective. The objective forecasting involves in developing a model by examining past relationships between an item and the factors thought to affect it. A subjective or judgment is mainly based on opinion of an individual. Rule of thumb and collective consensus are some of the outputs of a subjective forecasting. The Delphi methods are a popular used model for subjective forecasting. In this section, we will dis-

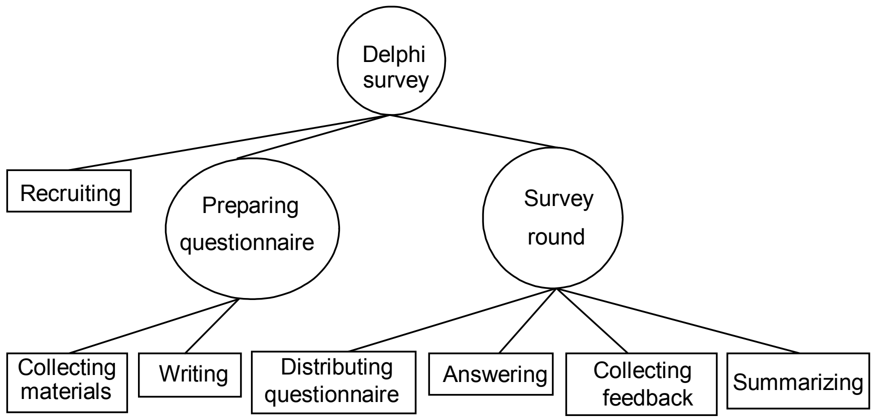

Figure 8. The hierarchical structure of Delphi activities.

cuss how Web technologies are applied to supporting dynamic Delphi-based group decision-making processes.

The Delphi survey instrument is a way of collecting expert ideas and judgments through multi-round surveys (Linstone, 1975). In each survey round, individual judgments are collected and summarized. It is hoped that those surveyed experts will evaluate and adjust their opinions upon the collective result available. It is also expected that a consensus can be reached at the end of a Delphi survey. A Delphi survey is mainly used in the situations where accurate information is unavailable or expensive to obtain, and the human judgmental input is crucial.

With the introduction of the Web, people are connected all over the world via the Internet. The ubiquity, real-time, low operating cost and convenience of Web features provide potential to release collective results dynamically between survey rounds. Yao and Liu (2006) thus proposed a variation of the Delphi survey model, namely the web-based dynamic Delphi survey model. Instead of providing feedback at the end of each survey round or iteration, collective opinions of panel experts will be released partially or fully dynamically between rounds.

A Delphi process can be viewed as a Delphi activity of a sustainable community. The hierarchical structure of a general Delphi activity is represented in Figure 8. A Delphi survey consists of three sub-activities or actions: recruiting, preparing questionnaires and survey round. Domain experts are recruited for conducting surveys. In the mean time, survey questionnaires are designed to collect the expert opinions for a sustainable decision. The survey round is an iterative activity. It normally takes at least two rounds to reach an acceptable consensus of an expert judgment. Questionnaires are first distributed to experts; answers from experts are collected after certain time. One of the challenging activities is to summarize experts' opinions on specific sustainable community issues and prepare for the next round of surveys. In the second round, a collective opinion is released to experts with the revised questionnaire.

A major difference between traditional Delphi activities and dynamic Delphi is that the later allows surveyed experts to access partial collective opinions between survey rounds. For example, an expert was requested for an online survey for a sustainable transportation system of a university campus. She decided to reply on the tenth day she received the request. She would get additional information online (a collective view of experts who have submitted their responses) at the moment that she conducts the survey. The collective view is named as local feedback in Figure 9 that shows the difference between a traditional Delphi activity (Figure 9a) and a dynamic Delphi activity (Figure 9b) with temporal structure. Please note that the local feedback can be released continuously or at a specific time interval.

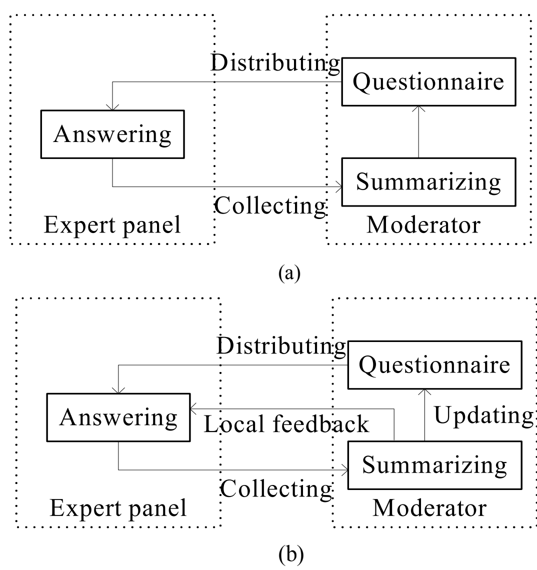

Figure 9. Traditional Delphi process (a) vs. dynamic Delphi processes (b).

We may view the relation graph of Delphi activities as metadata that glues together Delphi players, resources, the Delphi process, and survey results around the general semantics of Delphi activities. Table 1 shows types of relationships amongst activities related to a Delphi survey that flows the notation in Figure 4. It is observed that traditional and dynamic Delphi activities can be represented with a uniformed relation graph as the only difference is the time of releasing feedback.

Based on the relation graph of Delphi activities, we can construct a semantic knowledge repository for Delphi activities. By using semantic Web technologies, the data provided by the Delphi activities can be integrated into a sustainable information network. It is an advantage for the sustainable communities to improve the multi-disciplinary, multi-agency and multi-sector information sharing. Widespread information interoperability is one of the benefits that semantic technologies provide to the sustainable communities. With the richer, more accessible and autonomic information, some far greater capabilities such as intelligent search, intelligent reasoning, and truly adaptive computing will be more likely coming to reality.

Table 1. Various Types of Relationship for Delphi Process

Relation types	Description
Subordinate	Survey rounds
Prototype	Successful Delphi survey examples
Dependency	Other activities that need information from Delphi survey
Instance	Standard Delphi process
Bound	The feedback of Delphi participants
Role	Delphi participants, Delphi moderator
Resources	Email, paper, pencil, materials, and so on
Definition	The purpose, the predefined Delphi process
Log	Practical Delphi process, Delphi results

Delphi activities could be treated as information messages flowing among the Delphi participants and the Delphi moderator. SOAP provides a standard messaging protocol for Delphi activities. Each Delphi participant is called a SOAP processing node. The following three demonstrative examples show how these activities are expressed in XML documents and SOAP messages.

```
<?xml version='1.0' ?>
<env:Envelope
xmlns:env="http://www.w3.org/2003/05/soap-envelope">

<env:Header>
<m:distributing xmlns:m=http://host/distributing"
                env:role="http://www.w3.org/2003/05/soap-
envelope/role/next"
              env:mustUnderstand="true">
<m:reference>uuid:093a2da1-q345-739r-ba5d-
pqff98fe8j7d</m:reference>
<m:dateAndTime>2006-05-20T13:20:00.000-
05:00</m:dateAndTime>
</m:distributing >
<n:participant xmlns:n=http://host/participants"
                env:role="http://www.w3.org/2003/05/soap-
envelope/role/next"
              env:mustUnderstand="true">
<n:name>John Doe</n:name>
</n:participant>
</env:Header>

<env:Body>
<p:questionnaire
xmlns:p="http://host/distributing /questionnaire">
    <p:questions>
        <p:question1>Question 1</p:question1>
        <p:question2>Question 2</p:question2>
        <p:question3>Question 3</p:question3>
    </p:questions>
    <p:results
        <p:result1>Result 1</p:result1>
        <p:result2>Result 2</p:result2>
        <p:result3>Result 3</p:result3>
    </p:results>
</p: questionnaire >

</env:Body>
</env:Envelope>
```

Example 1. A questionnaire message.

The SOAP message in Example 1 contains two SOAP-specific sub-elements within the overall env: Envelope, i.e. an env: Header and an env: Body. A user “John Doe” participates a Delphi survey with three questions (Questions 1, 2 and 3). The current collective views of these questions are results 1, 2 and 3. These questions and results may be hyper-links from a participant point of view. The header contains two header blocks; each of them is defined in its own XML namespace and represents some aspect pertaining to the overall processing of the body of the SOAP message. For a questionnaire distributing application, such information pertaining to the overall request is a distributing header block that provides a reference and time stamp for this instance of distributing a questionnaire. In this example, we use URL host to represent a demonstrative Web site that the services reside. The two hosts may be different in a distributed environment.

The header blocks distributing and participant may be processed by next SOAP processing point encountered in the message. The fact that it is targeted at the next SOAP node encountered *en route* is indicated by the presence of the attribute env: role. The presence of an env: mustUnderstand attribute with the value "true" indicates that the node(s) processing the header must absolutely process these header blocks in a manner in consistent with their specifications, or else not process the message at all and throw a fault. The env: Body element and its associated child elements, questionnaires and results, are intended for exchange of information between the initial SOAP sender and the ultimate SOAP receiver in the message path:

```
<?xml version='1.0' ?>
<env:Envelope
xmlns:env="http://www.w3.org/2003/05/soap-envelope">

<env:Header>
<m:responsing xmlns:m=http://host/responsing"
                    env:role="http://www.w3.org/2003/05/soap-
envelope/role/next"
                  env:mustUnderstand="true">
<m:reference>uuid:093a2da1-q345-739r-ba5d-
pqff98fe8j7d</m:reference>
<m:dateAndTime>2006-05-20T13:20:00.000-
05:00</m:dateAndTime>
</m:responsing >
<n:participant xmlns:n=http://host/participants"
                    env:role="http://www.w3.org/2003/05/soap-
envelope/role/next"
                  env:mustUnderstand="true">
<n:name>John Doe</n:name>
</n:participant>
</env:Header>

<env:Body>
<p:answer
xmlns:p="http://host/responsing/answer">
    <p:answers>
        <p:answer1>Answer 1</p:answer1>
        <p:answer2>Answer 2</p:answer2>
        <p:answer3>Answer 3</p:answer3>
    </p:answers>
</p: answer>
</env:Body>
</env:Envelope>
```

Example 2. A feedback message.

Example 2 shows a feedback expressed in a SOAP message. If a survey participant wants to reply these questions, a new window will be popup for expert to key in his feedback. The feedback is listed as Answers 1, 2, and 3 that will be passed to moderator. The message exchanges in Examples 1 and 2 are cases where the XML-based content conforming to some application-defined schema is exchanged via the SOAP messages. The header blocks have similar format and contents as shown in the Example 1. The env: Body element is for the participant to provide answer to the questions. The feedback from a participant, i.e., Answers 1, 2 and 3, will be added to Result 1, 2 and 3 at moderator site. The later participants will get messages as shown in Example 1. However, the Result 1, 2 and 3 will be different as the previous expert's opinion is already taken into consideration in a dynamic Delphi survey.

```
<?xml version='1.0' ?>
<env:Envelope
xmlns:env="http://www.w3.org/2003/05/soap-envelope" >

<env:Header>
<t:transaction
xmlns:t="http://host/transaction"
env:encodingStyle="http://host/security/encoding"
   env:mustUnderstand="true" >5</t:transaction>
</env:Header>

<env:Body>
<m:summary
env:encodingStyle=http://www.w3.org/2003/05/soap-
encoding xmlns:m="http://host/collection">
      <m:collections
            …     …
      </m:collections >
</m:summary>
</env:Body>
</env:Envelope>
```

Example 3. Summary procedure.

The summary activity is carried out with RPC as show in Example 3. RPC stands for Remote Procedure Calls. It is a powerful technique for constructing distributed, client-server based applications. It allows one program making a service request from a program located in another computer without having to understand the network details. The RPC itself is carried as a child of the env: Body element, and is modelled as a struct which takes the name of the procedure or method, in this case summary. The design of the RPC in the example takes one input parameter, the collections corresponding to the collected survey data.

This section presents a simple demonstrative example for dynamic Delphi survey which is a part of foreacting activity.

Other sustainable community activities could be implemented in a similar manner.

6. Conclusions

We study the web-based support systems for sustainable communities. Sustainable community activities, their structure and relationships are first examined. Individual activities can be described in hierarchical structure or with a temporal structure. The relationships amongst activities, sub-activities and other factors are identified and represented in the relation graph. We also explore the potential supporting types for sustainable communities.

A model of web-based support systems for sustainable communities is proposed. The model is based on a multi-tier, component-based structure. Information technology instruments are integrated into relevant functional modules corresponding to their sustainable community activities. Each information sub-system works as an independent application service. Users can access it through standard Web browsers anytime and anywhere in a friendly manner. There will be no geographic and time restriction for such kinds of services. A web-based support system may combine various application services to support diversified sustainable community activities. Community members can choose preferable application services to accomplish their participation in the sustainable community activities.

As a demonstrative example, we discuss the XML-based management for Delphi survey in Section 5. Delphi survey is viewed as an important approach for activities in group decision-making. Based on the relation graph of Delphi activities, we can construct a semantic knowledge repository for Delphi activities. It is an advantage for sustainable communities to improve the multi-disciplinary, multi-agency and multi-sector information sharing. On the other hand, a Delphi activity can be treated as a SOAP message, and therefore dynamic Delphi and traditional Delphi activities can be represented uniformly.

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