Prototype Web-Based Construction Project Management System

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Abstract: This paper presents a conceptual model of a metadata-based information system for data exchange among Web-based documents for construction project management. The system retrieves useful data from the original documents, reorganizes the information according to specific tasks or users, and displays the information in an integrated web page. The study identifies the comprehensive functional requirements from existing Web-based collaboration systems, and finds out new user requirements by way of a Web-based survey in Singapore. Based on the requirement studies, a prototype model is developed using unified modeling language. Implementation of the conceptual model uses extensible markup language technology. Discussions on major concerns about information security, data accessibility, and service quality are included in this paper.

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Introduction

The use of the Internet for exchanging information in a work environment has become very important and will be more so in years to come. Industries that are interdependent and involve a large number of participants, information, and resources, tend to benefit from the use of a time-efficient system in communication, retrieval of information, coordination, and management work.

The Architectural, Engineering, and Construction (AEC) industry, in particular, is characterized by fragmentation (Howard et al. 1989), geographically, and functionally (O'Brien and Al-Soufi 1993). Geographical fragmentation is caused by the fact that most of the construction projects are based on temporary collaborations of owners, architects, contractors, subcontractors, and suppliers. In addition, the locations of the projects and the operational premises are usually geographically different.

Functionally, project partners assume different roles (horizontal fragmentation) throughout the entire construction process (vertical fragmentation) (Howard et al. 1989). Due to fragmentation, coordination among various participants throughout the construction process can be a difficult task. The exchanges of information between major players, such as project managers, architects, contractors, and engineers, occur very frequently in the forms of letters, change orders, drawings, etc. During the construction stage, effective communication between project participants on site and those operating from their offices are necessary to ensure that no misunderstanding or lack of information causes delay in the completion of projects.

Internetworking is ideal for the AEC industry since it is cheap, widely available, and not too difficult to use. It provides the best communication solution to the fragmented nature of the AEC industry. However, users of the Internet face problems, such as unstructured, slow, and insecure systems. The next-generation Internet (Tolman et al. 2000) promises to overcome the problems of the current Internet.

Research Objectives

This research proposes a conceptual model of a Web-based information system for construction project management to facilitate almost instantaneous data exchange among project participants. The system is able to intelligently search for relevant information, extract useful data from the original documents, reorganize the information according to specific tasks and users, and display it in an integrated web page accessible to all of the relevant parties in the construction project. The study focuses on project collaboration related functions, such as document exchange and cross-company communications, especially during the construction phase.

Web-Based Systems

At present, there are three types of Web-based applications for the AEC industry: The fee-based project management service; the build-it-yourself solutions; and the web-enabled software (Zhu, 1999).

The subscription fee project management services are provided by professional information technology (IT) companies called application service providers (ASPs). Benefits include low implementation cost, minimal IT expertise required, easy application upgrade, and simple system requirements. Its limitation lies

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in the control of information by a third party. Major concerns include information security, data accessibility, and service quality.

The build-it-yourself solutions are suitable for extremely large companies, so that they can tailor the application to best fit their business environment and maintain their own business style. The limitation is obvious in that it requires lots of investment, outsourcing, and a long development cycle.

The last type, Web-enabled software, refers to whole-set Web-based software that is bought and maintained by construction companies. This solution is a balance of the former two. It reduces the need for outsourcing, shortens the development cycle, and, at the same time, retains the sensitive information under the supervision of in-house technical staff. Limitations of this system are a higher initial cost, and greater know-how required from staff.

This study recommends the use of fee-based project management service because it facilitates interorganizational information sharing at an affordable price and with professional services, which sets the trend for Web-based project management.

Application Service Providers

The use of the Internet for project collaboration demonstrates great promise as a tool for increased productivity and business performance. Commercial collaboration solutions are provided by ASPs. Some of the well-known ASPs in the AEC sector are: AutoDesk (http://www.buzzsaw.com/), BIW (Building Information Warehouse, http://www.biwtech.com/), Bricsnet (http://www.bricsnet.com/), BuildingWork (http://www.buildingwork.com/), Causeway Tech (http://www.causeway-tech.com/), Citadon (http://www.citadon.com/), Constructware (http://www.constructware.com/), Cosential (http://www.cosential.com/), eBuilder (http://www.e-builder.net/), eRoom (http://www.eroom.com/), Meridian (http://www.mps.com/), and Primavera (http://www.primavera.com/).

By 2002, there were five major local ASPs for the Singapore construction market: Cyber-IB (http://www.cyberib.com/), CXHub (http://cxhub.com/), HDBuilder (http://www.hdbuilders.com/), icFox (http://www.icfox.com/), and icx123 (http://www.icx123.com/). Among them, icFox uses Citadon's technology; while Cyber-IB applies AutoDesk's. The icx123 and CXHub are mainly information providers. They do not provide Web-based project management services. Only HDBuilder has a local technology partner, who develops Web-based solutions solely targeting contractors. Currently, the Singapore local portals provide various services in e-commerce, e-project management, and information exchange for the local construction industry.

Current commercial web-based management systems are document based, acting as common information repositories for drawings and textual documents. The problems with a document-based system lie in many aspects, among which is information overload due to ease of retrieval or downloading. Consequently, the crucial information, buried in the midst of irrelevant information, is difficult to locate. This results in a waste of time and energy in searching for information to make decisions. Another problem is data incompatibility. Since drawings, calculations, and schedules are produced by various specialized software, users have to run applications to view a small part of useful information in each file, and switch between applications to get all fragmented information integrated in their minds.

System Features

In the ISTforCE project (Intelligent Services and Tools for Concurrent Engineering), Cerovsek and Turk (2000) summarized the requirements of a prototype Internet desktop system as: Open enough to integrate with other service or tools; customizable to persons and projects; scalable according to construction project size and level of IT infrastructures in the companies; and extendable enough to allow project participants to define a tailor-made solution that fits each project.

In the GLOBEMEN project (Global Engineering and Manufacturing in Enterprise Networks), Hannus and Kazi (2000) pointed out five managerial requirements: Standards for external communication; short setup time and low cost of the common working environment; short learning time of common tools; protection of proprietary knowledge; and clear division of responsibilities between team members.

Also in the GLOBEMEN project, Laintinen et al. (2000) highlights the user-centered requirements where users should be able to: Access and update the required information efficiently based on access rights; provided with functionality to search for valuable information in various sources quickly and easily; able to synthesize different pieces of information and organize existing knowledge; view the well-organized information from different perspectives depending on their role in the process; accumulate acquired knowledge orderly for future usage; and generate reports for decision making.

In this study, seven desirable features of the Web-based construction project management system are identified through a questionnaire survey. They are time and cost consideration; integration; search for information; knowledge base and intelligence; customizability to persons; customizability to projects; scalability; and others. The next section briefly describes each of these features.

Time and Cost Considerations

Time and cost considerations are the most crucial practical issues, yet seldom mentioned by the academy. To remain competitive against numerous upcoming systems with similar features, the system must demonstrate robust functions with an affordable price. Short Web-site setup time and short training time is also of the utmost importance. Therefore, there is a tradeoff between the effort put into system development and returns on investment.

Integration

Integration is provided throughout the project life cycle, with company database, and with project model [a project model contains object-oriented computer-assisted design (CAD), cost, scheduling, and other building information of every building element. It is considered the ultimate way to realize data interoperability among different software applications throughout the project life cycle] ; interoperability through AEC industry-wide standards for related information, allowing data sharing between any systems used by any project participant (e.g., ISO-STEP, IAI-IFCs, aecXML, etc.).

Integration is provided with solid modeling, virtual reality, and others. It is present in the software environment where users apply it in their jobs, so as to reduce rework. The software environment includes the general office software (Word, Spreadsheet), design and project management tools (CAD, scheduling, accounting, invoicing, electronic bid management, task and resource

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scheduling, and online tracking of plans). For example, the automatic retrieval of metadata residing in Word and Excel files will reduce re-entering metadata when uploading files. Integrating contacts and calendars with a users' local system will prevent the redundant input of contacts and tasks.

Intelligent Search for Information

The intelligent search for information means quick access to and efficient updating of required information; searching for valuable information in various sources, e.g., the project web, the Internet, local area network and the local computer; and synthesizing related data in different documents to form new complete information for decision making.

Knowledge Base

Knowledge base refers to accumulating and organizing acquired knowledge for reuse; supporting knowledge sharing among the team members by providing rapid location and retrieval of stored information; and integrating knowledge into team collaboration and decision making, all in an intelligent distributed system environment.

Customizability to Persons

Customization allows for personalized interfaces; and displays information from different perspectives tailored to a user's role.

Customizability to Projects

Customization to projects means the ASP solution is suitable for all kinds of projects varied in size, type, and degree of complexity.

Scalability, Compatibility, and Extensibility

Scalability means the ASP solution is usable for both low- and high-speed Internet infrastructure. The system should be compatible with data generated by various applications and support heterogeneous data exchange, if possible. Extensibility is to accommodate both existing and developing applications, both in-house and third-party services.

Others

Other useful features include the protection of knowledge proprietary and supporting the division of responsibilities among team members. From the perspective of technology, extensible markup language (XML) support is very important, which means transforming XML compatible documents into document specific XML files and then to generic XML files, e.g., ifcXML, via schema mapping.

Conceptual Model Development

The conceptual modeling is depicted in unified modeling language within a use case-driven approach. A use case describes the functionality performed by the system as a result of a request from an actor (Maciaszek, 2001). Thus, a use case-driven approach describes the system from the external user's point of view, most suitable for domain knowledge analysis.

There are five packages in the conceptual model, representing five important feature categories: Document Management, Workflow Management, Team Communication, My Project Place, and Administrate Project. Schematic diagrams illustrating the flow of and relationships among the activities are depicted in Fig. 1. The next few paragraphs discuss how these packages work.

Setup Project Website

The use case Setup Project Website is to establish the framework for the website. It defines the standardized templates to manage document and workflow. It also defines the business logics for the system to execute. A template determines the standards and structure of a portfolio. When the user creates a new file, the system obtains certain data from the template. Using a template will quickly create project-wide standards and decrease time-consuming data entry. An XML-based standardized template, such as a form for request for information (RFI), defines the meaning of each input field, which can be easily interpreted by the system.

Document Management

The Document Management package serves three main functions: Upload file, search file, and search topic. In uploading a file, metadata of the file, such as author, date, and descriptions, are required. With metadata, the file can be searched by various criteria. The metadata is then saved in XML format.

In the case of file searching, the system can neatly present various search results based on the user's search criteria other than full text search, such as by text in the description of the metadata of the file, or by the category of the file such as draft drawing or shop drawing. It enhances the quality of file search by presenting the most targeted file to the user.

Topic search is an integrated information search and display. It is the most important use case to demonstrate how a XML-enabled collaboration system differs from others. It searches related information in the project website, and integrates the search results into a single web page. This means the user can extract useful pieces of information from all sources in the project website and synthesize this for analysis and decision making. It shortens the time needed for information search and organizing, and allows the user to have more time for information analysis and decision making.

Workflow Management

In the Workflow Management package, standardized workflow management is realized through information templates and automatic execution of business rules. A workflow consists of several tasks. Tasks are small jobs that the project manager assigns to the project users, such as responding to an RFI, approving a change order, etc. When one task finishes, the system automatically brings out the next. When all of the tasks are finished, the workflow ends. The benefit of automatic workflow management is the speeding up of the communication and confirmation of decisions.

Team Communication

While Workflow Management is a formal way to manage collaboration information, Team Communication can act as a less formal discussion. The features of the bulletin board system, instant messaging, online conferencing, and e-mailing, provide speedy yet

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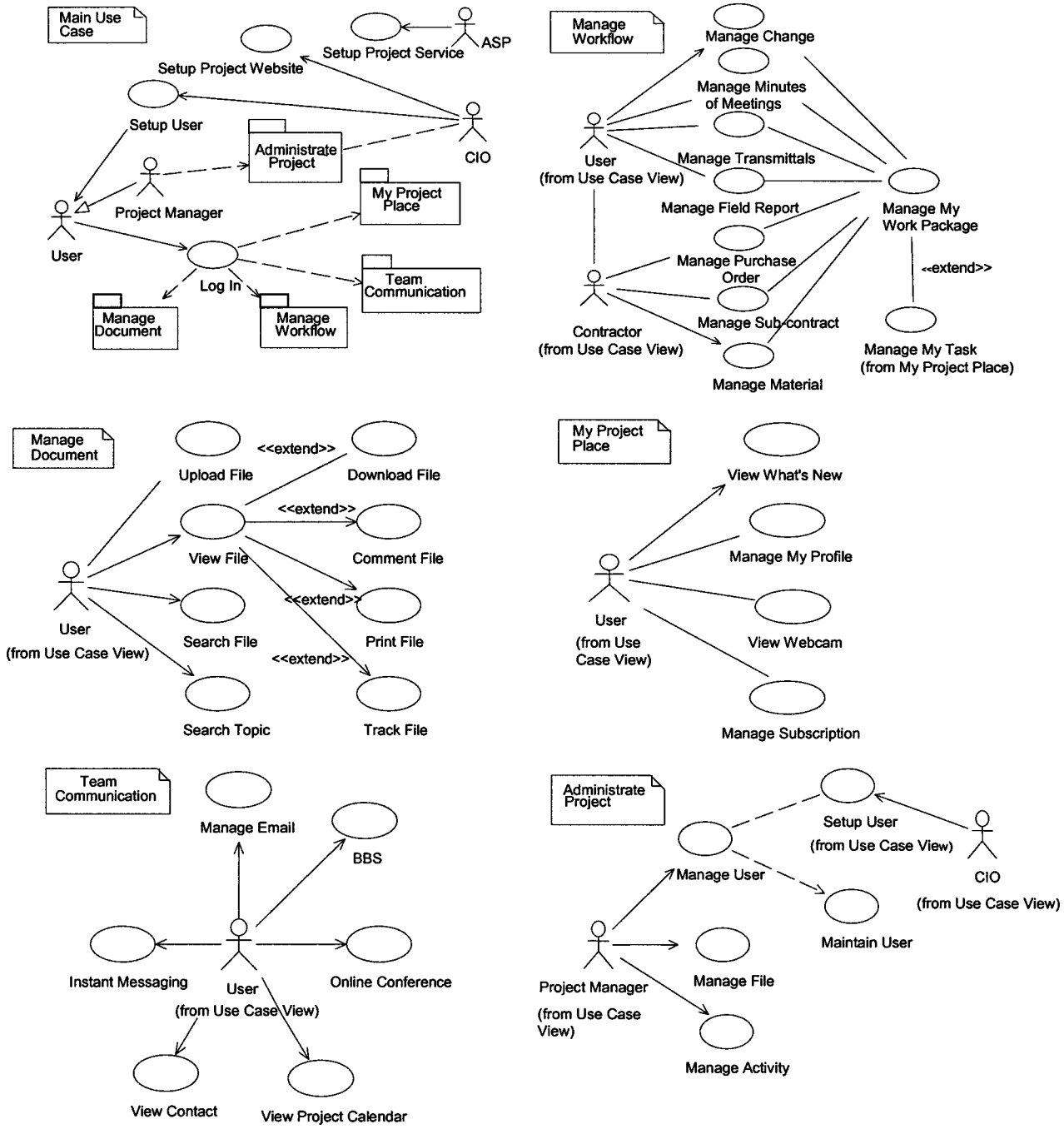

Fig. 1. Schematic diagrams showing the relationships among system activities

traceable means to record informal discussions and decision makings. Discussion results can be formally documented in workflow management, such as in the minutes of meetings, or in the decision making of approving or rejecting a change order. Team communication thus simplifies the processes of workflow. The inputs in team communication are also saved in XML format, and, therefore, are traceable by using Search Topic.

My Project Place

My Project Place is a personalized work station. Every user can view his own tasks, and update information that is relevant to his/her job. This simplifies the users' environment, and allows the user to concentrate on relevant information. It is possible with XML technology because the system tailors the information to suit the users' need.

In a workflow, each task automatically starts after its precedent event finishes, given that the tasks are assigned to the responsible parties by the Project Manager. This is done through the package of Administrate Project. The present business rules define a framework that spells out the responsibility of each person; a deadline for individual task; and actions to be taken if the task is not finished on time. The project manager only needs to fill in the specific items for each collaborative workflow.

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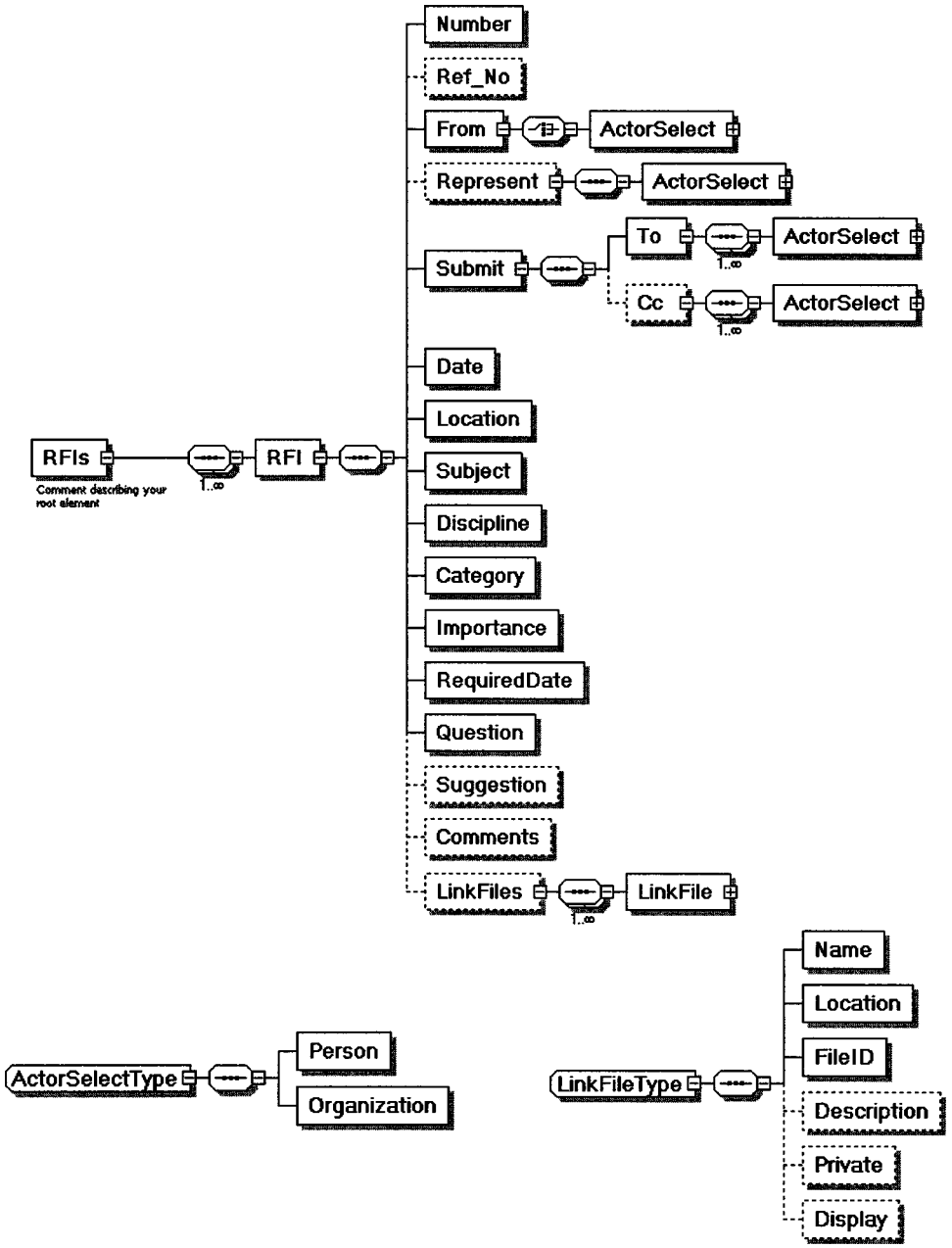

Fig. 2. Elements in the request for information schema

The packages described above consist of several top-level use cases. Each use case may consist of several subordinate use cases.

Extensible Markup Language

To overcome the problem of data incompatibility, the implementation of the system employs XML technology, which is a neutral file format acting as a common language to facilitate data exchange and rapid location of the information. XML is a markup language that handles structured data by separating the content from the presentation of the information. It is recommended by the W3C as "the universal format for structured documents and data on the Web" (W3C 2002a). W3C stands for World Wide Web Consortium, an international organization that develops technical specifications for the web's infrastructure (W3C 2002b).

In his "malleable frame" system, Zhu (1999) provided a methodology for identifying document-type definition (DTD) for construction documents. To date, XML schemas definition (XSD), instead of DTD, is applied in the construction industry. IfcXML(IAI 2001) is one of the internationally recognized XSDs in construction. However, the structure of the ifcXML schema is too complex and elaborate for direct use. Schema mapping between the document schema and the ifcXML schema is necessary. Fig. 2 shows the XML document schema of the RFI described in the following section. Schema mapping between the RFI document schema and ifcXML schema involves the extension of the ifc model to include schemas, such as ReRFI, and Responses.

Prototype System

The information used in the prototype system is obtained from a real construction project completed in Singapore. In this design-

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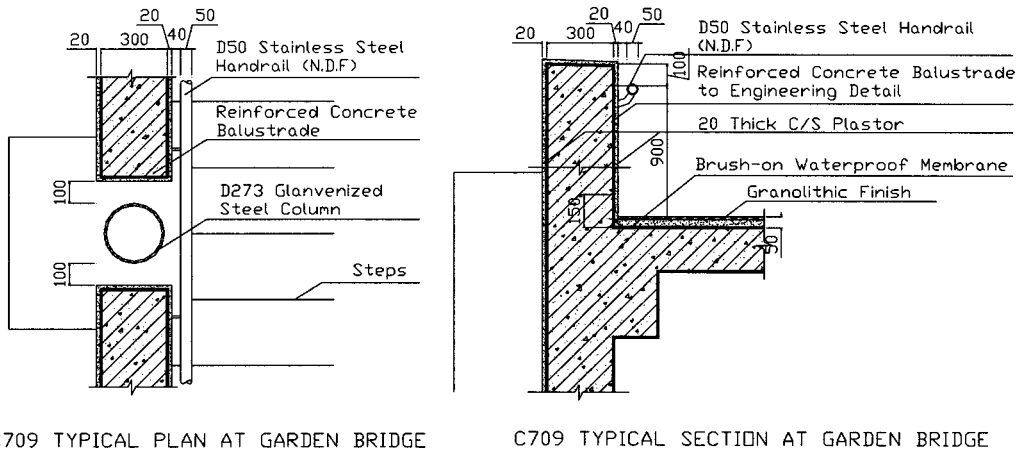

Fig. 3. Detail drawings of the parapet

and-build project, the Main Contractor (company MC) acts as the project manager and the Architect (company AR) works for MC. The Client (company CL) is a government agency in charge of the national mass rapid transit projects. The CL supervises the project, deals with major decision making, and authorizes changes to the project work. In company MC, Y. S. Liu is the Project Manager (PM), and M. Ang is the Quantity Surveyor (QS). K. Foo is the Qualified Person and chief architect in company, AR. In company CL, C. Tan is the PM, and R. Chee is the QS.

The RFI was about the location and material of a staircase handrail. The handrail could not be built as shown in the original drawing, due to position conflict with the steel column footings (Fig. 3). Since steel type was not specified in the original drawing, the MC also wanted to clarify the type of stainless steel to be used (Type 316 or Type 304).

In the proposed Web-based system, the process is simplified through automatic notification of relevant parties as depicted in Fig. 4. Liu logs in to the system to create and submit a new RFI. Drawing of the proposed solution is uploaded and attached to the RFI. The system notifies other parties by e-mail. Each party can easily retrieve both the proposed and original information, since it is integrated in one web page, with hyperlinks to references. To evaluate the impact on cost, for example, Ang extracts the handrail and column items from the original quotation, puts them under deduction items, and adds new prices to additional items.

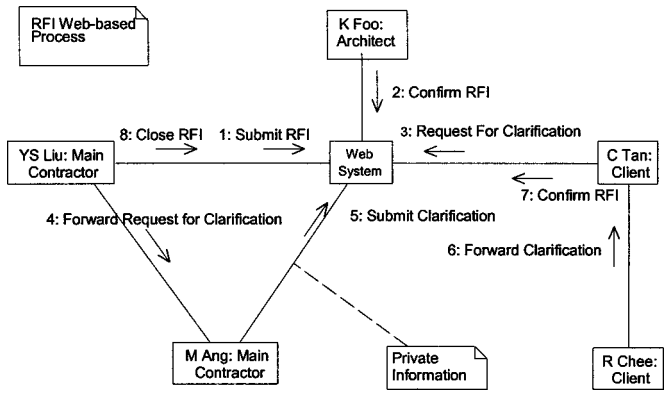

Fig. 4. Collaboration diagram of Web-based process

Fig. 5. M. Ang's headline page

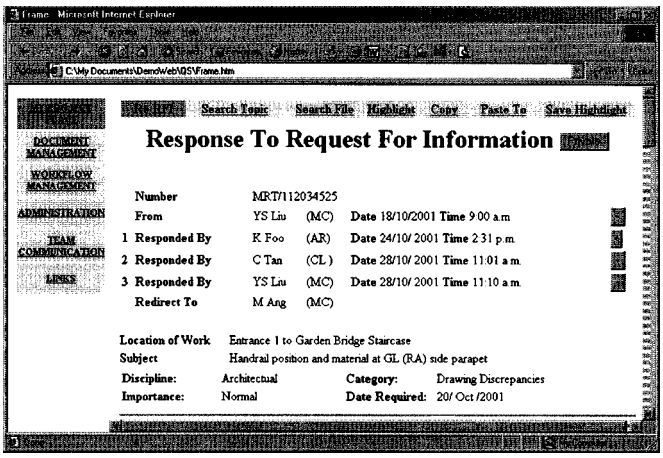

Fig. 6. M. Ang's response to request for information page

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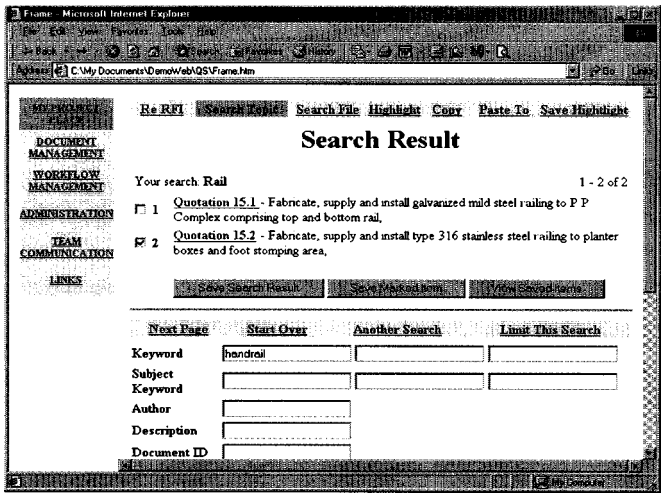

Fig. 7. M. Ang's research result page

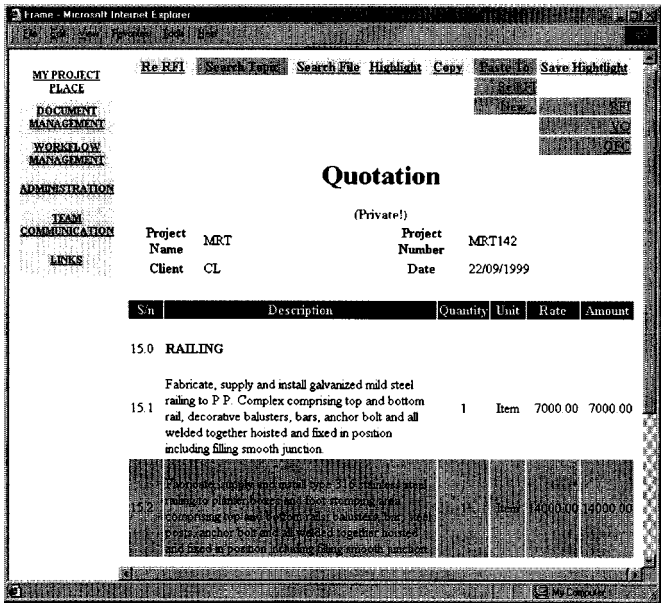

Fig. 8. M. Ang's quotation page

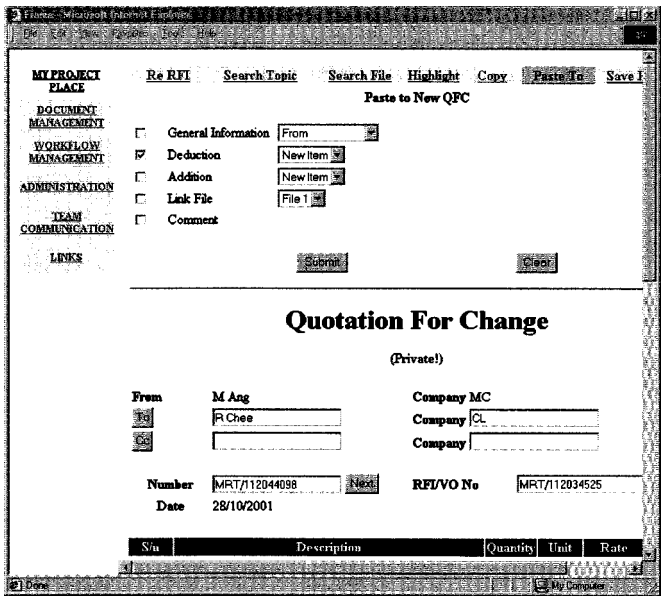

Fig. 9. M. Ang's quotation for change page

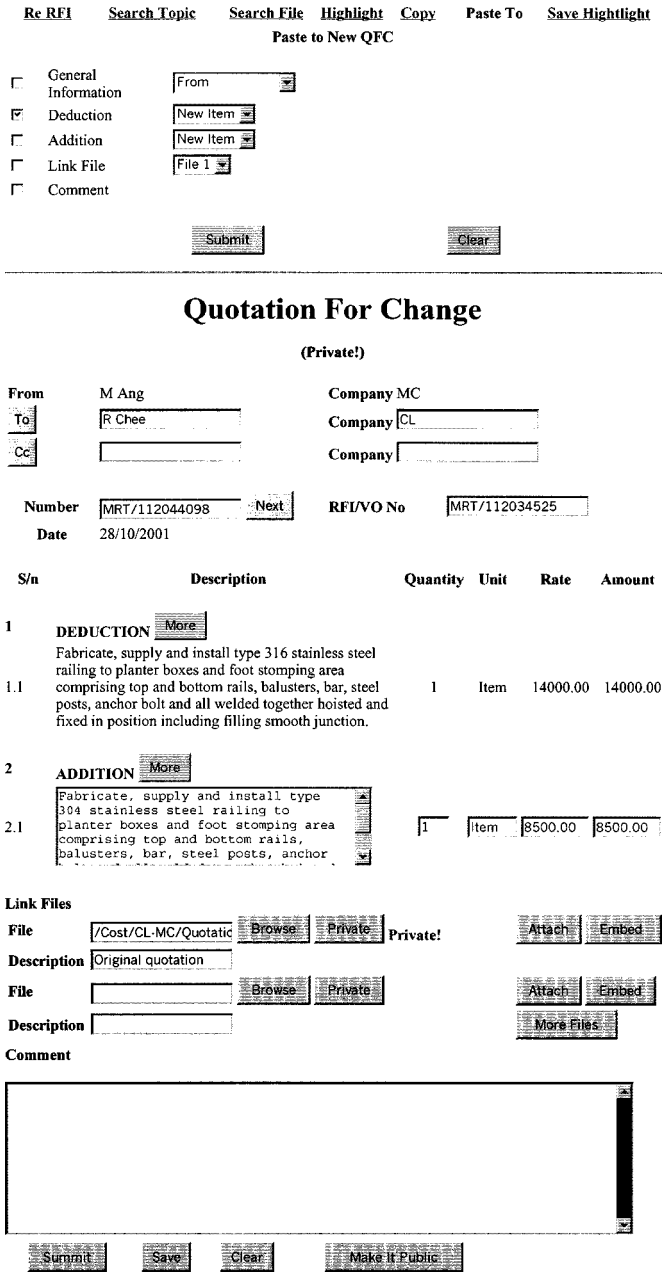

Fig. 10. M. Ang's quotation for change page

The new quotation only contains sufficient information for Tan to make the decision. The documentation of Ang's response is shown in Figs. 5–11.

Conclusions and Implications

This paper describes the prototyping of a system that can intelligently search for relevant information, extract useful data from the original documents, reorganize the information according to specific tasks and users, and display it in an integrated web page. The research demonstrates the capabilities of XML, the latest Web-based tool that enables fast data exchange in the construction project management environment.

Through a survey, the study unveils the current Web-based collaboration systems and the as-is features and their limitations, and identifies additional features to be included in the proposed

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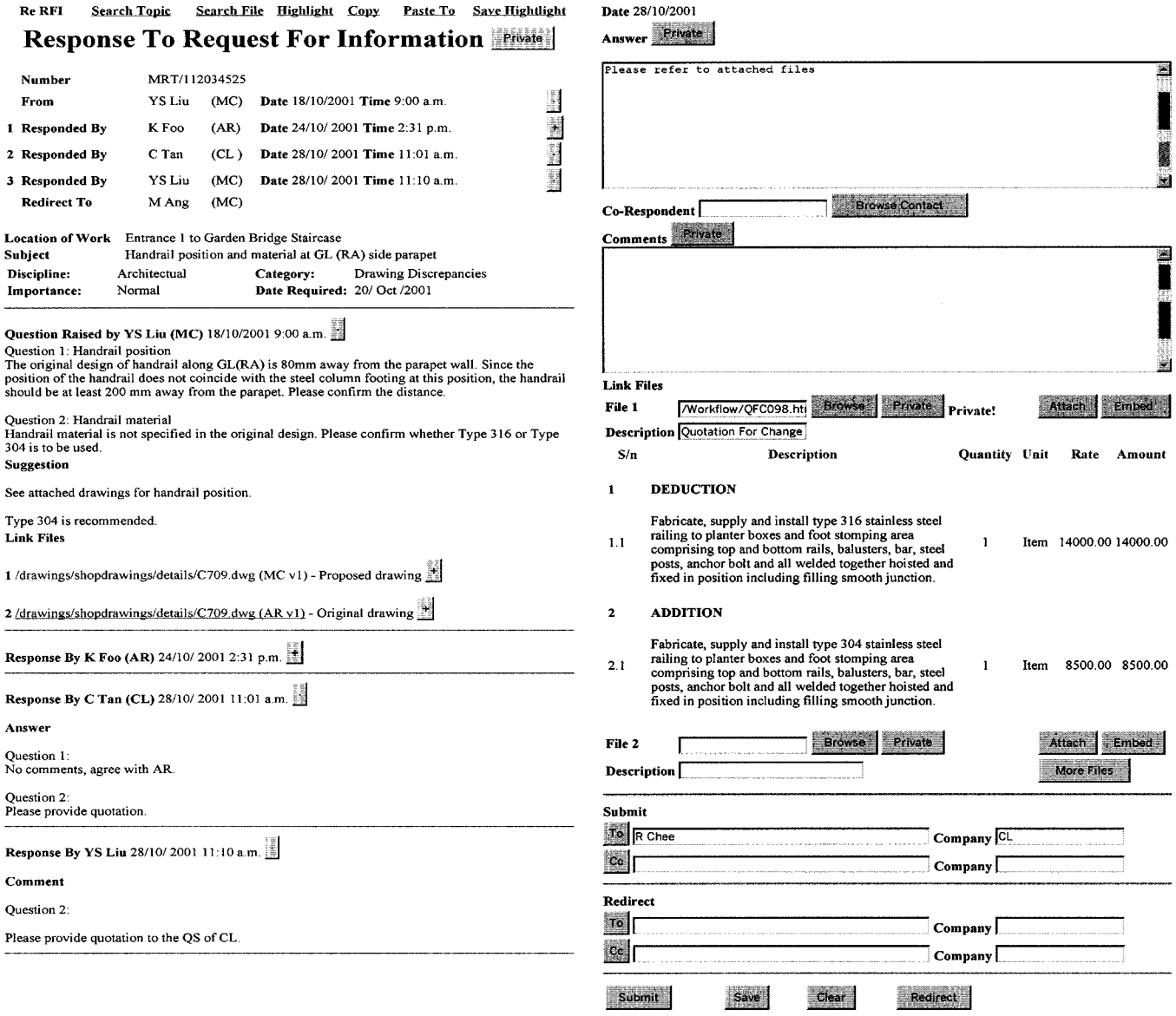

Fig. 11. M. Ang's response to request for information page when submitting

system. The conceptual model focuses on intelligent search and integrated presentation of Web-based information.

Prototyping the RFI case demonstrates the technical feasibility of implementing the conceptual model using XML technology. It is found that the Web-based process provides the convenience of ready, complete, and integrated information in a timely manner, which helps the users to make decisions faster and more accurately, so that downstream parties can take actions faster. It also helps to keep track of the collaboration process, reduce data reinputs, and minimize errors.

This research is meaningful for Web-based project management in that it explores a new direction for information integration, i.e., intelligent search. In the near future, Web-based collaboration systems will be developed toward the platforms for automatic information exchange and integrated representation. Such a change has profound influences on both business process redesign and collaboration in the AEC industry.

The study bridges the gap between present and future development of the Internet by exploring the possibility of intelligent search as one direction for the development of a Web-based project management tool. The conceptual model is based on an XML-enabled metadata system. The proposed system is better than the current Web-based systems for it is able to intelligently search for relevant information, extract useful data from the original documents, reorganize the information according to specific tasks and users, and display it in an integrated web page.

The research redefines the meaning of information: Information is a set of data useful for decision making. Not all data in a document is information for a specific user or a specific task. Therefore, it is important to filter the data in different documents and reorganize useful information to satisfy the need of a specific user or task. The research testifies that Web-based information marked up by XML can be linked, and faster data exchange among Web-based documents is possible.

However, the conceptual model discussed above is not complete. It only presents use cases most relevant to the development of intelligent search and integrated presentation of Web-based information. Phases in the lifecycle of software development include requirement analysis, system design, implementation, and evaluation. The research focuses mainly on requirement analysis.

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Study on the workflow of RFI presents a methodology for system design, but the actual development of the system will involve much more than an individual's effort. The value of the conceptual model is not fully realized until the whole system is actually built and tested.

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