Meta-Data-Based Collaboration In Construction Project Management

Nga-Na Leung*, Swee-Lean Chan** and Raja R.A.Issa***

*Ph.D. student, Rinker School of Building Construction, University of Florida, Gainesville, FL, 32611-5703; PH (352) 273 1179; nnleung@ufl.edu **Assistant Professor, Department of Building, School of Design and Environment, National University of Singapore, 4 Architecture Drive, Singapore 117566; PH (065) 68743419; bdgcsl@nus.edu.sg *** UFRF Research Professor, Rinker School of Building Construction, University of Florida, Gainesville, FL, 32611-5703; PH (352) 273 1152; raymond-issa@ufl.edu

Abstract

Web-based collaboration in construction has been in practice for several years. Current commercial Web-based management systems are document-based. To overcome the problems of information overload and data incompatibility commonly associated with document-based systems, this paper proposes a Meta-Data-Based (MDB) approach that extracts information from the original Web-based documents and re-organizes it in an integrated Web page according to specific users or tasks. The core technology used in this kind of system is the eXtensible Markup Language (XML), which serves as a common language that facilitates data exchange and rapid location of information.

A comparison of the paper-based approach and the MDB one for a Request For Information (RFI) case demonstrates a few advantages: the MDB process provides the convenience of timely, complete, and integrated information, which helps to speed up the decision-making process and increase its accuracy so that downstream parties can take faster action.

The method of converting traditional construction documents to MDB ones is discussed with the help of an XML schema for the RFI. Screen shots of the MDB process are presented and its applications and implications discussed.

Introduction

A Web-based project management system is a restricted network for project specific collaboration and communication. It supports information sharing, enables timely communication, and offers dynamic information for decision-making (Castle 1999). These solutions are provided by the so-called Application Service Providers (ASPs) (Asptip 2000). Current commercial Web-based management systems are document based. The problems with document-based systems are information overload and data incompatibility (Zhu et al. 1999; Liston, Fischer and Kunz 2000). Information overload results in a lot of time and energy being wasted trying to retrieve crucial information from a huge pile of information, much of which are irrelevant. Data incompatibility arises because drawings, calculations, and schedules are produced by various specialized software packages, thus users have to switch between applications to get the fragmented information integrated in their minds.

To solve the problems of information overload and data incompatibility, this paper proposes a MDB system. The concept is to regard documents as information containers, so that information can be extracted and tailored in a manner most convenient to a specific task or user (Chan and Leung, 2003). The core technology is a neutral file format, XML, acting as a common language to facilitate data exchange and rapid location of the information.

Comparison between Paper-Based and MDB Processes

The paper-based and MDB processes of a RFI case are modelled using the Unified Modeling Language (UML) (Chan, and Leung, 2003). Collaboration diagrams are used to model the process flows, with the tool of Rational Rose. The complete MDB conceptual model can be found in Leung's thesis (Leung 2002).

The information used in the prototype system was obtained from a real construction project completed in Singapore. In this design-build project, the Main Contractor (company MC) acted as the project manager and the Architect (company AR) worked for MC. The Client (company CL) was a government agency in charge of national Mass Rapid Transit (MRT) projects. CL supervised the project, handled major decision-making, and authorized changes to the project work. In company MC, YS Liu was the Project Manager (PM), and M Ang was the Quantity Surveyor (QS). K Foo was the Qualified Person (QP) and the chief architect in company AR. In company CL, C Tan was the PM, and R Chee was 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 a location conflict with the steel column footings (Figure 1). Since the steel type was not specified in the original drawing, MC also wanted to clarify the type of stainless steel to be used (Type 316 or Type 304).

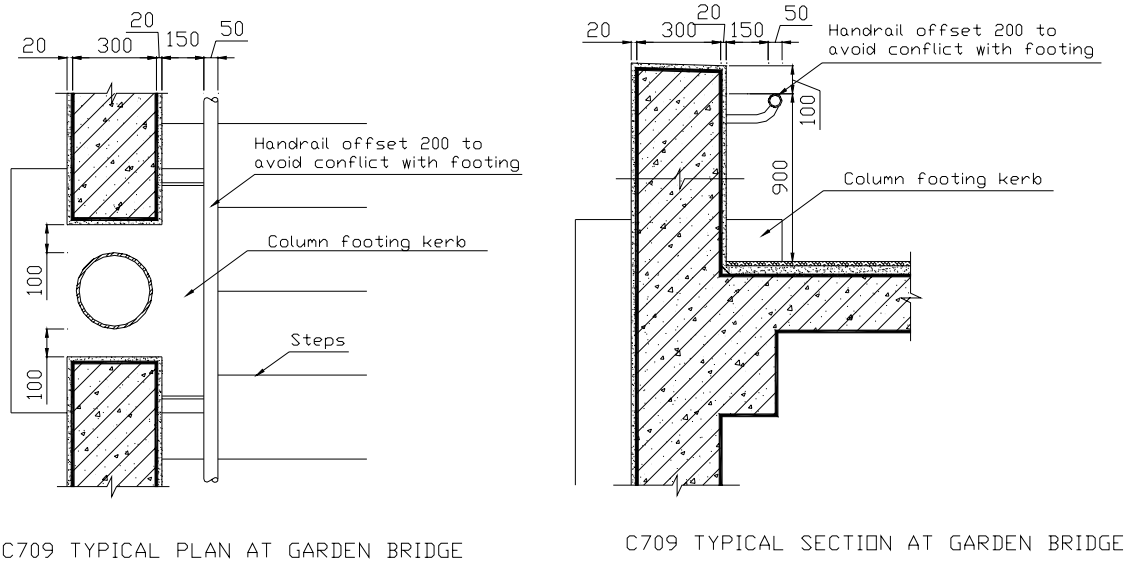


Figure 1. Proposed Drawings of the Parapet.

In the paper-based process (Figure 2), MC submitted his questions and recommendations in the RFI. The RFI was faxed to AR for clarification, then to CL for comment. Telephone conversations and site meetings were conducted for discussion before the final decision was made. MC recorded the change, faxed it back to each party, and installed the handrail.

The RFI was about a simple question circulated between three parties and five persons. It had been faxed at least 5 times, each of which resulted in new comments being added. At the closure of the process, the handwritten notes on the RFI were blurred and it was difficult to decipher. Confirmations on the two questions were made separately (AR confirmed the position of the handrail on the RFI, while CL confirmed the material on the Quotation For Change). This procedure could have easily caused conflicts since CL's confirmation was not documented on the RFI.

In the proposed MDB system, as shown in Figure 3, the process is simplified through automatic notification of the relevant parties. Liu logs into the system, creates and submits a new RFI. The proposed drawing is uploaded and attached to the RFI. The system notifies other parties by email. The RFI and all related responses are neatly documented in chronological order to reduce conflicts caused by ambiguity. References are easy to find since they are either embedded in the RFI or accessible by clicking on the hyperlink. Responsible parties accessing the system at different locations can concurrently respond to the RFI. This not only reduces the total response time, but also minimizes unnecessary delay in the whole process in case one if a party is absent from his or her work.

The main benefit of the MDB process in the RFI scenario is that it provides the convenience of ready, complete and integrated information in a timely manner, which helps the users make decisions faster and more accurately, so that the downstream parties can take action quickly. It also helps in keeping track of the collaboration, reducing data re-input, and minimizing errors. Another key benefit of the MDB process is information integration through extracting useful information from the reference files and integrating that information with the original RFI to facilitate the making of decisions. Some screen shots of the MDB system are shown in the Appendix.

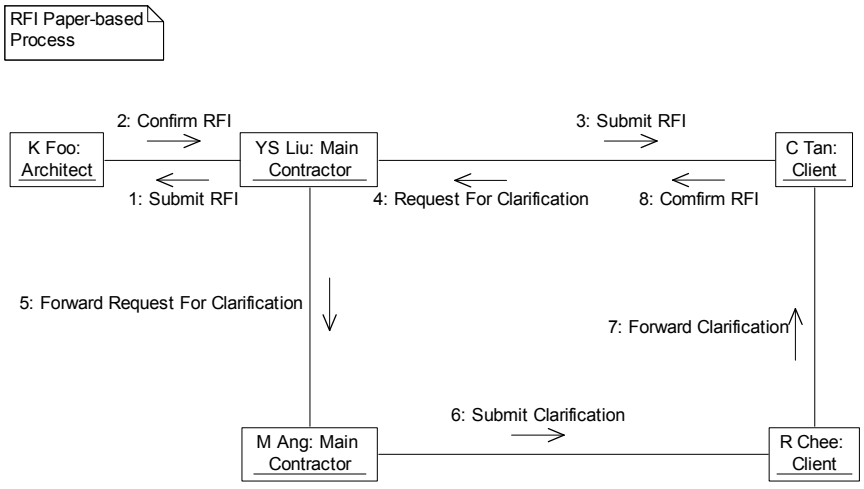


Figure 2. Collaboration Diagram for the Paper-Based Process.

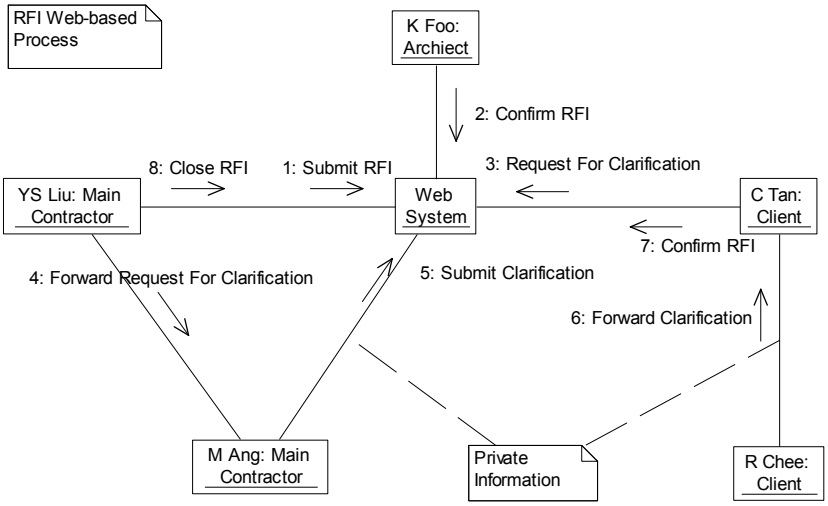


Figure 3. Collaboration Diagram for the MDB Process.

The Meta-Data-Based System

XML is a subset of the Standard Generalized Markup Language, which separates Web contents from their presentation (W3C 2001). XML 1.0 is the specification that defines what "tags" and "attributes" are. Beyond XML 1.0, "the XML family" is a growing set of modules, which include XML Schema Definition (XSD), XSL (XML Stylesheet Language), XLink, XPointer, XFragments, Document Object Model (DOM), etc (W3C 2001). XML schemas are used to define the hierarchy of data structures. XSL consists of two parts: XSL Transformation Language (XSLT) and formatting objects. XSLT is used to transform an XML document to HTML, XML, WML (Wireless Markup Language) or any other text-based document. In this research, XMLspy is applied to develop all the XML related documents, which is also used in the ifcXML development (Liebich 2001).

In the AEC industry, at least three consortiums are working on domain specific schemas: the bcXML (building and construction XML) developed by the European project eConstruct (Tolman et al, 2000); the aecXML (architectural, engineering and construction XML) initiated by Bentley Corp, USA (aecXML, 2001); and the ifcXML (industry foundation classes XML) developed by the International Alliance for Interoperability (IAI) (Liebich 2001).

The document exchange architecture of the RFI scenario is shown in Figure 4. Dynamic HTML (Hypertext Markup Language) Web pages are transformed from the document XML file by the document XSLT. The document XML file is defined by the document XSD. Schema mapping is then done by specialized applications between the document XSD and the ifcXSD. The ifcXSD defines the ifcXML document. Since all Web-based documents can ultimately be transformed into ifcXML documents, data in different ifcXML documents can be exchanged among one another.

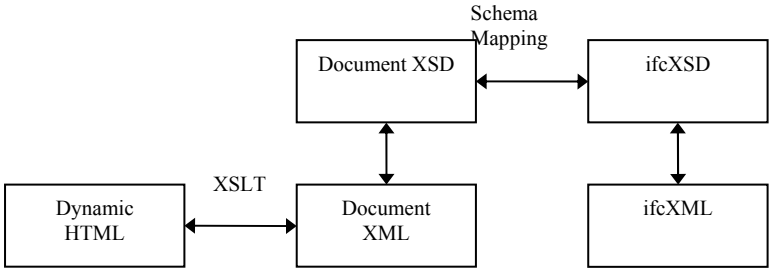


Figure 4. Document Data Exchange.

Schemas For The Response To Request For Information

The Response to Request For Information (ReRFI) file is analyzed as an example of the MDB process. The ReRFI schemas (ReRFI.xsd), ReRFI XML file (ReRFI.xml), and schema mapping between ReRFI.xsd and ifcReRFI.xsd are discussed in the following sections.

Figure 5 shows the top level elements of a ReRFI. `ReRFIs` is the root element. Each `ReRFIs` contains one or more `ReRFI`. Each `ReRFI` contains one `RFI`, one `Responses` and one `MyResponse`. `RFI` is the original question submitted by YS Liu. `Responses` is the group of previous responses, which consists of one or more `Response`. `Responses` is optional, since it does not appear to the first respondent (K Foo). `MyResponse` is the current user's response, which consists of one `Response`.

`The RFI` is defined as a complex type, the data structure of which is the same as the original RFI, i.e., the form submitted by YS Liu. `Response` is also defined as a complex type, so that it can be used in both `Responses` and `MyResponse`.

Figure 6 shows the expanded RFI complex type. A complex type is a global component that can be reused somewhere in the schema. Expanding the `Response` complex type (Figure 7), two nested complex types are defined within: `ActorSelect` and `LinkFile`, expanded and circulated in shadowed boxes. The `ActorSelect` complex type is used to declare the information providers and receivers. The `LinkFile` complex type is used to handle references.

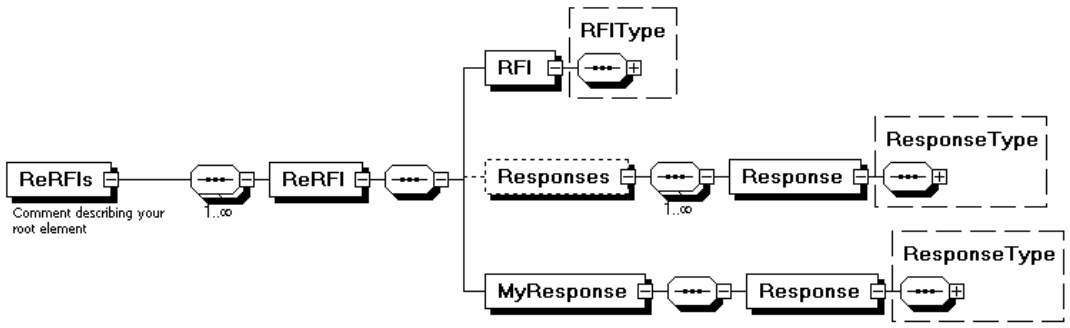


Figure 5. Top Level Elements in the ReRFI Schema.

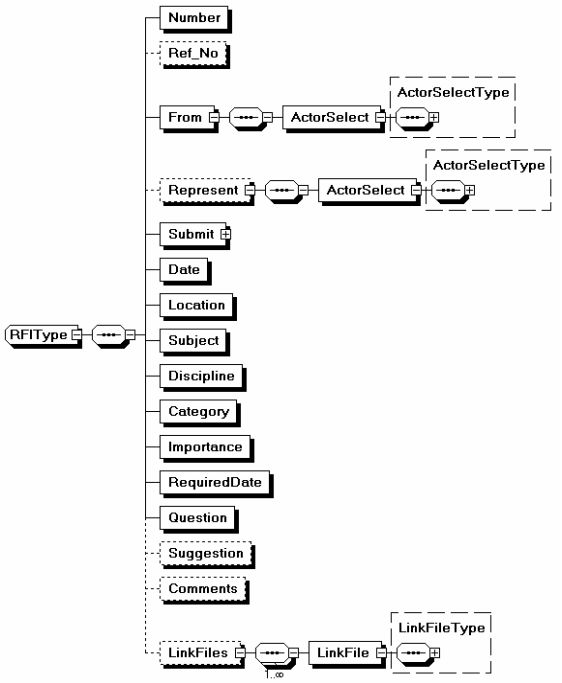


Figure 6. Sub-Elements in the RFI Complex Type of ReRFI.

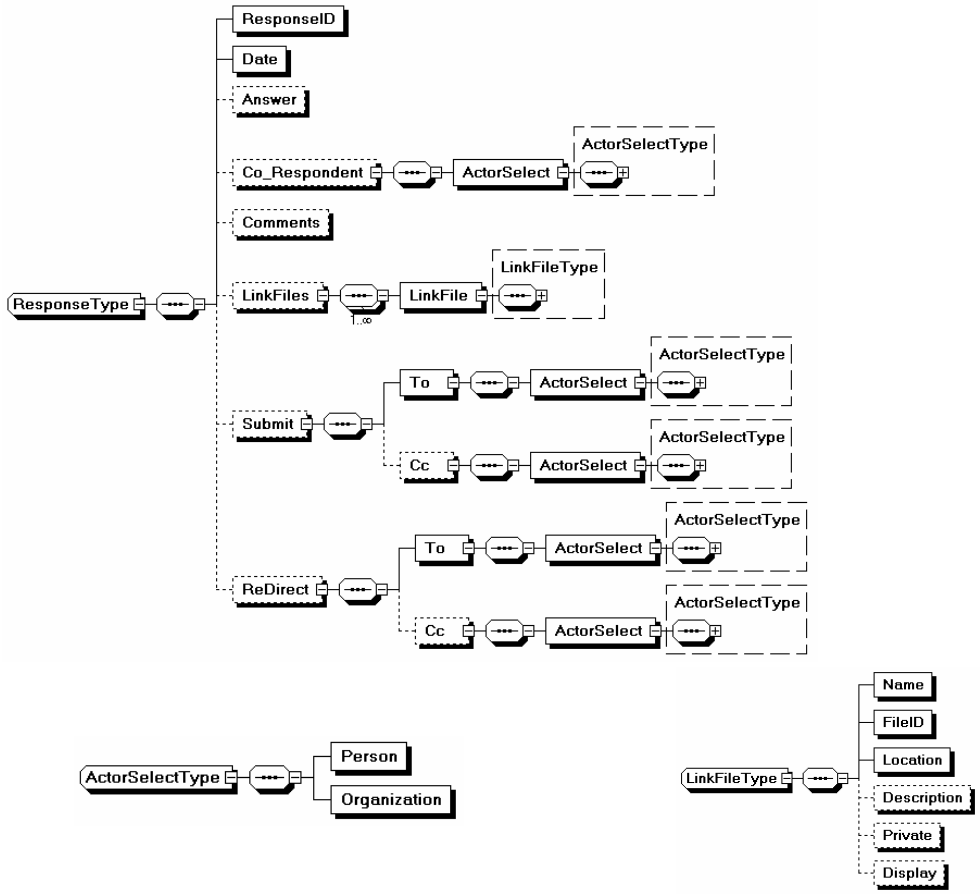
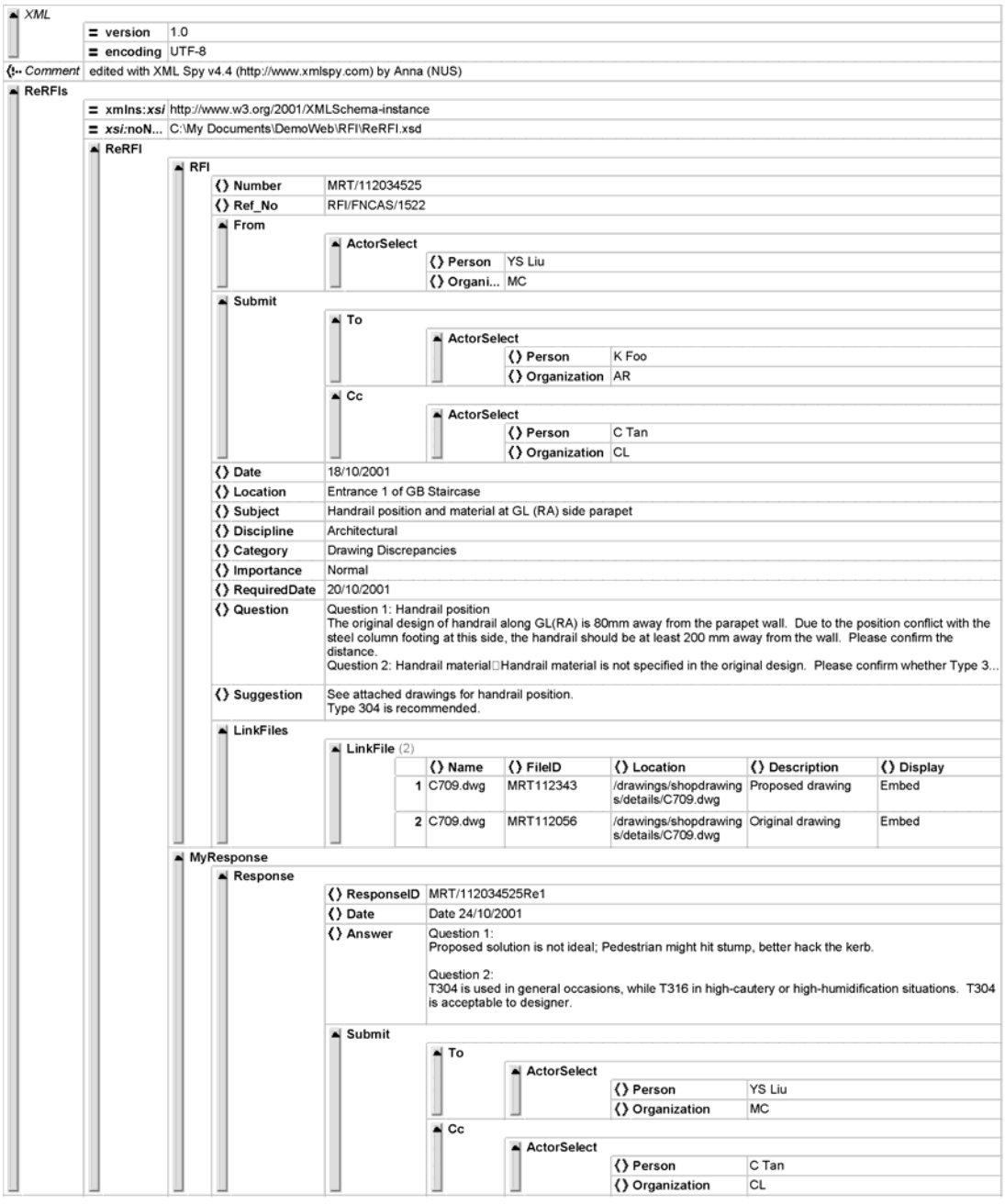


Figure 7. Response Complex Type in the ReRFI Schema.

XML File for the Response to Request for Information

When the schema is defined, XML files are generated by parsing the content of the RFI into the document schemas. Figure 8 shows both the hierarchy and the content of the ReRFI XML file.



XML
- version: 1.0
- encoding: UTF-8

Comment: edited with XML Spy v4.4 (http://www.xmlspy.com) by Anna (NUS)

ReRFIs
- xmlns:xsi: http://www.w3.org/2001/XMLSchema-instance
- xsi:noN...: C:\My Documents\DemoWeb\RFI\ReRFI.xsd

ReRFI

RFI

Number	MRT/112034525
Ref_No	RFI/FNCAS/1522
From	
ActorSelect	
Person	YS Liu
Organi...	MC
Submit	
To	
ActorSelect	
Person	K Foo
Organization	AR
Cc	
ActorSelect	
Person	C Tan
Organization	CL
Date	18/10/2001
Location	Entrance 1 of GB Staircase
Subject	Handrail position and material at GL (RA) side parapet
Discipline	Architectural
Category	Drawing Discrepancies
Importance	Normal
RequiredDate	20/10/2001
Question	Question 1: Handrail position The original design of handrail along GL(RA) is 80mm away from the parapet wall. Due to the position conflict with the steel column footing at this side, the handrail should be at least 200 mm away from the wall. Please confirm the distance. Question 2: Handrail material□Handrail material is not specified in the original design. Please confirm whether Type 3...
Suggestion	See attached drawings for handrail position. Type 304 is recommended.

LinkFiles

LinkFile (2)

	Name	FileID	Location	Description	Display
1	C709.dwg	MRT112343	/drawings/shopdrawings/details/C709.dwg	Proposed drawing	Embed
2	C709.dwg	MRT112056	/drawings/shopdrawings/details/C709.dwg	Original drawing	Embed

MyResponse

Response

ResponseID	MRT/112034525Re1
Date	Date 24/10/2001
Answer	Question 1: Proposed solution is not ideal; Pedestrian might hit stump, better hack the kerb. Question 2: T304 is used in general occasions, while T316 in high-cautery or high-humidification situations. T304 is acceptable to designer.
Submit	
To	
ActorSelect	
Person	YS Liu
Organization	MC
Cc	
ActorSelect	
Person	C Tan
Organization	CL

Figure 8. XML file of ReRFI.

XML Presentation

XSLT is used to transform an XML documents to HTML, XML, WML or any other text-based documents. More over, the same XML document can be published in different formats depending on the user or the task it serves. For example, if a Quotation For Change (QFC) document is marked as private, only the author and the explicit receivers can view the content. For other users, the XSLT renders the information as "private information not available for review" and skips the translation.

Schema Mapping between IfcXML and Document XML

IfcXML v1.02 is the International Alliance for Interoperability (IAI) recommended standard for converting IFC2x and beyond releases into XML schema specifications (IfcXML, 2002). IfcXML is expected to be the common XML schema for data exchange in the Architectural Engineering and Construction domain. However, the structure of the ifcXML schema is very complex and elaborated. Direct use of the ifcXML schema to define a document is neither convenient nor optimal because of the complexity of the schema hierarchy. Therefore, it is necessary to establish a mapping mechanism between the document schema and the ifcXML schema.

Weise et al. (2002) extended the IFC project model for structural systems. Following their methodology and based on the `PurchaseOrder` schema, which exists in the ifcXML and is similar to the RFI data structure, the schema mapping between the ReRFI XSD and ifcXSD is developed (Leung 2002).

Applications

The two characteristics of XSD, namely a hierarchy structure and nesting relationships, show that XML is ideal as a neutral format for data exchange. Figure 9 shows an example of information exchange, in which various types of information is translated into XML files and then integrated for selective display according to the purposes of the new documents. In other words, information in a document is broken down into elements, each of which is marked up with a schema defining its meaning. Elements that initially reside in different documents are then extracted and presented according to the specific information need of a user or a task.

It is assumed that various types of information are XML compatible, i.e., they can be translated into an XML file by specialized parsers. Since XML is becoming the commonly accepted data exchange format in the Information Technology domain, it is expected in the near future that information generated from specialized applications can be exported to XML format. Further discussion on the exchange between XML and these specialized file formats is outside the scope of this research.

Conclusion

Prototyping of the RFI process demonstrates a new methodology to extract useful data from the original documents, re-organize the information according to specific tasks and users, and display the information in an integrated web page. The prototype

also shows that Web-based information marked up by XML can be linked to one another and that data exchange among Web-based documents is feasible. A further amplification is made on data exchange among XML compatible documents. If the documents generated by specialized applications can be transformed into XML format based on the ifcXML data model or other similar standards, then data in these documents can be exchanged among one another in the MDB system. Further research on data exchange between XML and specialized data formats will facilitate the Web-based information integration approach.

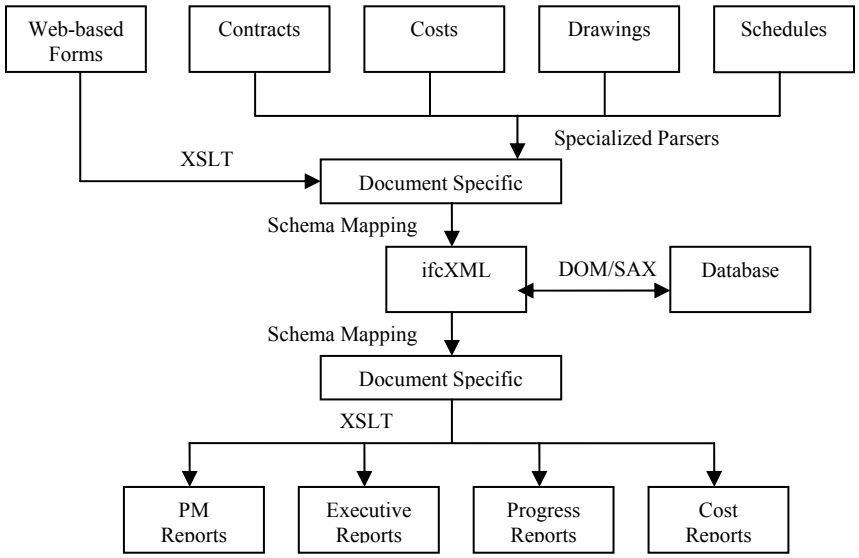


Figure 9. Information Exchange Architecture of the Meta-data System.

References

AecXML (2001). aecXML core documents. <http://www.iai-na.org/aecxml/documents.php > (May 2003)

Asptip. (2000) What is ASP? <http://www.asptip.com/whatis_asp.htm > (June 2002)

Castle, C. M. (1999). *Construction Project Networks: a study of Internet-based interorganizational Information Systems in the building industry*. Dissertation Abstract International, 60, 09A. (UMI No. 9946908)

Chan, S. L., and Leung, N. N. (2003) Prototype Web-Based Construction project management system. Manuscript accepted for publication, *Journal of Construction Engineering and Management, ASCE*.

IfcXML. (2002). IfcXML. <http://www.iai-international.org/iai_international/Technical_Documents/IFCXML.htm> (June 2002)

Leung, N. N. (2002). *A Conceptual Model For Web-Based Construction Project Management*. Master Thesis, National University of Singapore, Singapore.

Liebich, T. (2001). Ifcxml language binding of EXPRESS. Version 1.01. < http://www.iai-international.org/iai_international/Technical_Documents/IFCXML.htm> (June 2002)

Liston, K., Fischer, M., and Kunz, J. (2000). Requirements and Benefits of Interactive Information Workspaces in Construction. *The 8th International Conference*

on Computing in Civil and Building Engineering, August, 2000, Stanford University Silicon Valley, CA, USA, <http://graphics.stanford.edu/~bjohanso/iwork/iwork-retreat-cd/technol/liston/ASCE2000-RequirementsKL.pdf> (Dec 2002)

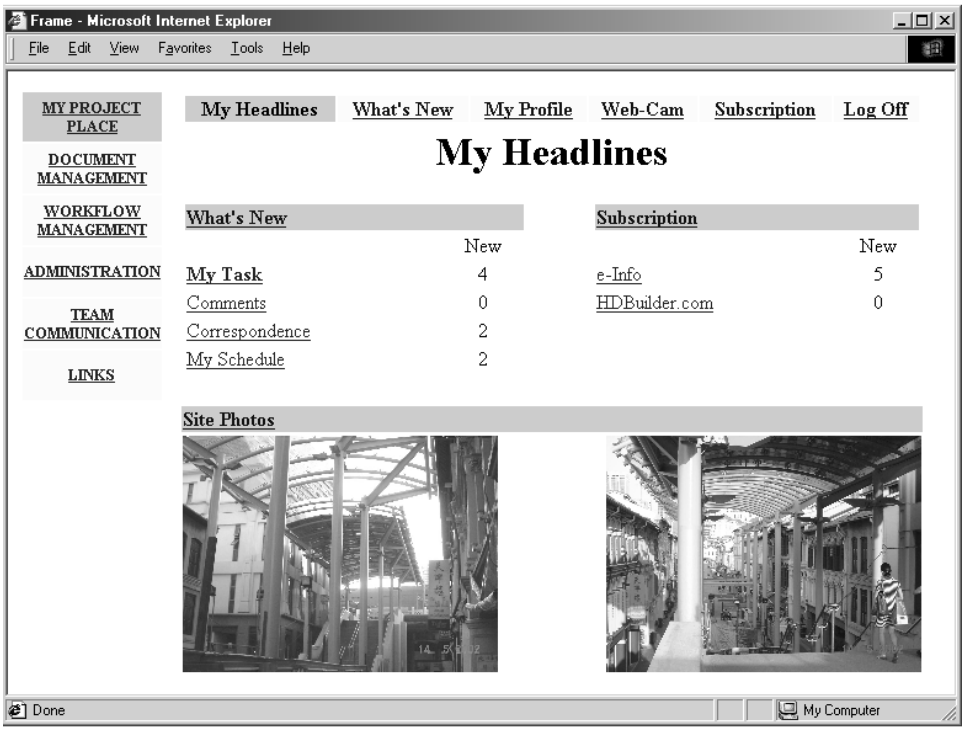
Tolman, F., Böhms, M., Leonard, D., & Stephens, J. (2000). Electronic communication in the building and construction industry: what will eConstruct bring about? In Gongalves, R., Steiger-Gargo, A., & Scherer, R. (Eds.) *Product and process modelling in building and construction: proceedings of the third European Conference on Product and Process Modelling in the Building and Related Industries*, Lisbon, Portugal, September 25-27, 2000. Rotterdam, the Netherlands: A.A. Balkema, 2000, 131-136.

Weise, M., Katranuschkov, P., and Scherer, R. J. (2000). A proposed extension of the IFC project model for structual systems. In Gongalves, R., Steiger-Gargo, A., and Scherer, R. (Eds.). *Product and process modelling in building and construction: proceedings of the third European Conference on Product and Process Modelling in the Building and Related Industries*, Lisbon, Portugal, September 25-27, 2000. Rotterdam, the Netherlands: A.A. Balkema, 2000, 229-238.

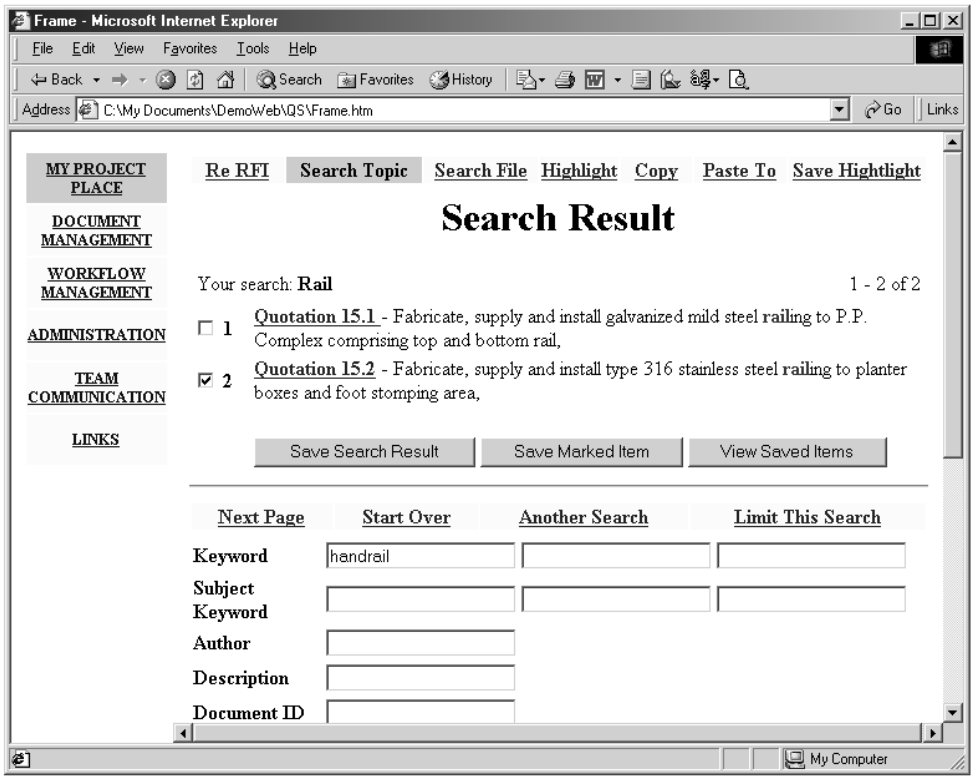
W3C. (2001).Extensible Markup Language. <http://www.w3c.org/XML/> (June 2002)

Zhu, Y., Issa, R.R.A. and Cox, R.F. (2001). Web-Based Construction Document Processing Via A Malleable Frame, Journal of Computing, ASCE, 15(3), 157-169.

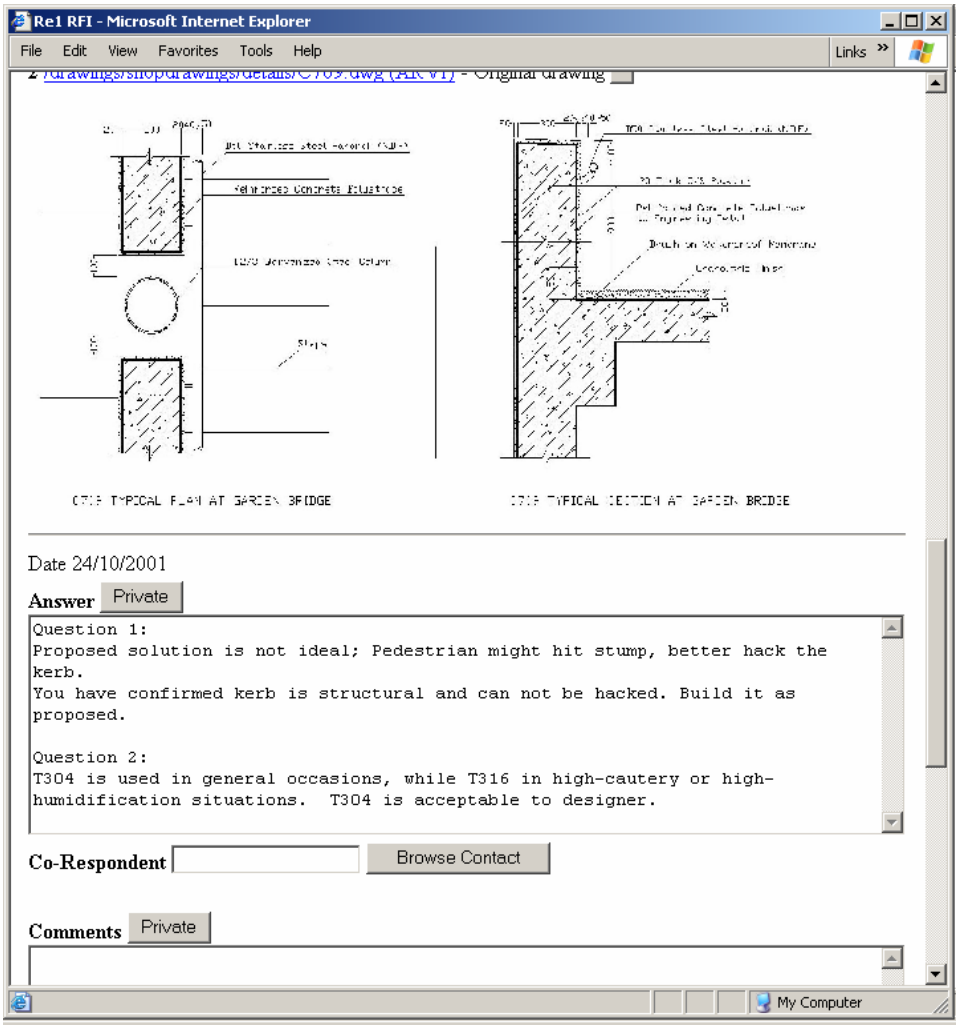
Appendix - Screen Shots of the MDB System



Headline Page



Meta-Data-Based Search



Comments and Drawings Integrated in a Page