# APPLYING WEB SERVICES WITHIN THE AEC INDUSTRY: ENABLING SEMANTIC SEARCHING AND INFORMATION EXCHANGE THROUGH THE DIGITAL LINKING OF THE KNOWLEDGE BASE

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## SUMMARY

The Architecture, Engineering and Construction (AEC) industry is fragmented by professions separated by skill, stigma and distance. This fragmentation has created a dispersed knowledge base with knowledge gaps occurring within and between the professions. These knowledge gaps can only be overcome through the exchange of information and past experiences. Presently this exchange is reliant on manual communication, which has proven inefficient and open to misinterpretation.

Web Services have been developed within the Information Technology industry to allow the cross-platform exchange of complex data. The application of this technology within the fragmented AEC industry holds significant potential. Research at the School of Architecture, Victoria University is exploring the integration of Web Services within existing databases to enable the searching, exchange and flexible presentation of relevant AEC information.

Following industry feedback the aecBEDRock concept has been proposed which would enable the digital exchange and searching of valuable AEC data between professionals. The aecBEDRock concept utilizes the properties of Web Services and Industry Foundation Classes to create a digital AEC information framework that could bind the knowledge base of the industry. A stronger knowledge base would increase quality levels within the construction process through increased professional awareness and efficiency.

## INTRODUCTION

This paper describes research undertaken at the School of Architecture, Victoria University in the field of digital information communication. The initial objective of the research was to improve the student's learning environment through provision of a concise construction information resource. As the project has evolved the research focus has shifted towards issues associated with all aspects of Architecture, Engineering and Construction (AEC) communication. However, throughout the research the goal has always been to ensure AEC knowledge is exchanged and utilized within the industry in the most appropriate format for the context.

An AEC data framework is required that harnesses the potential of structured AEC data and Web Services technologies to allow the semantic searching and exchange of AEC information between industry members. The utilization of Web Services would allow all parties to automatically exchange valuable AEC data through emerging XML based electronic commerce technologies. (Clabem, 2002)

## A DISTRIBUTED KNOWLEDGE BASE LEADS TO KNOWLEDGE GAPS

The Architecture, Engineering and Construction (AEC) industry comprises of a number of different professions reliant on the effective communication of information in order to successfully complete projects and conduct business.

Globalization has resulted in the architectural process increasingly being undertaken using local labor and imported materials to construct a foreign design financed by multinational corporations. Coupled with this trend the increasing complexity of construction technologies has dissolved the notion of the 'Master Builder'. Successful construction is now reliant on a growing number of specialized contractors, skilled in their own trade but oblivious of others.

As a consequence the knowledge base of the industry is thinly distributed across a broad spectrum of organizations and countries. Effective communication is required to ensure industry members have access to a comprehensive portion of the available knowledge base in order to make informed decisions in a potentially high-risk environment. To the detriment of the industry "these transaction communications are mostly conducted with phone calls, faxes and drawings, which in the world of the Internet seems grossly inefficient." (Etiel, 2000)

The role of the architecture school is to introduce future AEC professionals into the industry. Experience in this role has illustrated the difficulties and inefficiencies involved with such a distributed knowledge base. To this end digital research at the School of Architecture, Victoria University is examining how AEC information can be effectively exchanged between a wide spectrum of users in order to improve the quality of the AEC industry's knowledge base.

## SEARCHING AND EXCHANGING VALUABLE AEC DATA

The need for an Internet based AEC specific information system has been identified in previous research. (Bloomfield and Amor, 2001) Generic Internet 'Search Engines' are incapable of handling the vast quantities of Internet based information, "the top 11 search engines together cover approximately 42% of the total (web pages)." (Bloomfield and Amor, 2001) Due to the overwhelming quantity of raw data, contemporary Internet search engine providers are unable to provide a concise and comprehensive service to a single professional body.

In order to be of benefit within the AEC industry searching for Internet based information must be more efficient than traditional equivalents. Contemporary Internet search engine efficiency is hindered by an inability to handle AEC semantics. Search engines index raw and unstructured data, eliminating the possibility of performing 'intelligent' searches on behalf of the AEC client. For example a typical search for "brick wall detail" would return tens of thousands of matching web resources. On closer inspection most resources would be concerned with Wall Street, Pink Floyd and numerous adult fantasies.

The paper "The Semantic Web" (Berners-Lee, Hendler and Lassila, 2001) addressed the growing realization that Internet based information would require globally accepted data structures in order to create "an environment where software agents roaming from page to page can readily carry out sophisticated tasks for users." (Berners-Lee, Hendler and Lassila, 2001)

An AEC Semantic Web would allow professionals to quickly locate and utilize valuable information through the use of AEC specific terms. In the previously discussed case an AEC search engine (software agent) would break down the term "brick wall detail" into its component parts of material (brick), element (wall) and scope (detail) before searching a structured AEC index for relevant resources.

Searching AEC data is made difficult as numerous parties hold pieces of valuable information in a variety of different formats. An open AEC index cannot be constructed in the manner of contemporary Web-based search engines. Most information is not available for indexing due to its proprietary nature and safeguards placed against its retrieval. A closed index is required that safeguards the commercial value of AEC information whilst allowing users to search and locate relevant Web Service based data as illustrated in Figure 1.

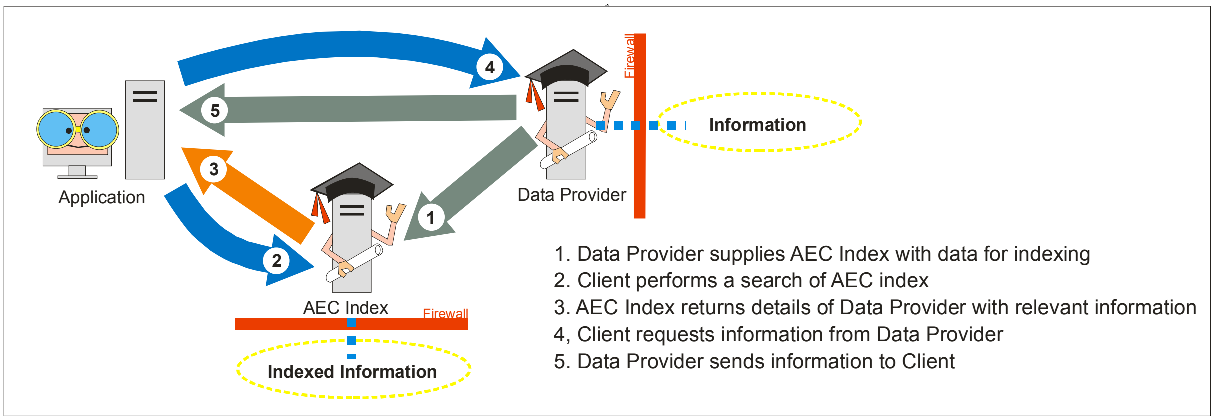


**Figure 1** Overview of Protected Index Required to enable searching of valuable AEC data

## WHAT IS A WEB SERVICE?

Any service provided on the Internet can be described as a Web Service. The most common services are search engines and electronic commerce websites. Initially Internet based services were offered via an Internet Browser and required the input of the user for initiation and comprehension.

To develop the potential for Internet-based services, various technologies have been developed to enable software to automatically engage with online services. Removing human interaction has enabled existing services to be made more complex and created opportunities for new types of Internet services. This rapidly expanding market has caused much debate in the Information Technology industry regarding how Web Services should be implemented and utilized (Morris, 2002).

To successfully provide a service two standard protocols are required. The first protocol describes the request for service whilst the second defines and enables the utilization of the request's output. For example, a client will approach an architect with a brief detailing the design criteria to be met within a set of limitations. The brief is defined through verbal or written communication in a common protocol (such as English). Once the brief is defined the architect produces a series of architectural drawings to satisfy the brief requirements. The drawings produced by the architect are in a format (protocol) understood by all practicing AEC professionals in order for the design to be built. If the client and architect cannot communicate in the same language or the documentation produced does not conform to prescribed standards the request for service will not be successful. In order to successfully request and communicate computer interpretable data structures Web Services rely on the same principles.

There are numerous tools available for communication between computers. Many of these tools are limited to a specific software/hardware platform and as such have limited potential in the field of Web Services. Current developments harness existing Internet technologies to create flexible, cross-platform Web Services. One such emerging Web Service technology is Simple Object Access Protocol (SOAP). SOAP enables software on almost type of computer to communicate and interpret complex data from another computer. This is achieved by exchanging structured messages in Extensible Markup Language (XML) over existing networks. These two features have enabled the standard to be developed and accepted throughout the Information Technology industry (Jones, 2001).

XML is a term given to plain text documents that adhere to a data structure set by global or local standards. Accepted data structure definitions are used to prescribe how an XML document should be formatted in order to portray some form of information. As XML documents have a defined structure they can be intelligently interpreted and created by computers and people.

A SOAP message identifies the sender of the information and the intention of the request. Software present on the computer interprets the message and if needed sets in motion any tasks required to complete the request. When complete a SOAP response with the resulting output can be sent back to the client where the process begins again.
To enable third party utilization the SOAP framework defines technologies for the description and searching of Web Services. These two technologies are Web Service Description Discovery Language

(WSDL) for describing services and Universal Description, Discovery and Integration (UDDI) for their indexing. Whilst UDDI is intended to enable basic searching of Web Services it is not intended for use within the complex AEC environment. "While this (UDDI) may work for toy applications like checking the weather, this is far from reality for applications like the inventory management example." (Ragaraman, 2001)

The creation of technologies such as SOAP has enabled complex Internet-based services to be incorporated within software applications. An application can now seamlessly identify and utilize services and resources offered by third parties. The ease at which Web Services can be developed, deployed and utilized has led to a multitude of free and commercial Web Service enabled software packages and services.

An AEC Web Service requires communication of AEC data in a globally accepted data structure to enable utilization by all parties. Industry Foundation Classes is an emerging standard for conveying digital AEC information. The International Alliance for Interoperability (IAI) is continually developing the standard to cover all aspects of the AEC industry. The IFC object model has been successfully mapped to XML (ifcXML) enabling IFC data to be communicated using Internet technologies such as SOAP.

Application within the AEC industry could prove to be the most fertile ground for the development of Web Services. As outlined previously this industry relies on the communication of fragmented information amongst a loosely linked collective of professionals. Web Services technology has been developed in order to achieve such a goal.

## A PRIMER FOR CONSTRUCTION KNOWLEDGE

Research related to the communication of digital AEC information began at the School of Architecture during the early 1990's with the Construction Primer. The Construction Primer is a concise construction resource intended for use by the New Zealand AEC industry. Conception of this project began with the observation that students lacked a concise resource to aid in their construction studies.

In order to assist future students, course work and research undertaken in construction was edited and collated into the Construction Primer, an encyclopedia of New Zealand construction terminology and building practice. For the last eight years student research (in the form of HTML documents with accompanying images, documents and video) were catalogued and made accessible over the Internet (http://www2.vuw.ac.nz/architecture/primer/). Figure 2 illustrates the Internet based Construction Primer and the variety of text, image and video based information available to the user.

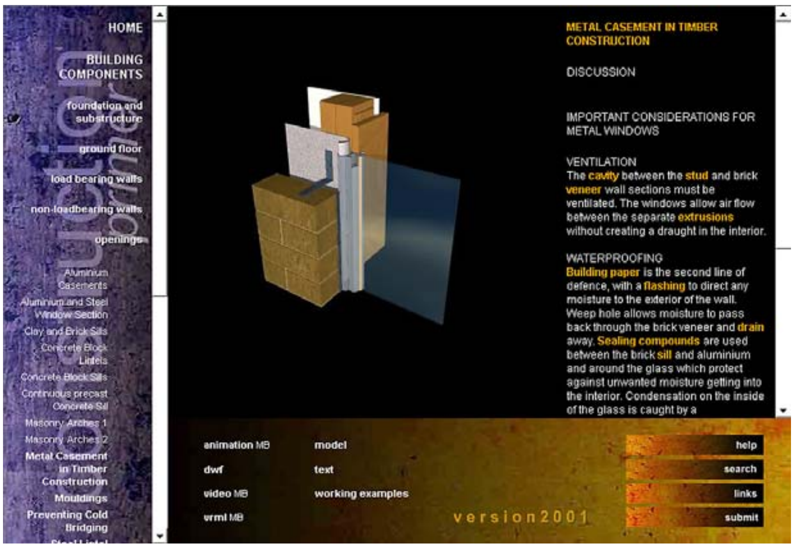


**Figure 2** The Construction Primer 2001 Web Interface

The Construction Primer proved an invaluable study aid and teaching tool for students and staff involved in construction related studies within the School. The Construction Primer also drew industry attention due to the clarity and variety of information it portrayed.

By 2001 the manual cataloguing process was proving unmanageable due to the amount of data involved and the inflexibility of HTML as a data storage medium. The HTML based nature of the documents also minimized search options available to the students, limiting the effectiveness of the resource. In order to provide a comprehensive service the information held within the Construction Primer was required in number of different web and print formats to suit the experience and working environment of the user.

The decision was made to shift the resource from a static set of documents into a dynamic web resource capable of being accessed by a number of different applications. XML based 'Web Services' were implemented to provide the most flexible utilization of the data.

The application of Web Services focused on linking existing data-sources from the three digital research strands within the School; construction (http://primer.arch.vuw.ac.nz), building simulation (http://www.aecsimqa.net) and structural systems (http://soadsd.arch.vuw.ac.nz:8080).
The design of the Web Service was to provide a concise tool for performing semantic searches of the existing data.

The creation of a Web Service 'gateway' to several data-sources separated the presentation aspect from the XML based data. This enabled efficient three-tier development to occur amongst several researchers as illustrated in Figure 3.

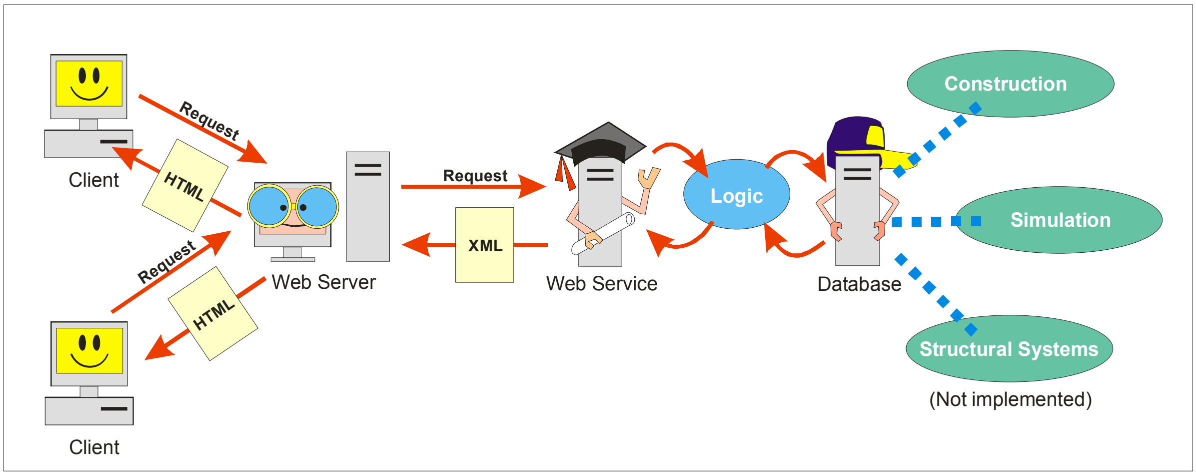


**Figure 3** Web Service Integration Strategy, School of Architecture, Victoria University

The strategy of linking and exposing the data-sources through Web Services was given the title of Architecture Information Database (AiD). The benefit of the AiD strategy was the flexibility of the XML data and the relative speed and efficiency with which applications could be created. A prototype AiD Web Service (http://aid.arch.vuw.ac.nz) and a proof-of-concept Construction Primer web application (http://rodgers.arch.vuw.ac.nz) were developed to explore the concept.

The application and underlying principles of the research was showcased to New Zealand industry members in April 2002. Whilst not a finished product the AiD concept did signal the potential benefits within the New Zealand AEC community for distributed information searching and exchange over the Internet. Several industry members expressed an interest in exposing their knowledge base using such a strategy. Their feedback however outlined the difficulties faced when exchanging and searching valuable information over the Internet. All industry members required profit to be made from the sale of their information and in order for this to be achieved the service had to embody e-commerce principles within an industry accepted data format to guarantee investment return and utilization.

## INITIAL STEPS TOWARDS A WEB SERVICE ENABLED INDUSTRY

Industry Foundation Classes and Web Services have begun to be implemented within the digital tools of the AEC professional. Several leading CAD applications now import and export IFC data to various simulation, quantity estimation and management applications.
At the workgroup level the IFC Model Server development (Adachi, 2001) employs Web Services and the IFC model to provide a cross-platform interface to information present on the server. The utilization of these technologies has simplified the server's development and ensured support from the wider AEC software community.

Whilst the IFC Model Server is targeted at the workgroup, an information framework is required that binds individual data-sources to enable efficient searching and exchange of AEC data across unrelated organizations and countries. This framework should implement the technologies already present within emerging AEC software tools and information systems. Just as Web-based search engines spurred the growth of the Internet, such a framework would foster information exchange and encourage binding of the AEC knowledge base.

## LINKING KNOWLEDGE ISLANDS THROUGH aecBEDRock

"In construction it is essential to rely on past knowledge and information when dealing with new projects. The implication of this theme is that the industry will require strategic systems, which allows capturing of previous knowledge." (Amor, Betts, Gustav and Sexton, 2002)
The School of Architecture has proposed aecBEDRock (Built Environment Data Repository) as a conceptual model possible of fulfilling the requirement for a strategic AEC data framework.

Figure 4 outlines the major components within the concept. The basic operational flow would follow the series of events as outlined in Figure 1. The goal of this framework is to link current and proposed AEC data-sources with an open, Web Service based interface tied to a privately held search index.

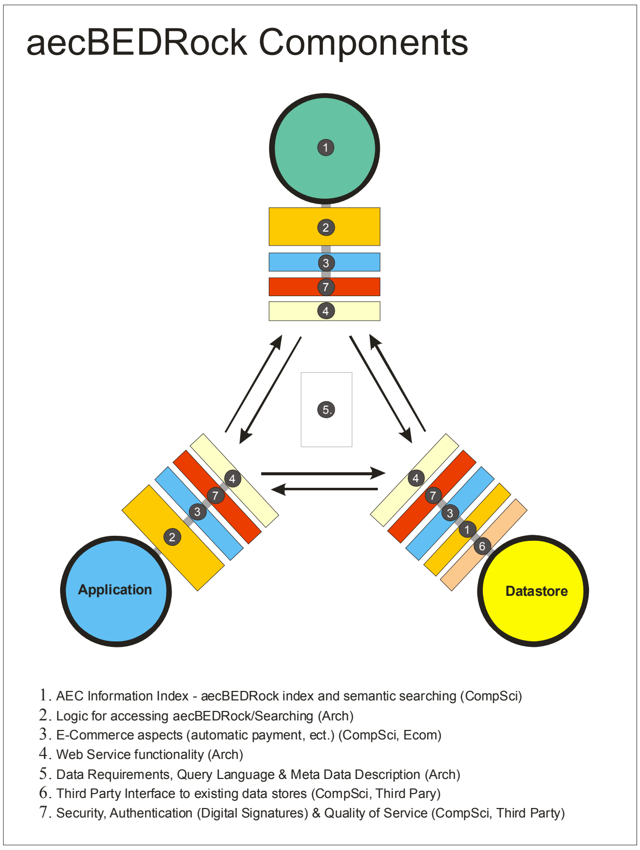


**Figure 4** The basic components behind the aecBEDRock concept

The AEC information network would be created by SOAP Web Services exchanging XML formatted Industry Foundation Classes (ifcXML) data. The Web Service would establish a common interface between the different platforms and handle electronic commerce, security and authentication issues. These tasks would be achieved by international XML standards in development such as ebXML. As long as information was exchanged in accepted data structures the exposed information could be utilized globally.

With a Web Service network in place formal agreements could be established between knowledge providers and third parties to enable the creation of privately held indexes of data. The indexes could cater for distinct markets through unique interpretation and categorization methods. Such a system would allow users to perform searches based on a specific classification system or semantic interpretation. This is preferable to adopting a global classification or semantic system as national and cultural differences make this objective impossible.

The XML data within Web Service requests could convey complex semantic concepts, enabling intelligent searches to be performed on the search indexes. A search index would interpret the search request and respond with a list of globally unique AEC resource identifiers pointing to data fitting the search parameters. The AEC resource identifier would be based on the same principles as the Internet based Unique Resource Identifier (URI). Each identifier would point to a specific piece of information on an AEC data provider. A standard methodology for categorizing AEC resource identifiers (for example by project or component) would enable AEC data to be easily recognized and accessed. To attain required information a Web Service for the information provider would be queried. Once financial and security concerns had been satisfied the requested information would be sent to the client in ifcXML format.

Transportation of the information in an accepted AEC XML data format would enable the creation of very flexible client environments. Software could interpret the AEC data for publishing to Internet browsers, CAD, virtual reality systems, WAP enabled cellular phones, office applications and print formats such as Adobe PDF files. The flexibility offered by such a system would open numerous avenues of development for the use of AEC information within the workplace.

Best practice guides could be sent directly to the builder's cell-phone using a pay on demand system. Architects could bring up government regulations directly within their CAD environment whilst they construct object-based models from components linked directly to the manufacturer's specifications. The code and resource sharing functionality of Web Services would minimize the development burden of these applications, and as the World Wide Web has shown, the possibilities for such a network would be limited only by our imaginations.

## FUTURE RESEARCH AT THE SCHOOL OF ARCHITECTURE

The aecBEDRock concept model illustrates the idealistic but long-term goal held within the School of Architecture for a unified AEC digital information network. Industry Foundation Classes and Web Services are potential building blocks for realization of this concept. In the immediate future postgraduate research at the School of Architecture intends to explore the real-world potential for these Information Technologies. This exploration will include both the handling and end-user application of distributed AEC data.

Before future applications and information systems are developed, research in association with the Building Research Authority of New Zealand (BRANZ) will attempt to identify areas and practice within the New Zealand AEC environment that stand to be improved through the provision of Information Technology tools. This 'back to basics' approach will ensure future research is focused on real, rather than perceived shortcomings within the industry. Similar research in this field of study has failed to be integrated into the industry. This could be attributed to aspects of the research being inattentive to end user requirements (NATSPECC//Construction Information, 2001).

The intention of future postgraduate study within this field is to ensure research theory and models developed can be successfully applied within the AEC industry to enhance communication quality and the knowledge base within the industry as a whole. The successful application of research requires a strong practical grounding in order to achieve the most beneficial results.

“A common complaint heard from academics and software vendors is that those involved in the construction industry are resistant to change. I feel that this does a disservice to many professional people who are not so much ‘luddite’ as realists. They will not take on technology because it is new, but because it is beneficial.” (Wix, 2000)

## CONCLUSION

Web Services have been developed by the Information Technology industry to enable cross-platform communication of complex data. This technology holds significant potential within the highly fragmented Architecture, Engineering and Construction (AEC) industry. For the implementation of AEC Web Services to be successful a standard AEC digital data structure, such as Industry Foundation Classes is required to enable the communication to be interpreted by all parties.

A strategic framework that enables exchange of valuable AEC structured data across organizations would increase the cohesiveness of the industry’s dispersed knowledge base. Once structured information exchange is achieved, complex AEC specific search indexes can be constructed to enable the semantic searching of valuable AEC knowledge. The ability to efficiently search and exchange AEC knowledge would potentially increase the quality of the construction process through increased professional awareness and efficiency.

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