

STATE-OF-THE-ART INTERNET TECHNOLOGY IN SINGAPORE'S CONSTRUCTION INDUSTRY

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SUMMARY

With the increase in popularity of the use of Internet technology, more and more web-based applications are being developed and adopted by the construction companies. This paper describes the efforts of the Singapore government and individual players in improving the management efficiency of the construction industry through the use of information technology, particularly the Internet service, in the various stages of the construction process. Users, who need to incur large expenses in order to upgrade the manual operational procedures into a computer-driven way of operation, may not be totally satisfied with their investment. Some enhancements to the existing IT tools are expected. An empirical study was conducted in May 2002 to determine the as-is and to-be features of the current Internet tools, the awareness and expectations of the users in Singapore's construction industry. Generally, players in the construction industry are aware of the benefits and potentials of IT tools, but are apprehensive about the investment cost, security and IT infrastructure constraint. Improved speed of data transfer and the incorporation of intelligent and task-based features in the design of future ASPs and web-based construction-related systems are two main concerns among the users.

INTRODUCTION

Since the launch of Information Technology (IT) initiatives in 1981 with the ultimate goal of transforming Singapore into an intelligent island, IT has permeated every aspect of the society - at home, work, and play (Chun, 1997). More advanced technology is being involved now: Internet technology and broadband networks, multimedia, telecomputing, and technical standards (Chun, 1997). The implementation of IT tools in the construction industry was still in an early stage. A study that can identify the existing problems or shortcomings of the tools currently in use, and the users' expectations can further help the industry to make improvements in this area and to achieve a quantum leap in its drive for higher productivity and modernization. The findings are useful for public and private organizations that are keen to re-engineer the business processes of the construction industry, software vendors who intend to upgrade their computer products and to meet the greater needs of the customers from the construction industry.

WEB-BASED COLLABORATION

The use of Internet for exchanging information in a collaborative work environment has become very important and more so in years to come. Web-based collaboration is ideal for the fragmented nature of the Architectural, Engineering and Construction (AEC) industry, since it is cheap, widely available and not too difficult to use. Extranet operates as a restricted private network and uses the public telecommunication system to share part of a business's information or operations with suppliers, vendors, partners, customers, or other businesses. In the AEC industry, where abundant information, graphical data and instructions need to be communicated among companies, an extranet can link together the owner, architect, engineer and contractor through a project-specific Website. This enables instantaneous information exchange, more accurate accessibility of project documents.



Commercial web-based collaboration solutions are provided by Application Service Providers (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/>), to name a few .

The features of the current web-based collaboration systems, also called as-is features, can be divided into 7 categories: general system; document management; workflow management; administration; user centric workplace; team communication; and ASP server performance. The category of general system includes some general features that do not fall into any specific category, such as public project web pages; project cloning; links to AEC industry information services; and web camera on site, etc. Document management contains features that manage files generated by various applications, which include remote viewing, printing and commenting of files through web browsers; document revision control with file locking and check-in/check-out; handling external references for CAD drawings; and digital approval, etc. A workflow is a process that involves collaboration among project players, e.g., the process of approving a change. Standardized workflow management is achieved through the use of web-based forms and templates. Other features include integration with e-procurement; issues linking; automatic generation of customizable reports; and tasks management, etc. Administration is done by the so called Chief Information Officer (CIO), whose duty is to manage the project web throughout the whole process of web site utilization. The features for administration include access control; auditing; set-up of project website templates, workflow and other project specific business logics; and task allocation, etc. A user centric workplace is similar to the desktop of an operation system, such as Microsoft Windows. It can be customized according to the user's working habits. These features include customizable interface; headlines page; multiple languages support; multi-project support; drag-n-drop, and right-click, etc. Team communication is Internet enabled communication, such as email, instance messaging, discussion forum, online conferencing, etc. These features provide supplementary information for formal communication. Compared to traditional communication means such as phone call, fax, and face-to-face meetings, the team communication features have the advantages of low cost, fast speed and traceable record. Server performance is a very important factor for evaluating the quality of ASP services. Since all services are Web-based, the availability of project website, the browsing speed, the file transfer speed, and the data security against external hackers are all factors that have significant impacts on the project team's activities.

The to-be features are those under development, which act as the general research directions of web-based collaboration systems. These features have been classified into 8 categories: time and cost consideration; integration; searching for information; knowledge base and intelligence; customizability to persons; customizability to projects; scalability; and others. Time and cost considerations include short set-up time and low cost; and short learning time for common tools. Integration is provided throughout project life cycle, with company database, and with project model, interoperability through AEC industry-wide standards for related information, etc. Intelligent search for information means quick access to and efficient updating of required information; searching for valuable information from various sources; and synthesizing related information in different documents to form a new, complete information for decision making. Knowledge base means accumulating acquired knowledge for future usage; incorporating into decision support system, supporting what-if analyses; and generating reports for decision-making. Customization to user allows for personalized interfaces; displays information from different perspectives tailored to a user's role. Customization to projects means the ASP solution is suitable for all kinds of projects varied in size, type and degree of complexity. Scalability means the ASP solution is usable for both low and high speed Internet connection, compatible with files generated by software of different versions, and extensible to accommodate the developing applications, such as e-plan-checking. Other useful features include protection of knowledge proprietary, and supporting division of responsibilities among team members. From the perspective of technology, 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.

EFFORTS OF SINGAPORE GOVERNMENT AND ENTERPRISES

Construction and Real Estate Network (CORENET) is a major IT initiative led by the Ministry of National Development and driven by the Building and Construction Authority in collaboration with other public and private organizations in Singapore to improve the overall productivity in the construction industry. The system provides an important infrastructure that integrates the four major processes of a building project life cycle: design, procure, build and maintain. To date, 3 main functions of the CORENET, viz. Electronic Submission System (eSS), Electronic Information System (e-Info) and Electronic Buildable Design Appraisal System (e-BDAS) are available for use by the developers, consultants and contractors in the construction industry. The e-Submission function allows electronic submissions and processing of project-related documents to the governmental agencies for inspections and approvals. The e-Info provides construction related resource information, such as codes, regulations, guidelines, standards, product catalogue, contractor performance and Singapore standards. The e-BDAS is an electronic tool that allows industry professionals to compute the buildability scores of their projects while at the same time check for compliance of building plans against the "Code of Practice on Buildable Design". Other functions of the CORENET, include IT standards for Computer Aided Design; and legal framework for data security.

At present, 5 major local ASPs are in use in the Singapore construction market: Cyber-IB (<http://www.cyberib.com/>), CXHub (<http://cxhub.com/>), HDBuilders (<http://www.hdbuilders.com/>), icFox (<http://www.icfox.com/>), and icx123 (<http://www.icx123.com/>). Among them, icFox forms a strategic partnership with Citadon and applies its collaboration solution; while Cyber-IB partners with AutoDesk. The icx123 and CXHub are mainly information providers, but do not focus on project management services. HDBuilders has a local technology partner, who develops web-based solution targeting at the local contractors only. It extends the open bidding system (e-bidding) of public projects to main tenders, who can submit as many bids as required to arrive at a competitive bid. The Singapore local portals provide various services in e-commerce, e-project management and information exchange for the local construction industry. Their effectiveness and impacts on the construction industry are yet to be determined.

THE WEB-BASED SURVEY

This section reports on a survey that was conducted to find out the general awareness, satisfaction levels, and expectations of Internet services and ASP among users in the Singapore AEC industry. This is to offer feedback and future improvements in the area of Internet technology development for the construction industry.

Sample frame

The survey targeted at high educational-level professionals in the AEC industry who have greater exposure to such sophisticated IT tools. The randomly selected respondents have sound construction knowledge, and are the most likely persons that are actively involved in IT applications in construction. A total of 284 companies in the construction industry were invited to participate in the survey. Of the 47 responses received, 30 are complete and are deemed suitable for the analysis.

Survey methodology

The survey was conducted via the Internet (<http://annaliang.hypermart.net/>), first as a pilot survey and then a final survey. The results of the pilot survey were excluded from the final analysis since it was to troubleshoot format and content problems in the structured questionnaires.

The survey was conducted as web-based rather than paper-based because the former, with hyperlinks and java scripts, can conveniently direct the readers to designated webpages where relevant examples, explanations or instructions are provided. Results from the pilot survey showed that without web-based examples the respondents could not really understand the ASP features explained in plain texts. With java scripts, definition of a terminology is automatically displayed when a respondent points the cursor at it. The use of hyperlinks helps the web-based survey form to

produce screen shoots (Figure 1) and animated demonstrations in the form of live examples in order to explain almost every ASP features, which can never be made clear by paper-based survey.

3.6 How do you find / expect the usefulness of the following ASP features for construction project management? (You may CLICK on the URL to see an example of that feature.)

	Very Useful	Useful	Neutral	Not So Useful	Not Useful At All	Not Sure (Pls Explain)
General System						
Public homepage introducing the project to the press;	<input type="radio"/>	<input type="text"/>				
Links to construction industry information services (e.g. Corenet e-info);	<input type="radio"/>	<input type="text"/>				
Web camera on site.	<input type="radio"/>	<input type="text"/>				
Application Support / Document Management						
Supporting multiple file formats;	<input type="radio"/>	<input type="text"/>				
Remote viewing, printing and commenting of files;	<input type="radio"/>	<input type="text"/>				
Handling external reference for CAD drawings;	<input type="radio"/>	<input type="text"/>				
Digital approval of drawings and documents;	<input type="radio"/>	<input type="text"/>				
Searching documents with intended criteria, e.g., name, author;	<input type="radio"/>	<input type="text"/>				
Accessing project information using PDA.	<input type="radio"/>	<input type="text"/>				
Workflow Management With Templates						
Drawing management with version control;	<input type="radio"/>	<input type="text"/>				
Integration with cost and accounting software;	<input type="radio"/>	<input type="text"/>				
Integration with scheduling software;	<input type="radio"/>	<input type="text"/>				
Supporting change management;	<input type="radio"/>	<input type="text"/>				
Archiving daily communication;	<input type="radio"/>	<input type="text"/>				
Auto compressing files when up-/down-load.	<input type="radio"/>	<input type="text"/>				
Administration						
Controlled access to site by user name and	<input type="radio"/>	<input type="text"/>				
Controlled access to files according to user'	<input type="radio"/>	<input type="text"/>				
Document log for versioning, revision control;	<input type="radio"/>	<input type="text"/>				
User activity log showing login time, up-/down-	<input type="radio"/>	<input type="text"/>				
User Centric Workplac						
Headlines page with new information highlig	<input type="radio"/>	<input type="text"/>				
Multiple languages support (English, Chinese	<input type="radio"/>	<input type="text"/>				
international projects;	<input type="radio"/>	<input type="text"/>				
Easy access to multiple projects with single	<input type="radio"/>	<input type="text"/>				
Drag & drop, right click.	<input type="radio"/>	<input type="text"/>				

Figure 1 A Screen Shot of the Survey

SURVEY FINDINGS

Respondents' profiles

Among the 30 respondents surveyed, 23.3% are clients, 50% are consultants, 16.7% are contractors and 10% are academics. None of the respondents is a supplier or manufacturer. Of the profile of the respondents, 26.7% are senior executives, 50% are construction-related professionals, 13.3% are site management staff, 10% are full-time students, but no one is IT-trained. Of the respondents, 70 % have 2 to 10 years of construction-related working experience, 23 % have been working for more than 10 years and only 7% have less than 2 years working experience. The above findings reveal that the respondents are construction domain experts, rather than IT experts. They have sufficient working experience and construction related knowledge to understand the usefulness of IT and ASP as a tool for their work.

General use and networking

Among the 30 respondents, 80% report that their companies have homepages on the Web, most of which are for company introduction (70%), customer services (33.3%), recruitment (26.7%), business marketing (23.3%) and project collaboration (16.7%). Another 10% of the respondents select "others" and indicate that the functions are for online project cost management and information sharing, which is the same as project collaboration. Only 3.3% or one respondent uses their homepage for open tendering, while none uses it for e-procurement.

Since the survey is web-based, all respondents have one or more means to access the Internet,

unlike a few years ago when modem was the most popular means (Rivard, 2000). Today, ISDN (Integrated Services Digital Network) and broadband constant connections are becoming more and more affordable. Among the respondents, 44% use constant connections in their firms, 33% use ISDN and the remaining 23% use modem. No one uses wireless connection.

For internal information system, 87% of the respondents' firms have their own local area network. For maintenance of the IT systems, 30% of the respondents' firms have full-time IT management staff, 40% have IT staff with other responsibilities, and the remaining 30% do not have such an assignment. Approximately 82.7% of the respondents use computer in their work, 76.4% makes use of electronic mails and 57.2% utilize Internet for their work. However, using wireless mobile phone web access such as WAP (Wireless Application Protocol) phone or PDA (Personal Digital Assistant) at work is not common.

Most of the construction related documents are still being exchanged in traditional means using papers, mails (74.6%) and fax (44.2%). However, exchanging documents using email has become a more common practice (43.3%). Respondents believe that the use of IT can speed information transfer. They also reckon that IT can provide more useful information, reduce mistakes in documentation, decrease construction variations and lower difficulty of project coordination.

Uses and acceptance of ASP

The survey makes use of scaled responses to capture the subjective evaluations. In the case where there are several scaled answers to the questions, for example, "Very Useful", "Useful", "Neutral", "Not So Useful", "Not Useful At All", and "Not Sure", to compute the mean value for the rating, a numeric value from 5 to 0 is assigned to each response, with 5 as the highest rating ("Very Useful") and 1 the lowest ("Not Useful At All"), while 0 for "Not Sure". The mean value is then calculated by using the following formula:

$$\text{MeanValue} = \left(\sum_{i=1}^n \text{value}_i \cdot \text{Count}_i \right) / \left(\sum_{i=1}^n \text{Count}_i \right) \quad (1)$$

In the following discussions, the mean values are indicated in brackets. Two thirds of the respondents state that they are using or intend to use the ASP to exchange information among the project team. However, their colleagues' overall willingness to use the solution is most likely to be neutral or slightly involved (3.7). Main perceived benefits of adopting ASP include cost saving, efficiency, better communications, and well-organized and complete documentation (Figure 2). The use of ASP has not been required by client, nor regarded as the means for competition. Major concerns are high investment costs, risk on data security, greater know-how required from staff, and IT infrastructure constraint (Figure 3).

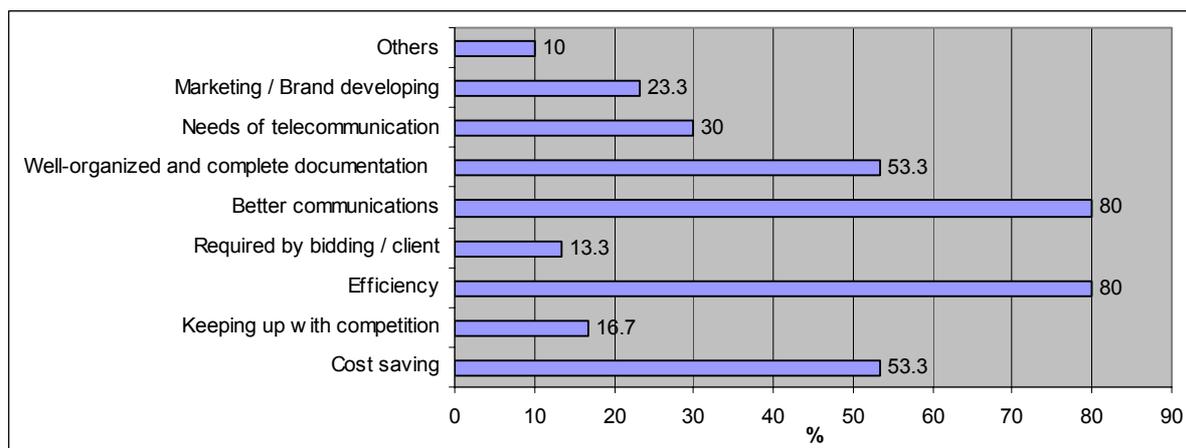


Figure 2 Major Benefits of Using ASP

This means that the development of ASP in Singapore is still in its initial stage. People are more concerned with investment and infrastructure than the solution itself. However, standardization has also been stated as a major concern, which demonstrates the urge to have a common platform for heterogeneous information exchange.

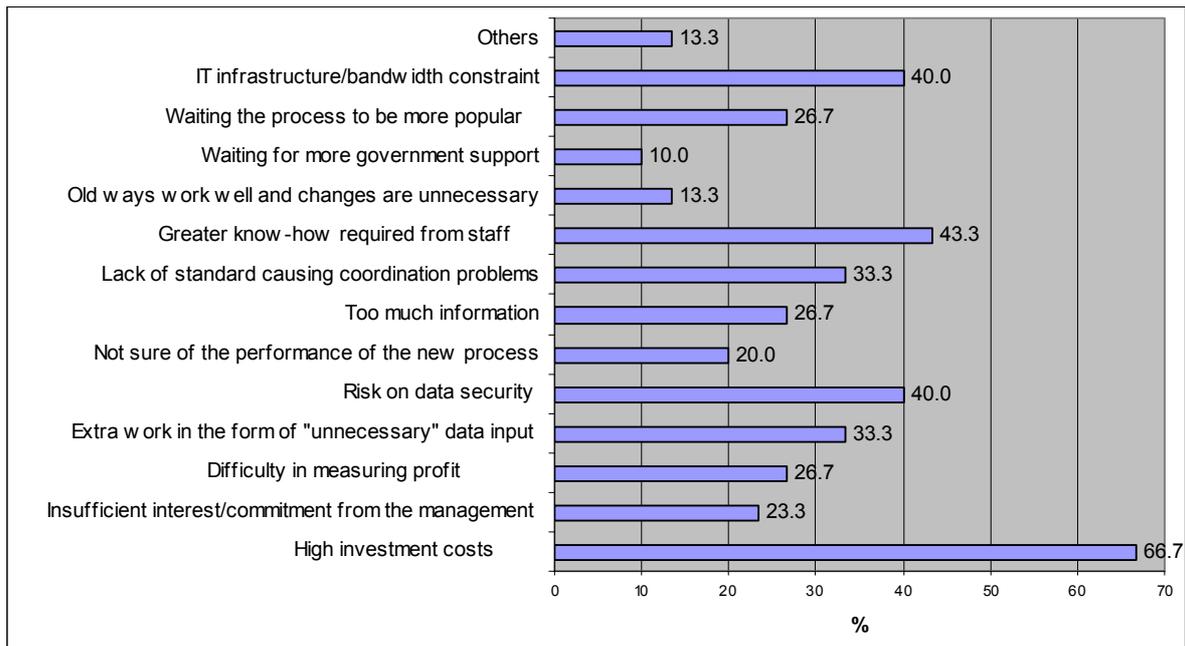


Figure 3 Major Concerns of Using ASP

Awareness of ASP

The result of general awareness of ASP is rather disappointing. Among the listed 5 local ASPs and 11 international ASPs, only 3 respondents' firms have used one or more of them. They are Primavera, eRoom, CXHub, and Buzzsaw/Autodesk. Two respondents know two other solutions that are not listed. Five respondents do not know any of the 16 ASPs. Most respondents know about 3 to 5 ASPs, namely, HDBuilder, Primavera, icx123, icFox and Cyber-IB. None of the 5 local ASPs is used by the respondents for collaboration purpose.

As for the three Internet-based construction services in Singapore, most respondents use or learn about the Corenet e-Info (73.3%) and two the Corenet eSS (63.4%). Only 40% use or learn about the e-bidding services of HDBuilders.com (Figure 4).

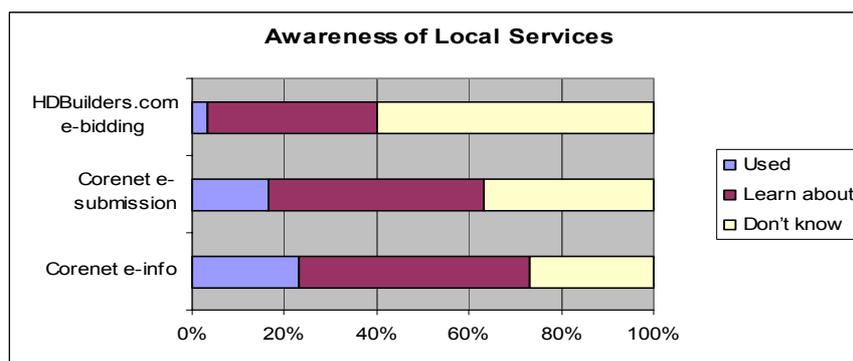


Figure 4 Overall awareness of local services

Very few of the respondents have knowledge about ASP. Players in the construction industry welcome the C21 thrust (1999) which is a strategic blueprint that spells out the vision and strategies to re-engineer Singapore's construction industry. To the practitioners in Singapore, it is only a matter of time the business processes will be standardized with greater use of IT. They are, in general, aware of the potential power of the Internet, but are actually waiting for the technology to be commonly accepted by the industry, like the ubiquity of AutoCAD, before they are willing to put efforts into implementing it in their firms. A respondent commented on this:

"Until standardization is in place - at least down to 2 major systems and at least 99% certainty of the ASP's long term survival to protect our investment and reduce disruption to service, it would be

difficult to convince management to adopt ASPs. I suspect that at this moment, many CEO's are giving the ok without being fully aware of the risks."

Due to a low degree of awareness of ASP and Internet-based services, the evaluations of ASP features are more of an expectation than a fact.

Expected impacts on time

By adopting the ASP, the time spent on all the 8 listed activities at work is expected to be reduced. Some are expected to be shortened greatly, while others shortened only slightly (Figure 5).

Among the three physical activities (attending meetings outside the firm, making site visits, traveling overseas), the mean value computed using equation 1 for traveling overseas is the highest (3.8). This means that ASP is expected to be most useful when applied to projects that are across national borders. The time spent on making site visits is expected to be reduced slightly (3.3). It is unclear whether the respondents are unaware of the site web-cam feature of the ASP solution, or they do not believe that web-cam can substitute physical visits to sites.

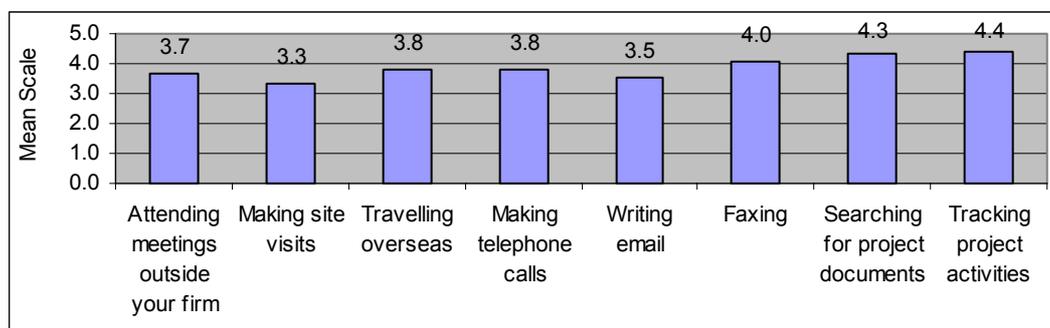


Figure 5 Mean reductions in time (minutes) with the use of ASP

Note: Mean Scale is 5.0 = Much Less Time; 4.0 = Less Time; 3.0 = Same Time; 2.0 = More Time; 1.0 = Much More Time; 0 = Don't Know.

Among the three communication means (making telephone calls, using emails, and faxing), time on faxing (4.0) and making telephone calls (3.8) is expected to reduce greatly but time on using emails will only reduce slightly (3.5). About 44.2% of construction documents are exchanged through faxing. The document warehouse function of ASP is similar to document exchange by faxing. Therefore, it is possible that ASP will partially substitute faxing. Email has become a common practice in the Singapore construction industry (43.3% of construction documents are exchanged via email; about 76.4% of the employees in the respondents' firms are using email for their work). The trend is that people will prefer email to phone call when written records are needed. They will also prefer email to faxing when a softcopy is better than a hardcopy. Therefore, time on using email is not expected to reduce much after applying ASP.

Two "soft" activities, searching for project documents (4.3) and tracking project activities (4.4), are expected to be most efficient with the help of ASP. This is true because ASP provides well-organized and complete documentation, which eases the search of information and the tracking of project activities.

Evaluation of as-is features

Major features are listed in each category, with a screenshot hyperlinked from a commercial ASP website. The respondents are asked to evaluate each category, instead of each feature. They are expected to evaluate the usefulness of the concept rather than each detailed features. Four of the 7 categories (Figure 6) are considered very useful: document management (4.4); workflow management (4.4); administration (4.3); and team communication (4.4). They are the cornerstones of a collaboration system.

Evaluation of to-be features

In this evaluation, a mean value of 5 represents very useful. Among the 9 listed categories (Figure 7), the very useful to-be features are time and cost consideration (4.2); integration (4.2); intelligent search (4.2); and knowledge base (4.1). The improvements of these features are most likely to have the interests from the common users. They represent the research direction in the future.

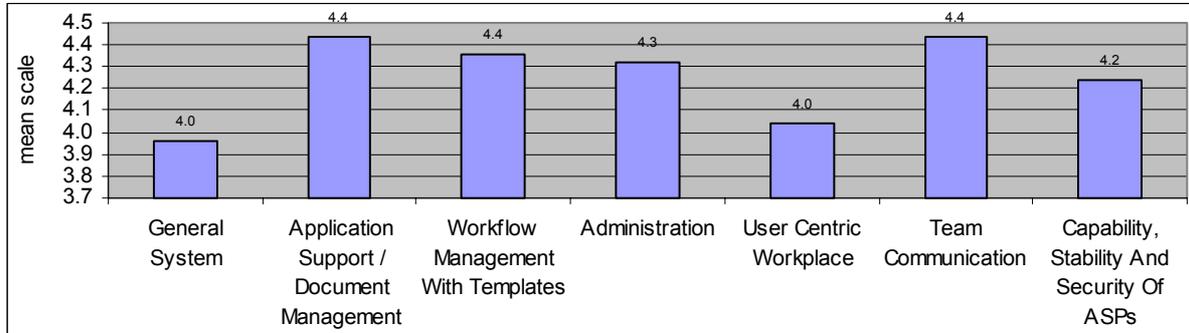


Figure 6 Evaluation of ASP as-is features in terms of mean scales

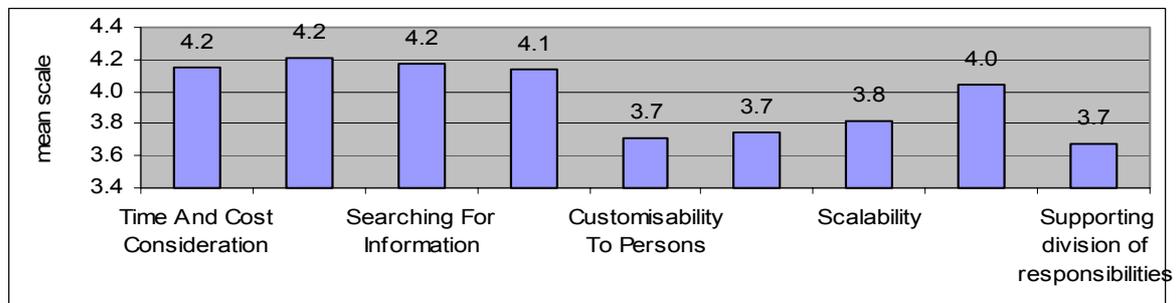


Figure 7 Evaluation of ASP to-be features in terms of mean scales

CONCLUSIONS AND RECOMMENDATIONS

Information technology represents a paradigm shift with respect to the way we design, procure, build and maintain buildings. Adopting the new technology and adapting to the change is the best way to leap forward and re-engineer the industry. With the state-of-the-art developments in IT, and the government's keen interest and support, many local industries are poised to process re-design. The construction industry, in particular, should make use of the current technology to help shed its traditional image as an unproductive and unprogressive sector. The industry stands to gain much from learning about and applying the advanced technology to improve the processes of construction.

It is clear from the survey that the most significant impacts of IT on the construction industry are faster information transfer, reduction in difficulties in project coordination, better means of communication, and easier and faster access to common data. Although the Internet has been adopted by most firms surveyed, a lot of information is still exchanged in its traditional means.

Email is the most common electronic means of exchanging information, but it is somehow hindered by huge graphic data files that slow down the speed of information transfer. There is a great need to develop some fast and powerful network systems that can handle this type of data, and large text documents without sacrificing on the speed of transfer or downloading time from the Internet so as to encourage more user participation.

The development of web-based collaboration in the Singapore construction industry is still in an initial stage. Many recognize the benefits of adopting ASP which include cost saving, efficiency, better communications, and well-organized and complete documentation. Major concerns are high investment costs, risk on data security, greater know-how required from staff, and IT

infrastructure constraint. By adopting the ASP, the amount of time spent on various project management activities is expected to be less.

Some ASP as-is features that are regarded very useful are document management; workflow management; administration; and team communication. The categories of ASP to-be features that are considered very useful include: time and cost consideration; integration; intelligent search; and knowledge base. Intelligent features such as direct notification of relevant parties following an event or schedule; automatic updating of work schedules; documentation of important evidences for verification of claims, and the like should be incorporated into the design of future ASPs and web-based construction-related systems.

With the advancements made, the remaining obstacle is a mind set change among the players in the construction industry to adopt the new technology for their work.

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