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An application of the Internet-based project management system

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Abstract

The great advance in information technologies (IT) and the availability of a wide range of software in recent years have brought many changes in the construction industry. The Internet, a new member of IT, offers a medium with new opportunities to manage construction projects. This paper describes an Internet-based project management system called ''Total Information Transfer System'' (TITS). TITS comprises six major functions including data exchange, information exchange, Internet chat, live video-cam, search engine and auxiliary services. TITS is demonstrated for project monitoring with a real-life project. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Construction communication; Information technology; Internet; Project monitoring

1. Introduction

The construction industry has a multi-party nature, with its project success relying heavily on timely transfer of information among the parties involved such as owners, project managers, contractors, designers [11]. It is also one of the most information-dependent industries, among others, with its diversity of forms of information which include detailed drawings and photos, cost analysis sheets, budget reports, risk analysis charts, contract documents, and planning schedules. The amount of information generated and exchanged during a project lifetime is enormous even for a small-sized construction project. Timely and accurate information is important for all project participants as it forms the basis on which decisions are made and physical progress is achieved. However, the distance between headquarters and construction sites further augments the communication barrier to achieve timely and accurate information transfer. This is more evident in construction projects carried out far away from headquarters. Wasting of time and cost in construction projects can be traced back to poor coordination caused by inadequate information — insufficient, inappropriate, inaccurate, inconsistent, late, or a combination of them all. This occurs despite the remarkable advancements in information management, handling, storage and exchange techniques. Thus, improving communication among project participants and management headquarters is always the key factor leading to the success or failure of a construction project.

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2. Background

In recent years, there is a trend that more engineering, design and construction companies are operating at a national or international level [10]. Many construction projects managed by Hong Kong construction firms were carried out overseas such as in Southeast Asia or Mainland China [12]. This fragmentation of the construction process certainly affects the project decision-making process. The physical distance between headquarters and project sites generates communication barriers. In addition, the variety of communication media and modes in construction further augments communication difficulties. Messages are sometimes distorted or delayed. Further, using long distance calls or overseas facsimile is very costly, so it is expensive to collect, maintain and update the information for overseas construction sites.

3. Related work

According to a recent survey [8], Internet-based or Internet-related information technology (IT) solutions were reported to be very useful at varying degrees in the construction industry. These solutions include E-mail, sharing files with E-mail attachment, shared databases, Intranet (internal Internet), and Internet (World Wide Web, WWW). Among those solutions, E-mail was reported the most useful application with 83% responding facility managers in Fortune 500 firms finding it very useful, and Internet was considered as emerging technology with 15% responding rate. Without exception, all solutions were expected to become more useful in the next 5 years. Internet was considered as having a great potential in the construction industry with 48% respondents indicating that it would become very useful in the next 5 years.

Internet-based solutions to construction project management have been recommended by researchers [6,14]. A WWW-based construction daily reporting system has been reported [10]. The system used Hyper Text Markup Language (HTML) as the foundation for storage and retrieval of construction project information which can then be easily shared by project participants at different geographical locations. Fruchter and Reinter [5] proposed a model-centered World Wide Web Coach (WWW Coach) which uses a shared CAD project model to guide and customize the collection, organization and sharing of relevant network information services. Some Internet-based applications are also reported [3], such as allowing real-time dialogue between interested parties and project monitoring; remotely monitoring the remediation of contaminated groundwater; and coordinating efforts to investigate and remediate environmental damage. The WWW has also been used to expedite the internal communication process within the firm [1,2,9].

The use of Internet as the communication platform can help information transfer more effectively during the construction process. Internet provides speedy information transfer, so messages can not only reach the recipients more speedily and accurately, but also can be traceable. Besides its speedy transmission, it also saves money in communication with overseas construction sites through the computer network, as compared to the traditional information handling methods, because the cost of using the Internet services is much lower than that of the IDD and express courier services. Internet is a global network which is not restricted by locations, time or different computer-operating systems. In summary, using Internet networking system for construction project management is more effective.

4. Total Information Transfer System (TITS)

An Internet-based project management system called TITS has been developed [12]. TITS has used Linux (UNIX Platform) and Microsoft Windows ’95 (PC Platform) for setting up the information transfer system. Linux can provide a multi-tasking environment to handle the complex construction information while Microsoft Windows ’95 provides a common and user-friendly computer-operating system. Followings are the brief introduction of six major functions of TITS with the detailed description of the system in Tam [12].

4.1. Data exchange formats for construction: File Transfer Protocol (FTP) and Telnet

The major data exchange tools provided by the system include Telnet and FTP. First, the Telnet protocol allows an Internet user to log in to a remote host from his local host computer. While running Telnet, the program effectively makes the local computer invisible during the session on the remote computer. When the remote log in session terminates, the application returns the user to the local system. Telnet is a powerful tool in resource sharing and multi-tasking. Similarly, due to its direct connection to the remote system, the system can provide a cheap and efficient method to get information compared with fax, phone or post.

FTP is a way of sending files across the Internet. This function enables file transfer from one computer to another, even if each computer has a different operating system and file storage format. Once logged into the Internet FTP system, files can be transferred to the directory of the user's computer in a relatively short time. Users can only access the directory in which a password has been registered. This can ensure the security of information. File transfer across the Internet is reliable because machines involved can communicate directly, without relying on intermediate machines to make conversions.

To overcome the physical separation of construction sites and headquarters, Telnet and FTP give a good solution which enables construction sites to communicate with the headquarters. Site staff can use a personal computer connected into a local Internet service provider via a modem to remote log in and control the information in the head office. For example, users can log in their Internet account in Beijing and get the drawing files or view a CAD drawing through the Web browser from the headquarters in Hong Kong within minutes.

4.2. Information exchange: E-mail

Electronic mail allows users to send messages electronically to individuals or groups of people. E-mail can almost reach every corner of the world as the coverage of Internet expands. E-mail is a popular form of information exchange and may become one of the core technologies for data exchange and sharing in the future [4]. E-mail can be used as informal communication within and between organizations. Companies can define E-mail applications in the transition of data through an organization and keep track of its progress [7].

However, communication in the construction industry is complicated by its structural problems. For example, design drawings are always amended. The revised drawings or instructions need to be in a hard copy form confirmed with the architect's chop or signature and its receipt needs to be acknowledged by the contractors in writing. Using E-mail, in fact, can alleviate the problem of distribution to various parties like quantity surveyors, suppliers, subcontractors, engineers, site supervisory staff, etc. Nonetheless, sending messages in an electronic form cannot complete these endorsement procedures. For the time being, the design architect needs to deliver his mail electronically to his representatives in sites who then convert the file into a hard copy form for further distribution.

4.3. Internet chat enhanced with on-screen images / pictures / drawings

Construction project staff can communicate with overseas colleagues using ''Internet Chat'' which can simulate phone calls if microphones and loudspeakers are installed or communicators can type in words on the screens. The system is further enhanced with on-screen images, pictures, photos or drawings so that people can view and zoom in or out the picture while talking with each other.

''Internet Chat'' can operate like an international convention so that the construction firm can remote-control the project.

4.4. Live video-cam function for site-based data capture

This function enables live transmission of video captured at sites to the headquarters. Management can view the construction site immediately by connecting a video-cam to a personal computer at site which sends the images through the Internet superhighway back to the Internet server. Site staff can

also take pictures from the site with a digital camera and dispatch the pictures through the Internet. Using this function, the project team can get instant views on the construction site progress directly. The server can also store the pictures for record purposes. If a number of live video-cams can be installed at different essential locations of a construction site, every detail of the site can be recorded and noted. However, the live video function of the system cannot generate video-like quality images but the pictures are being updated at a time interval of 10–20 s. Having said that, this can provide a ''feeling of the work place'' which forms an important component of using Internet to manage remote construction sites.

The live-cam function can also be used for recording site productivity data. Site shots can be sent back to the server through Internet at 20-s intervals. Images and site productivity can then be analysed by a fast play back.

4.5. Up-to-date data collection: link and search engine

Users can use the same Web page platform to search other information to assist them in decision making. They can see the changes of the international property market, fluctuating material prices and the Heng Seng Index, Don Jones Index, etc. This can help managers make decision quickly and reliably.

4.6. Auxiliary services

Construction firms can use their Web site presentation to recruit new staff and seek feedback by setting questionnaires. Of course, construction firms can advertise their services through their home-pages or promote their company's image to potential customers around the world.

5. Example project

TITS has been tested with a group of participants recruited from local construction industry in Hong Kong. The test has verified the reliability of the system [12].

In the following, an application of TITS for project monitoring with a real-life project will be presented. The project is a small-scale, residential project located in Mainland China. The main contractor's head office is located at Hong Kong while a site

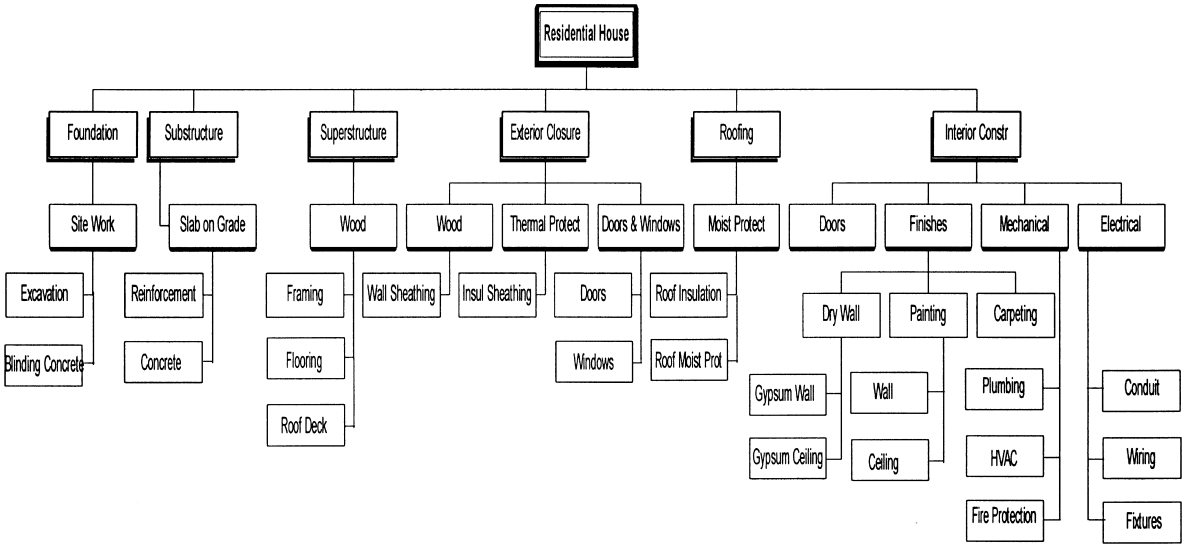

Fig. 1. Project WBS.

office, situated in the proximity of the project, is responsible for the execution of works. At the very beginning, a traditional project monitoring system is being followed at the head office through facsimile communication. Weekly progress report and cost profile were sent from the site office for the information and decision making of higher management and executive staff at the head office. Because of the geographic separation between the two communicating ends, cost incurred for this project information system (PIS) is enormously high. So an Internet-based PIS for this project delineating the mechanism of data input from site office, data retrieval and processing by intelligent HTML and Java programming was established. The conceptual framework of the developed PIS, including data input and retrieval hierarchies, will be described.

5.1. Project description

The residential project has been segregated into its work breakdown structure (WBS), as shown in Fig. 1.

The WBS helps information filtering according to its levels of detail required for the organizational hierarchy. The level of information detail at the second row (in Fig. 1) corresponds to the ''Executive Level'' while the third and remaining rows are for ''Manager Level'' and ''Field Level'', respectively. Particular identification numbers to the pro-

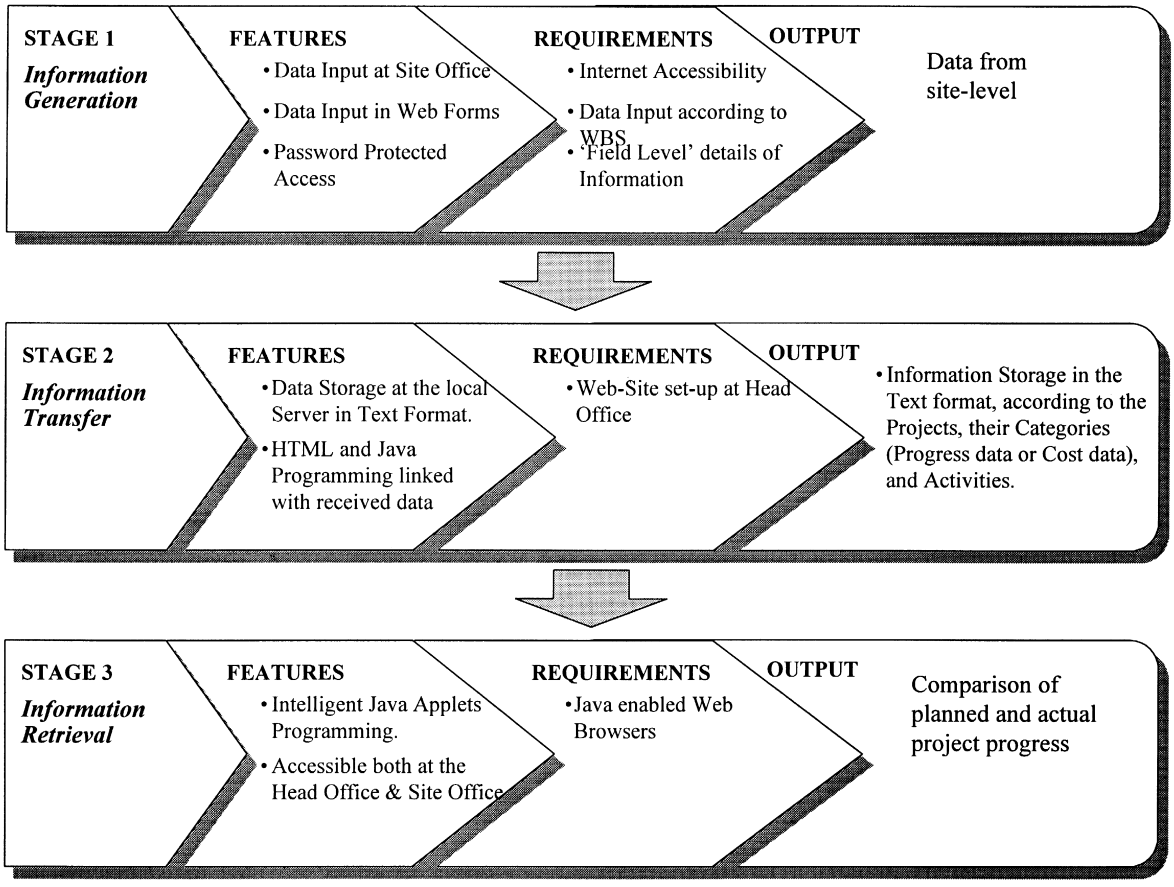

Fig. 2. Conceptual model of PIS.

ject activities have been assigned according to this WBS in the developed PIS and this can help in sorting the required information details according to the organizational hierarchy.

5.2. Conceptual framework of the PIS

Project monitoring from the head office may require a close observation of several components which participate directly or indirectly towards the accomplishments of project objectives. These components may include work progress reports, contractual matters, cost profiles, site inventory, and other general administration reports. However, weekly monitoring of project progress and cost scenario is more important to ensure the work efficiency and profitability at site. Because of these factors, our conceptual framework of PIS focuses on the mechanisms of ''Information Generation'' (by data input at site), ''Information Transfer'' (by Web-based communication) and ''Information Retrieval'' (by an intelligent graphical view on the Web). A conceptual model of the developed PIS is shown in Fig. 2.

This conceptual model delineates the necessary ''Features'', ''Requirements'' and ''Output'' at each stage of information handling. Only the authorized users, e.g., project manager at the construction site, is allowed to submit the data through a secured access at the information generation stage. A user-friendly form has been designed to input the weekly data, while the submission of this form to the main server is just a click away of a ''Submit'' button. A

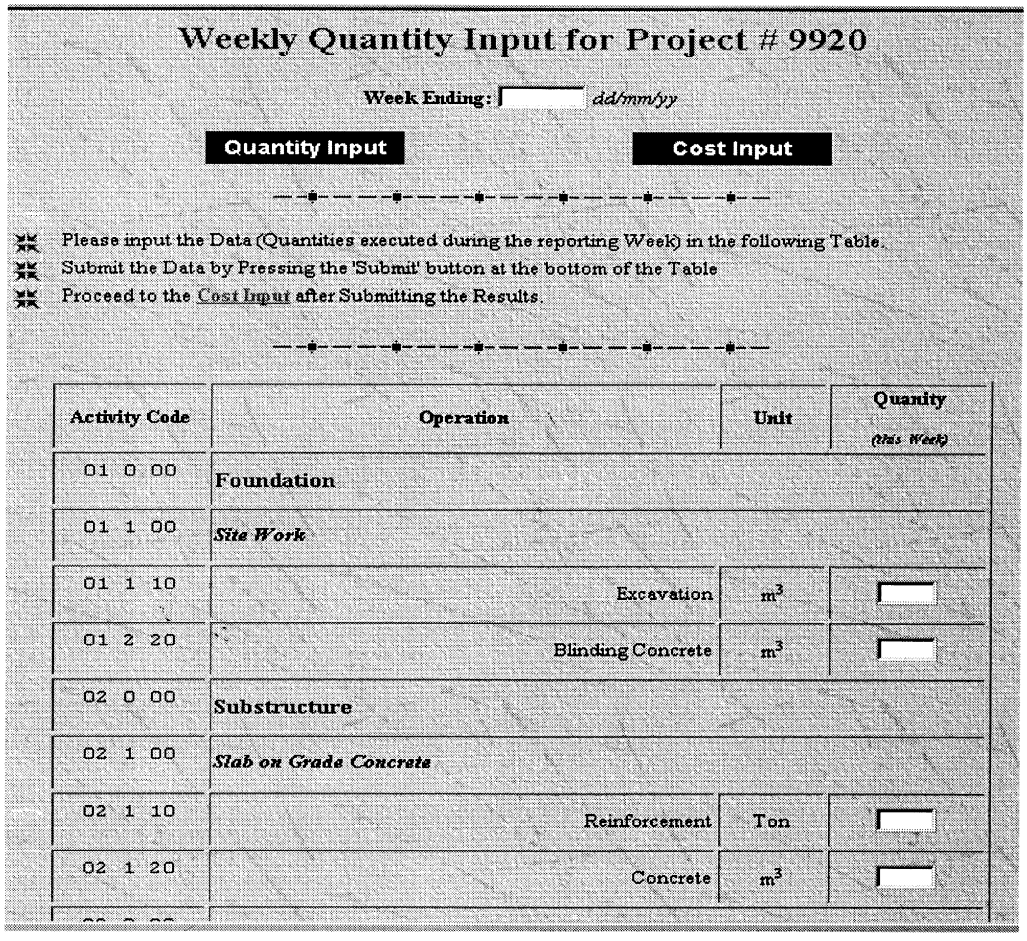

Fig. 3. Data input form for PIS.

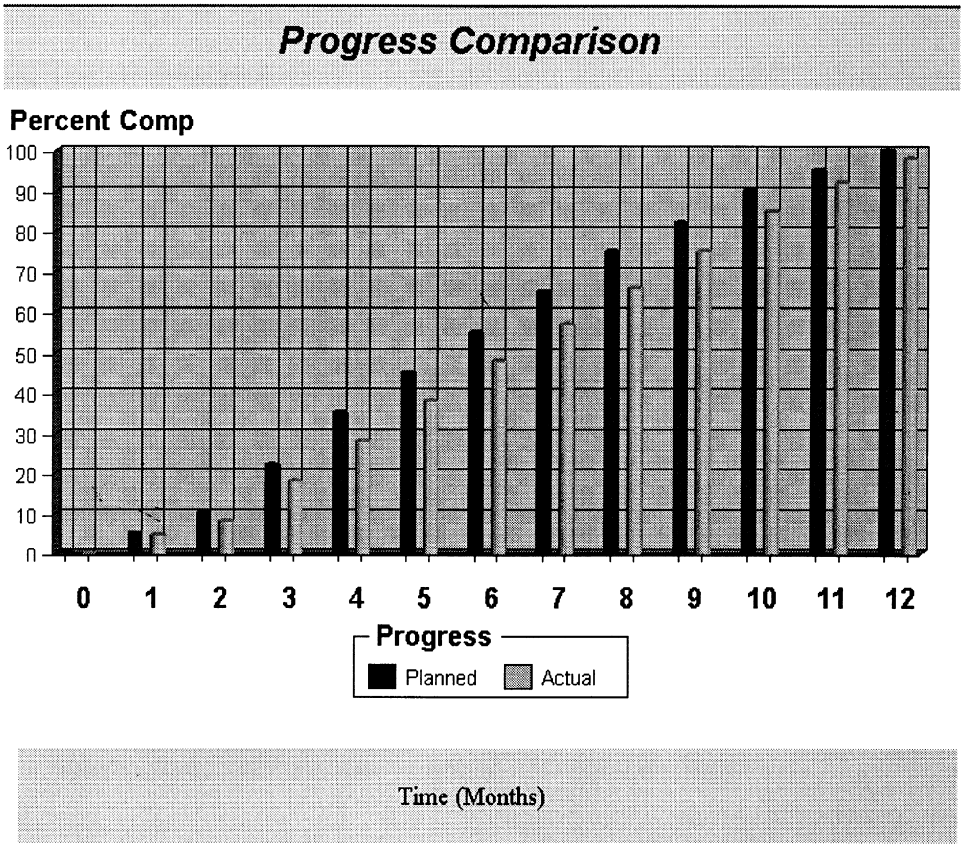

Fig. 4. Progress comparative plot.

sample form for the prototype project is shown in Fig. 3.

The data submitted from the site through this form is saved in a ''Text Format'' file in the Web server located at the head office during the second stage of the conceptual model. This text file has already been linked to the Java applets, programmed specifically to handle this data. The executable ''Class Files'' for these applets have been borrowed from Internet resources. According to the authors' best knowledge, general use of these executable files for Java applets is not restricted. The third stage of PIS starts by reloading the Web-site and allowing the applets to refresh their parameters values from the text files. Latest real performance at the project site can hence be compared with the scheduled/estimated performance both from the progress and cost scenarios. Such a progress plot generated after the upgrading of progress data at the end of the scheduled completion time (12 months) is shown in Fig. 4.

Moreover, the results can also be seen as ''Line Graphs'' and ''Gantt Charts''. Use of the activities' identification numbers for information filtering according to different levels of organizational hierarchical structure is still under the process of development in our PIS.

6. Conclusion

From our experience in setting up the TITS, it is found that the system can handle information sharing efficiently between the various parties in a construction project. The system offers many benefits such as improved efficiency, better management and decision making, and enhanced performance to construc-

tion firms [12]. This has been demonstrated by the application of TITS for project monitoring with a small residential project. The application has used only part of the functions provided by the TITS. As pointed out by Veeramani et al. [13], however, one of the real challenges in implementing change (e.g., Internet-aided technologies) in the construction industry is the highly fragmented nature of participants, even on a small construction project. A conceptual PIS needs to be developed for the implementation of TITS on the case project and to meet the specific requirements of the case project.

References

[1] O. Abudayyeh, Intranet-based project control systems for the construction industry, Proceedings of the Congress on Computing in Civil Engineering, Reston, VA, USA, 1998, pp. 577–583.
[2] B. Bradbury, G.F. Salazar, Intranet: short-term benefits within a construction management firm, Proceedings of the Congress on Computing in Civil Engineering, Reston, VA, USA, 1998, pp. 847–849.
[3] M.D. Bucknam, E.F. Hawkins, M.A. Sanfilippo, Net gains, Civil Engineering ASCE 68 (11) (1998) 49–51.
[4] J. Carroll, Electronic mail, workflow and you, CMA Magazine 67 (5) (1993) IM9–IM11.
[5] R. Fruchter, K. Reinter, Model-centered World Wide Web Coach, Proceedings of the Third Congress on Computing in Civil Engineering, Anaheim, CA, USA, 1996, pp. 1–7.
[6] C. Garcia, G. Garcia, F. Sarria, D. Echeverry, Internet-based solutions to the fragmentation of the construction process, Proceedings of the Congress on Computing in Civil Engineering, Reston, VA, USA, 1998, pp. 573–576.
[7] K. Hales, Workflow management: an overview of some applications, Information Management and Technology 26 (5) (1996) 203–221.
[8] R.E. Johnson, M.J. Clayton, The impact of information technology in design and construction: the owner's perspective, Automation in Construction 8 (1998) 3–14.
[9] A.J. Levine, X.J. Irias, N.J. Irias, Accessing engineering data with ASP and JavaScript, Proceedings of the Congress on Computing in Civil Engineering, Reston, VA, USA, 1998, pp. 707–710.
[10] L.Y. Liu, A.L. Stumpf, S. Chin, Global project documentation and communications using HTML on the World Wide Web, Proceedings of the Third Congress on Computing in Civil Engineering, Anaheim, CA, USA, 1996, pp. 15–20.
[11] E.M. Rojas, A.D. Songer, Web-centrics systems: a new paradigm for collaborative engineering, Journal of Management in Engineering 15 (1) (1999) 39–45.
[12] C.M. Tam, Use of the Internet to enhance construction communication: Total Information Transfer System, International Journal of Project Management 17 (2) (1999) 107–110.
[13] D. Veeramani, H.P. Tserng, J.S. Russell, Computer-integrated collaborative design and operation in the construction industry, Automation in Construction 7 (1998) 485–492.
[14] M.P. Walch, K.S. Leo, J.N. Antevy, Internet — project management in the millennium — today, Proceedings of the Congress on Computing in Civil Engineering, Reston, VA, USA, 1998, pp. 858–867.