WEB-BASED INFORMATION FLOW MODELLING IN CONSTRUCTION

Yasemin Nielsen[1] and Taner Sayar[2]

[1]*Middle East Technical University, Ankara, Turkey*
[2]*Mitas Construction, Ankara, Turkey*

In this study a web-based case study is carried out in a building project to test a suggested information flow model. The model is a common industry process that is flexible to the differing needs of construction projects whilst providing a basis for automation and securing the information flow, document control and communication in construction companies.

Keywords: communication, document control, information flow, information sharing, website.

INTRODUCTION

The construction industry is a multi-disciplinary, multi-national and multi-billion economy involving large numbers of actors working concurrently at different locations and using heterogeneous technologies. In the construction phase of a project, a large number of disciplines require different pieces of information at various times.

The result is a huge quantity of complex information that is often managed insufficiently. Sharing information is critical for the success of construction projects but organizational and technical barriers reduce the timeliness and accuracy of information. The construction industry has been increasingly recognizing the need for more effective exchange of information between project participants. Not only have the manual systems failed to satisfy the needs, the various computer applications have also not allowed for such communication. New information technologies improve sharing project information, and due to the Internet some of the needs can be met by using tools that are mature, yet simple.

Computer usage is expected to increase in the construction industry, the largest potential growth being in electronic information services and communication via Internet. There are no universally accepted models of the building construction process, but collection and analysis of information is essential for the quick detection of time, cost, scope and quality deviations from planned performance.

Information technology is fundamentally changing global construction business. The Internet and more specifically the World Wide Web (WWW) will be the key to this change. In pre-internet days, design information was exchanged primarily through face to face meetings, telephone conversations, or physical delivery of drawings and other data. Now, with Internet access reaching virtually all types of business, the barriers are falling. A new breed of Internet based products is enabling design teams to establish project-specific web sites called extranets and share a wide variety of data almost instantaneously. These products allow designers, contractors, owners and

Nielsen, Y and Sayar, T (2001) Web-based information flow modelling in construction. *In:* Akintoye, A (Ed.), *17th Annual ARCOM Conference*, 5-7 September 2001, University of Salford. Association of Researchers in Construction Management, Vol. 1, 219-29.

suppliers to collaborate electronically throughout the course of a project-regardless of where firms are located.

There is a consensus that in the longer-term future participants in a construction project will work with an integrated cross-disciplinary view of that project. Such a "project model" will develop concurrently, by the participants, and will therefore, need to support multiple discipline-oriented views, localized development of designs, maintenance of design alternatives, and the resolution of conflicts when designs are merged. An information repository, which fulfils such a role, could co-ordinate design, planning, costing and construction, and be used, subsequently to drive the maintenance and management of the facility during its lifetime.

This study examines computer usage and information systems in five leading construction contractors in Turkey. The investigation attempts to reveal the computer usage for the main functional roles, the level of details being used and assesses in what direction the industry is now heading in regard to the use of Information systems.

The general principles of management information flow between site and head office was considered in order to specify a web based virtual desktop. Electronic sharing of information by using Internet applications is proposed for exchange of information and communication in construction process.

INFORMATION FLOW BETWEEN SITE AND HEAD OFFICE

A construction project involves the execution of a large number of diverse activities by many participants, and evolves in both space and time, normally in a hostile and changing work environment. A smooth information flow will enable construction personnel carry out their duties more efficiently and effectively. The construction industry has always been confronted with great difficulties in sharing information among its participants. When more people are added to the organization and the volume of work increases, it is essential to encourage information to flow freely in all levels. This allows managers to learn of the organization and/or projects and their problems simultaneously so that decisions and instructions can be made and received uniformly.

An analysis of the characteristics of the construction contractor's management information flow is illustrated by Ndekguri and McCaffer (1988) which may be considered as a foundation for further research towards the development of the desired integrated construction project management information systems. The general principles of recording data flow within a construction organization were considered by Baxendale (1994) in order to specify an integrated management information system.

The main objective of integrated construction management systems is to provide decision makers, e.g. project and executive managers with engineering, construction and other operational information that will help in reducing project duration, making better use of resources, increasing labour productivity and decreasing cost. Convergence of data from site operations into information and the control of information should not increase the reporting burden but the correct, necessary and sufficient information should be given to the correct manager or supervisor as quickly as possible for his consideration, decision, and action. Raw data, daily site records, is taken and converted into information. Collecting vast amounts of data often fails to

satisfy managerial information needs. Data is filtered, sorted and combined in various ways to serve managers needs.

Internet or intranet gains importance not only for organization, storage, searching and retrieval of information but also sharing information in organization in all directions, i.e. upward, downward and laterally.

METHODOLOGY

The findings of research on process modelling, data flow diagrams, site records and management information system reported in this study aimed to identify information modelling and set up a background for further steps in IT implementation. Electronic sharing of information; e.g., project plans and spec.'s, contracts, schedules, etc. by using internet applications is proposed for exchange of information in construction process.

Consultations with contractors and expert opinions were carried out. As IT plays a role in any improvement, the general picture of IT tools of the construction companies was addressed.

Table 1: Consulted companies

Company	Type of Work	Project Size (USD)	Contracting Method	Specialization
1. General Contractor	Heavy / Civil Sector	5 to 600 million	General contract Turn-key	Highway, Buildings, Industrial, Offshore
2. General Contractor	Heavy / Civil Sector	Quarter to 40 million	General contract Turn-key	Housing, Building
3. General Contractor	Heavy / Civil Sector	5 to 650 million	General contract Turn-key	Highway
4. General Contractor	Heavy / Civil Sector	5 to 350 million	General contract Turn-key	Industrial plants
5. General Contractor	Heavy / Civil Sector	Quarter to 10 million	Turn-key	Energy transmission, Communication

As part of the study, computer usage and information systems in five leading construction contractors in Turkey were investigated. The findings were:

- The biggest potential growth is in electronic information services, and communication via the Internet.
- Current networking technology is able to provide the communication links between project participants and individual applications.
- First steps towards achieving the integration were to map out:
- Characteristics of the flow of information among the management functions of the construction contractor
- The general principles of management information flow between site and head office

Considering these, a web based virtual desktop was specified. Electronic sharing of information that is already distributed in the paper form by using Internet applications was proposed. This study suggests the industry’s future: sending people to the web for documents instead of sending the documents to them. This set up facilitates document sharing instead of document or drawing issuing and ownership. The web is a way to get out from under a mountain of e-mail and paper.

Managing Information Flow For Contracting

Fig.1 is a broad model of the operations, flow of information, and decision-making processes typical of the feedback – control system for managing construction organizations and medium to large engineering and construction projects. This model can be used or applied in any form of contract. The context diagram is subdivided into three main sections; pre-contract stage, contract stage (fig. 2), and purchasing and materials management. It is found appropriate to produce three separate models to cover the stages of construction, as invariably there is an overlap in the information requirements at these stages.

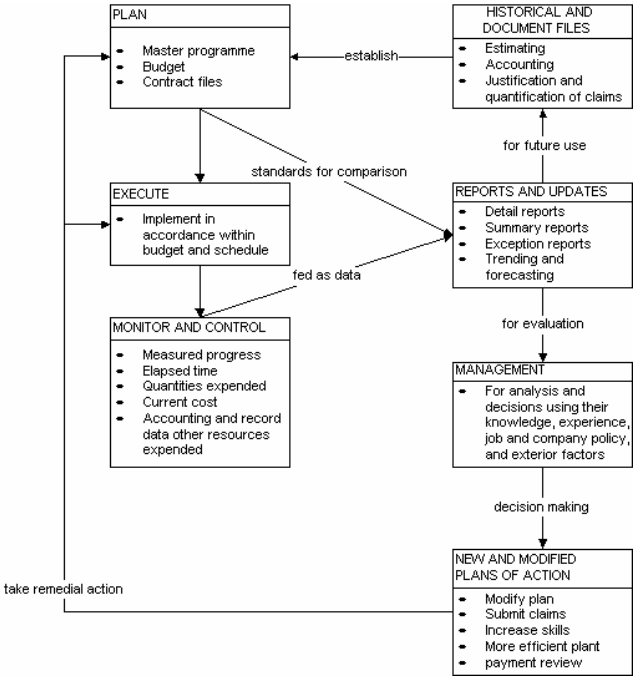

Figure1: Management Information Flow for Contracting

After signing the contract during construction, the following basic management functions of the contractor were studied with a view of identifying the generic informational entities entailed: Planning, Cash flow forecasting, Valuations, Cost control, Accounting.

Process modelling is an essential step in developing on IS or evaluating it from a business professional's viewpoint. DFD methodology was selected because of its relative simplicity of use.

Daily Site Records

Daily site reporting gains importance to measure, collect, verify and quantify data reflecting the progress and status of the operations on the project. Collection and analysis of site information is essential for the quick detection of time, cost, scope and quality deviations from planned performance; causes and appropriate corrective actions.

Benefits of an organized, accurate and efficient means of site reporting include ability to monitor and control the construction process; performing a fundamental role in resolving construction conflicts and disputes and faster response time in dealing with problems.

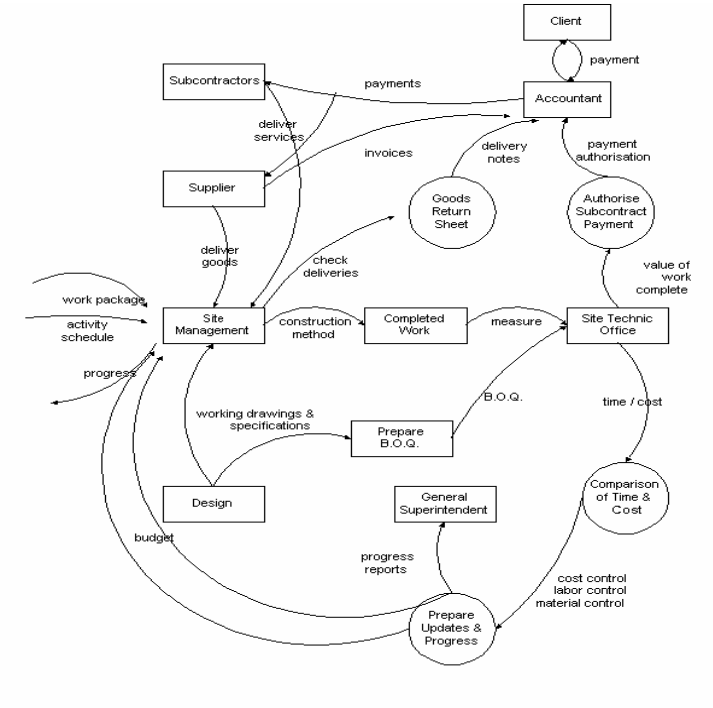

Figure2: Data Flow Diagram – Contract Stage

Site records consist of a range of information relating mainly to progress, cost and quality. The progress records were in focus since it is most important to address what data should be collected on a daily basis to provide a useful image of the current status of the overall project. Every consulted company had developed their own information flow to meet their needs, developed by the top management. Daily site records and contents may therefore vary from company to company. Some items are recorded daily in one company while they are recorded weekly or monthly in another one or even not recorded at all. At least two types of data are required in found progress reports: overall project context information; and data on ongoing work tasks as described in terms of activities.

A number of problems with site records are accessibility, legibility, continuity and consistency. The most important function is the integration of the site reporting, project planning, project scheduling and schedule updating. Russell (1993), McCulloch and Gunn (1993) and Scott and Assadi (1999) have all expressed their dissatisfaction with the quality of the progress records kept on construction sites. Russell (1993) describes a computerized approach for collecting and processing site information. The most important function is the integration of the site reporting, project planning, project scheduling and schedule updating. Pen – based portable computers that could be used directly in the field (McCulloch and Gum 1993) are utilized for employee timekeeping and material management functions to provide significant time saving for field supervisory personnel and to solve the impending paper burden encountered on construction projects by field personnel.

Improvement of site records will not only add contribution to management information reports but also provide a feedback to site personnel. This would increase the likelihood of site records being properly completed. Better methods of record keeping by using standard forms, computerizing record-keeping process, keeping more detailed records and keeping joint records with other parties should be

introduced. Clear rules and guidelines shall be provided to ensure better site records and the quality of site records shall be checked by regular inspections. Training of site staff and providing more time for the record keeping process also receive high priority.

A comprehensive statement about each item of daily site records is summarized in table 2.

THE IMPACT OF THE INTERNET ON THE CONSTRUCTION INDUSTRY - A CASE STUDY

Zafer construction co., an Ankara-based construction firm, is the case study for a web-based solution. As other companies Zafer construction co. has set up a corporate LAN, servers and a dedicated connection to Internet via frame relay in the head office. The Internet technologies are employed in a corporate environment that is internal company-wide networks, as Intranet in which there is a security system to separate network from the Internet.

Documents transferred by e-mail consist of daily site records, daily project photos, Requests For Information (RFI), submittals, Instructions To Contractor (ITC), drawings, specifications, material logistics, planning and finance reports, etc. Added to this heavy documentation burden informal communication among project participants creates amounts of e-mail that is often hard to manage.

Using WWW For Information Sharing

The centre of this study was the development of an Internet-accessed, enterprise-wide project management solution for the construction firm. The software features a centralized database of project information that facilitates the management of project documents and increases communication among parties, including contractors, subcontractors, architect and owner.

Module groups include project overview, daily site records, project documents, drawings and specifications, participants, photos, material logistics and search folders.

Daily site records allow project members to enter information directly from the remote site. In the project documents folder, request for information, instruction to contractor and submittals can be entered into the system by users and can thereafter be tracked through the processes involving architect, engineer and owner.

Importantly, these web pages were developed using common tools; MS FrontPage on an MS Personal Web Server, FrontPage Server Extensions, MS Active Server pages (ASP).

Internet security is in control of the web server’s security functions. The built-in security model involves user names, passwords and three levels of access. The Project Homepage can be accessed by authorized users only, and is the starting point for browsing project-related information.

Structure of the Web Site

The opening page, Project Overview describes the brief introduction of the project including visual graphics and simple tool-bar navigation.

Daily site records are stored in a database with a web interface so that date inquiry, data input and output to the database can be done via a Web Client. Daily site records track site environment conditions, work-force parameters including tracking of

Table 2: Daily Site Records

		a)who keep it?	b)Where do you keep?	c) used for preparing	e)computer usage
A)	**GENERAL CONDITIONS**				
1)	Site Environment conditions				
	Weather	Engineering and technical staff	standard daily record sheets	Historical data; monthly progress report	Standard hard-copy form
	Ground	Engineering and technical staff	standard daily record sheets	Historical data; monthly progress report	Standard hard-copy form
2)	Work-force parameters				
	Labour	Engineering and technical staff	standard daily record sheets	Historical data; monthly progress report	Standard hard-copy form
	# of skilled personnel and skills	Engineering and technical staff	standard daily record sheets	Historical data; monthly progress report	Standard hard-copy form
	Technical personnel	Engineering and technical staff	standard daily record sheets	Historical data; monthly progress report	Standard hard-copy form
	Equipment	Engineering and technical staff	standard daily record sheets	Historical data; monthly progress report	Standard hard-copy form
3)	Description. of the work task performed that day	Engineering and technical staff	standard daily record sheets	Historical data; monthly progress report	Standard hard-copy form
4)	Minutes of site meetings				Word-processing or hard-copy
B)	**ONGOING WORK TASKS**				
1)	Program and Schedule Update				
	Status of a work task	Engineering and technical staff	Weekly progress report	Historical data; monthly progress report	Standard hard-copy form
	Recording exactly when construction works take place	Engineering and technical staff	Weekly progress report	Historical data; monthly progress report	Standard hard-copy form
	Identifying links between construction activities	Engineering and technical staff	Weekly progress report	Historical data; monthly progress report	Standard hard-copy form
	As-built program / Schedule	Engineering and technical staff	Weekly progress report	Historical data; monthly progress report	Project Management
2)	Problems				
	Problem encountered, sources and its consequences of the work task	Engineering and technical staff	Weekly progress report ; monthly progress report	Historical data; monthly progress report	
	Suggestions and actions to deal	Engineering and technical staff	Weekly progress report ; monthly progress report	Historical data; monthly progress report	
3)	Field quantification (working hours; man-hours; machine-hours)	Forman	time-keeping form	Accounting payrolls; monthly progress reports	Standard hard-copy form

number of hours of supervisory, administrative staff, foreman and labour, equipment used that day, materials delivered, description of the work task performed, problems, instructions, corrections and safety. It was found feasible to enter daily site data by field personnel directly into the computer via web browser in the site office.

Project schedule consists of the reports; baseline schedule, master schedule, master target and weekly subcontractor schedules.

In Project Documents folder, users will create, log and track Requests For Information (RFI), Instructions To Contractor (ITC), and submittals. Web-based forms speed project delivery through better co-ordination of information, faster resolution of outstanding items, quicker review cycles and the removal of communication bottlenecks. The project documents can be stored, tracked and viewed by all in the Project Documents folder. Project Dwg.'s and Spec.'s link to ftp site, which allows to update and copy project drawings and specifications.

Project Participants contain continuously updated list of contact information for all the members of the project. From here, e-mail can be sent to project members, or visit their personal home pages.

Project Photos consist of list of last updated project photos providing on immediate illustration of progress. Live site environment conditions supported by project photos, gives an accurate description of site condition.

In Material Logistics folder, there are three reports; warehouse stock, packing lists and delivery trace. These reports give an overall picture on material logistics. The search form component provides a text search capability to find content on the entire web.

Future Work

The basic Internet capabilities (e-mail, www, ftp) allow considerable improvements for distributed teamwork. Because the tools are mature and easy to learn, the efficient usage of them can be expected to continue. There is a continuous flux of Internet technologies and applications, which offer new opportunities for the construction industry. The opportunities for improving the www communication are:

- Plug-ins portable software modules allowing viewing and simple manipulation of data through a Web browser without necessity to have a commercial license of the original software application, which created the data. Any document type especially CAD files viewing and adding comments, mark-ups etc. with redlining capabilities enhances document management. Automatically converting files into a viewable format such as pdf file may eliminate plug-ins or any additional software.
- On-line web camera over Internet for building site monitoring, video conferencing. On-line conferencing allows document sharing, chat or whiteboard as MS NetMeeting has already provides these features.
- Improved security is a necessity for data access providing security down to the document level, data transfer enabling secure sockets layer (SSL) encryption of all data transfers form and to the database and data storage backed up daily. In this case, project finance data of budgets, bonds, change orders, subcontracts etc., shall be included in the project web where construction companies are very sensitive about.

- Third party collaboration for Request For Information, Instructions To Contractor and submittals simplify approval process and automate workflow. Client module improves, client satisfaction. Today's networking technology provides communication links between project participants and individual applications.
- A project information manager should be appointed who will be responsible for managing the flow and quality of information. He/she will be the single project administration of the project web.
- Virtual reality as user interface to complex databases and building product models.
- Advanced intelligent systems embracing knowledge based systems, artificial intelligence, case-based approaches, and neural technology.

CONCLUSION

Now even more than during the previous researches into Internet for construction, the explosion of Internet use has familiarized everyone with generic communication tools like email software and Web browsers. The steps followed in this study were to reveal the computer usage level, flow of management information including collecting raw data, such as daily site records, information convergence to reports and finally development of web based solution for project information sharing. A web based virtual desktop can be developed for the Web, which can be used or adapted to address some of the information needs of the construction industry. The set-up in this study were deliberately not project-specific, but the significant benefits are summarized:

- Free information flows in all directions instead of reporting hierarchy results
- Elimination of delays caused by sequential project information flow
- Collaboration over time zones, national, organizational and geographic barriers
- Cost saving in terms of delivery of drawings and controlling travel costs
- Access project data from any computer with Internet browser anytime.

Various barriers within the construction industry to applications described in this study can be divided into organizational, cost, legislation and human resources. Today, the outstanding legal aspect barrier should be eliminated by an agreement of each party, just after contract signing, to take documents residing in database as reference in case of a project dispute. Digital signature and changes in legislation to accept the use of information through IT media is at the very heart of the present e-commerce developments.

REFERENCES

Baxendale, T. (1994) Information systems development for contracting. *Automation in Construction.* Elsevier, **2:** 291-302.

Bridges, A. H. (1997). Internet for the construction industry. *Automation in Construction.* Elsevier, **6:** 45-49.

Laufer, A., Cohenca-Zall, D., Shapira, A. and Howell, G.A. (1994) Process of planning during construction. *Journal of Construction Engineering and Management.*, ASCE. **120**(3): 561-578.

McCulloch, B.G. and Gunn, P. (1993) Construction field data acquisition with pen-based computers. *Journal of Construction Engineering and Management..,* ASCE. **119**(2): 374-384.

Ndekguri, I.E. and McCaffer, R. (1988) Management information flow in construction. *Construction Management and Economics.* U.K., **6:** 273-294.

Russel, A.D. (1993) Computerized daily site reporting. *Journal of Construction Engineering and Management..,* ASCE. **119**(2): 385-401.

Seren, K.J. (1997) Internet based computer integration in building construction – a process view. *Design and Construction, Integration of Information Processes in Building / Construction by use of IT*. Iceland: Reykjavik, (9 May).

Scott, S. and Assadi, S. (1999) A survey of site records kept by construction supervisors. *Construction Management and Economics.* U.K., **17:** 375-382