

39 THE INTEGRATED USE OF INFORMATION AND COMMUNICATION TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

Malcolm Murray, Raymond Nkado, Angela Lai
Universities of the Witwatersrand and Port Elizabeth

Abstract

Information technology is widely used throughout the international construction industry. Web sites are used for information and publicity purposes and their use in project management as centres of information has been developed over recent years.

In this paper the current use of information and communication technology (ICT) in the international construction industry is examined. The development of the construction project chain is examined, its role players identified and the activities carried out throughout the chain described. An overview is given of software available to the international construction industry for these types of activities and its use within the South African industry discussed.

The integration of the project chain on a project-by-project basis by the promoter is recommended and the potential benefits are described by referring to economies gained in design-construct and build-operate-transfer contracts.

Finally it is argued that ICT can readily be used by the sub-Saharan African construction industry given the low capital investment levels required and the benefits to be gained, the only requirement being the need for investment in ICT education throughout the continent.

Keywords: *Integrated information and communication technology, construction industry*



INTRODUCTION

Towards the end of the 20th century the world moved inexorably towards being a global village. The merging of multi-nationals across borders and continents, the growth in international transport, the increased use of English as an international language, the dropping of trade barriers and the ease of communication have all contributed to this trend.

During 2000 world business attention was focused on the development of electronic trade, following the boom, bust and subsequent stabilisation of a number of dot-com companies. The international construction business has been just as affected by the above changes as any other.

In this paper a brief description will initially be given of the current use of information and communication technology (ICT) in the international construction business. The project chain, from initiation by the developer to management by the facilities specialist, will then be described and an overview of the software available for use by the various professional entities involved in the project chain will be given. The paper will finally describe how economies of time and money could be won by integrating the whole process by the use of web-sites designed and implemented by the developer for each project. Examples of effective integration achieved by regulatory means – design construct and build-operate-transfer-contracts- are given and the paper concludes with an examination of how the proposed systems, and others, could be implemented by the sub-Saharan African construction industry.

AN OVERVIEW OF THE CURRENT USE OF INFORMATION AND COMMUNICATION TECHNOLOGY IN THE INTERNATIONAL CONSTRUCTION INDUSTRY

During the 1990's the international construction industry started using with increasing confidence information and communication technology (ICT). The use of e-mail became usual and web-sites were established for marketing purposes and then for one-way, followed by two-way, communication. Intranets and extranets were established to facilitate communication within companies and throughout their branches.

Towards the end of the decade e-businesses started to be established and web-sites to be used for the purchase of items like books, air-line tickets and hotel accommodation. Web-sites were also established for on-line banking and specialised portals were established, providing a wealth of information on suppliers, specialised contractors, consultants, bidding opportunities etc in the case of the construction industry.

More recently web-sites have been established for the sale, sometimes by auction, of construction equipment and three large international contractors are currently in the process of establishing a joint web-site, presumably to carry out joint procuring on the global market of personnel, materials and equipment.

During the 1990's software for carrying out specific tasks has been much improved, most software now being windows-based, and steps have been taken towards integrating design and construction processes by the use of web-sites.

A number of web-based project-management systems have been commercially developed and have been reported on (Murray and Lai, 2001). That paper advocates the establishment of project-specific web-sites on a project-by-project basis, a project meaning in this case a construction project, such as a dam or a building.

THE PROJECT CHAIN AND ITS ROLE PLAYERS

Before a dam or a building is actually constructed a lengthy process takes place, often over a period of between two and five years, or even longer. This process is driven by the promoter or the developer and, depending on the type of project, may involve large numbers of skilled professionals and companies with, quite often, much repetition of activities and accumulation of paper-work.

Figure 1. illustrates the flow process required to take a project from inception to implementation and completion. The model is evidently simplified and does not show the iteration which is usual in the design and decision process. From the flow chart it can be seen that certain professional groups take part in the process from start to finish. If the period is lengthy, however, the professional groups involved may be substituted by others at varying intervals, or there may be turn-over of professional staff within the groups. An integrated project information system would minimise the potentially disruptive impact of groups or personnel movement during the currency of a project and would provide the project participants with an on-going memory.

ACTIVITY	ROLE PLAYERS										
	P	PM	A	QS	E	C	S	FM	LA	B	L
Project inception	●										
Preliminary design	○	○	●	○	○				○		
Feasibility study	○	○	○	●	○						
Approval by local authorities	○	○	○						●		
Raising of finance	●			○						○	○
Detailed design and costing	○	○	●	●	●						
Tender process	○	○	○	●	●					○	○
Construction	○	○	○	○	○	●	○		○		
Management of facility								●	○	○	○

Key:

● - Initiation

○ - Information

P - Promoter

PM - Project Manager/principal agent

A - Architect

QS - Quantity Surveyor

E - Engineers

C - Contractor

S - Sub-contractors, suppliers, plant hire companies etc

FM - Facilities Manager

B - Bankers

LA - Local Authorities

L - Lawyers

Fig 1. The project chain and role players

DISCRETE ACTIVITIES CARRIED OUT DURING THE PROJECT CHAIN

The professional teams which participate in the project chain all have specific functions to carry out and the functions are made up of a number of discrete activities. Examining the activities carried out by the teams leads to the conclusion that different teams deal with similar information, therefore that information needs to be passed along the chain from team to team. This is often done in practice by paper transfer of, for example, drawings, reports etc. Recently, information has started to be transferred electronically.

Fig. 2 illustrates the above point. From the figure it can be seen that the majority of the role players require access to the majority of the project information at one time or another. It also shows that different entities often deal with similar data. The discrete information is usually prepared or processed by electronic means, as will be shown in the next section.

INFORMATION	ROLE PLAYERS										
	P	PM	A	QS	E	C	S	FM	LA	B	L
Drawings	0	0	●	0	●	●	0	0	0	0	
Specifications	0	0	●	0	●	0	0	0	0		
Bills of Quantities		0	0	●	●	0	0				
Budget	0	0	0	●	0	0	0			0	0
Contracts	0	0	0	●	●	●				●	●
Planning	0	●	0	●	●	●	●		0	●	
Personnel control		●		●	0	●	●				
Materials control		●		●	0	●	●				
Equipment control		●		●	0	●	●				

Key: As in Fig 1.

Fig 2. Information-Role Player matrix for a typical project chain

PREPARATION OF PROJECT INFORMATION

Most of the professional firms involved in the project chain prepare their part of the package electronically. Quite often firms may independently prepare similar information using different software packages.

Fig 2 for example illustrates how both the quantity surveyor and the contractor need to prepare priced bills of quantities; these professionals may, however, use different and incompatible software for taking off quantities, preparing a bill, pricing the bill and for interim and final measurement. The duplication of information here is evident.

In the next section a brief review is carried out of the variety of software currently available to construction professionals.

SOFTWARE AVAILABLE TO THE INTERNATIONAL CONSTRUCTION INDUSTRY
Project Management (PM) software

PM software available to the international project management professional has been surveyed by the Project Management Institute (PMI, 1999). The book surveys 32 suites, which are software suitable for overall project management of activities; 17 examples of process management software; 34 of schedule management (i.e. planning) software; 24 of cost management; 26 of resource management; 16 of communications management; and 15 of risk management software.

There is a certain amount of overlapping: for example the software package, Web-project appears under all seven categories; Microsoft Project 98 in five of the categories.

There are a also number of suites designed specifically for PM of the international construction industry that have been reported on (Murray and Mavrokefalos, 2000; Murray and Lai, 2001).

In South Africa the CSIR has developed Ipros, Integrated Project Services (CSIR). This is a web-enabled project information management system, which is based on the CSIR web-site.

The use of electronic communication in construction has been described (Cole, 2000). Oddly, this book did not emphasise the potential role of web-sites in communication.

Specific software

Table 1 gives a sample of the variety of specific software packages available on the international market for use by construction professionals of different categories.

It should be noted that in the "functions offered" column the capabilities of the software are listed as described by the supplier: these have not been verified.

It is to be noted that there is a bewildering variety of software available to design and other professional. The use of software by the South African industry is reported on in the next section.

ACTIVITY	SOFTWARE	FUNCTIONS OFFERED
Site surveying		
GIS	R2V	
	Trimble GPS	GIS data collection
Contouring	QuickSurf and SurfMate	Survey and digital terrain modelling
	DatumMate	Datum conversion of drawings
	SurvCADD 2000	
	Civil designer- Design centre	CAD, survey, import and digital terrain model functions
Design and Drawing		

Architectural	AutoCAD Architectural Desktop	Bridges gap between "object-oriented" 2 and 3-D design and construction documentation
	Autodesk upgrade AEC 5.1 Plus	Used in conjunction with AutoCAD. Has enhanced design detail and offers access by multiple users to the same data
	AutoCAD LT 2000i	Allows design with internet collaboration and professional 2D CAD features
	Data CAD	
	Genesis	
Earthworks	Civil Designer-Survey and terrain	Interactive earthworks and design
Drainage	Civil Designer-Stormwater	Runoff and network design
	StormCAD	Storm sewer design and analysis
	Flowmaster	Open channel, pipe and inlet design
	Culvertmaster	Culvert design and analysis
	PondPack	Urban hydrology and detention pond design
	Contech	Stormwater detention design software
Water and sewage	Pipe Maker	Design package for the design of sewer, water and storm water pipes
	PipeMate	Sewer and stormwater design
	WaterMate	Water reticulation analysis/design and simulation
	Civil designer-Sewer	Calculate flows
	Civil designer-Aquanet	Design of pressure networks
	SewerCAD	Sanitary sewer modelling
	WaterCAD	Water distribution modelling
	Storm and Sanitary SelectCAD	Integrated storm water and sanitary sewer design
Geotechnical	Not reviewed	
Structural	Strap	Structural analysis, bridge failure analysis, rendering and animation
	Adapt	Analysis and design software: concrete, prestressing and post-tensioning
	GTS-CADBuild	Analysis and design software: Frame analysis, finite elements, steel design, RC design/detailing, roads, drainage, geotechnics
	Prokon	Structural analysis and design, geotechnical analysis
	Lusas Bridge	Structural design for bridge engineers
	CivilTech Software	Sharing design software
	RebarMate	Concrete detailing and scheduling

	Larsa 2000	Non-linear finite element analysis
	Model Maker	Survey and design software utilities with integrated CAD functions
Roads	Road Maker	Design package for the design of rural and township roads
	RoadMate	Urban/freeway design
	Civil designer- Road	Road design and area calculations
Measurement		
Taking off	BidPoint XL	Digitises directly into Excel. Click on an Excel cell and electronically measures drawings in seconds. Digitised drawings are saved with the Excel cell.
Bill of quantities	QS Plus 2000	Cost plan/estimating, bills of quantities, certificate valuations, final accounts
	QS Plus 2001	As above but used in conjunction with QPL's interactive catalogue, which makes formulating of descriptions for bills of quantities easy
	Win QS 32	Networked, bills of quantities
Budgeting		
Estimating	HeavyBid	Estimating software for heavy/highway contractors
	Sharpe 2000	Automated unit conversions, download bid items from Caltrans website, "what if?" comparisons, unlimited unit bid item levels, fully multi-user capable, autolink between imported items and historical prices
	Kwikest and Kwiktarriff	Estimating and calculation of professional fees
	Excel	Spreadsheet adapted for estimating
Planning		
	Primavera	
	Suretrak	
	MS Project	
Procuring		
	Invitation to Bid	Bid solicitation
Accounting		
	Asset 94	Monitors lifecycle costs, acquisition, disposal and accountability, administration of business assets from more than one site
	Pastel	Accounting software

Table 1. Software packages available for typical construction activities

INFORMAL SURVEY ON THE USE OF SOFTWARE BY SOUTH AFRICAN CONSTRUCTION INDUSTRY PROFESSIONALS

Survey on products used by the South African construction industry

A survey was conducted via telephonic interviews in order to ascertain what products are actually being used by the industry. A standard questionnaire with all the relevant issues relevant to the topic was posed to the interviewees some of whom had difficulty understanding a number of the questions. This leads to a suspicion that sections of the South African construction industry are not entirely comfortable with information management and the information age. Constraints and difficulties in conducting the interviews included disinterest in what was being researched and the benefits to be obtained from it as well as being directed to the wrong person, for example to the network support professional.

In analyzing the results of the questionnaires it was found that architectural and quantity-surveying firms did not have individual departments as such, whereas other consultants and contractors often have numerous departments using different packages.

Architects

The most common architectural software package used is AutoCAD 14 and 2000, with fewer firms using DrawBase and DataCad. Cost was cited as a factor – AutoCAD is apparently considered to be very expensive. The firms did not have any overall planning software which integrated all of the activities carried out. The architectural firms tended to not have web-sites to manage projects. However, some firms did have web-sites for use as a marketing tool with others using the internet mainly for e-mailing, citing the maintenance of a web-site as being too demanding. Opinions on the possible use of a multidisciplinary web-site were sketchy due to lack of understanding of what this meant. Responses were varied from being in agreement especially in the case of isolated sites for large and fast-track projects, to concern about costs for small projects and the belief that it would take a long time for industry participants to actually reach that stage; it was believed that the ‘technology was not there yet’.

Quantity Surveyors

For quantity surveying firms Win QS 32 and QSPlus were used for bill production, Brilliant Accounting TurboCash and Pastel for the financial aspect of the business and Excel used as an estimating tool. Excel as part of the MS suite is not designed for estimating as such, however, it can be cleverly adapted by using the spreadsheet functions for estimating. An in-house designed template is often used and changed for different jobs. This is an inexpensive way of estimating because of the saving on an estimating program, however, it is time-consuming, tedious and can get very confusing for large jobs. A similar approach is adopted for valuations where a standard template is used. No overall planning software is used. Web-sites are used as marketing tools; however, more proprietary software is used than portals or in-house designed software. Apparently, for one firm, a multi-disciplinary web-site is considered to be viable as one was actually used on a large building project.

Contractors

Contractors tended to be large and have different functional departments. The departments mentioned were technical engineering, building, civil engineering, open cast mining, IT, earthworks, plant, site services, estimating, quantity surveying, costing and accounting. It was difficult to categorize particular software for the individual departments as sometimes the programs overlapped i.e. different departments often use the same software. There was also found to be difficulty in identifying common departments because designations differed from company to company. For this reason, only a list of programs used will be given. It was found that CCS, Primavera, MS Project, Prokon, Novell 5.1 and AutoCAD are used for all the contracting requirements. None of the companies uses an overall planning software package. In terms of overall financial software the following were the most commonly used: AS 400, BMS (for costing and accounting) and ACCPAC. Websites are used, but mainly as a marketing tool and even then not to a great extent, with Intranet being more in use. Usually, proprietary software was used; however, one contractor did possess an in-house designed software program, namely DMS (design management systems). As with the architectural firms, opinions differed on the use of a multi-disciplinary web-site. Comments ranged from agreement, particularly for isolated sites where it would be easier to extract information, to disagreement due to confidentiality issues: i.e. because of the need for restriction on certain information it was felt that there could be access problems. The general view, though, is that contractors rely quite heavily on computerization.

Consulting engineers

As with the contractors, consultants had a number of different departments. The civil engineering departments made use of Pipemate, AutoCAD 14, Prokon 32 and Fesdek. For project management Primavera and Suretrak used. The other departments i.e. industrial, mechanical and electrical, water and services, roads, dams, bridges and building structures used similar programs. There no overall planning software in use by any of the consultants. For accounting software, MIS (management information systems) and Solution 6 were used. Web-sites were used for marketing only. In terms of comments on multi-disciplinary web-sites, positive feedback was received.

Discussion

The general conclusion reached is that proprietary software is widely used, however, there is a lack of knowledge of technological advancement in the use of web-sites and multi-disciplinary web-sites. There is not much interest in the subject and rather a lack of understanding of how they could work in practice.

From the survey of products available and products actually used it can be seen that only a small spectrum of products is used, with some companies adapting existing software to suit their needs e.g. Excel for estimating. This demonstrates that not only is web-site knowledge weak but so is software awareness.

INTEGRATION OF THE PROJECT CHAIN

The use of web-sites in Project Management

One of the fastest-growing areas in the use of ICT (Information and Communication Technology) in management is that involving the use of web-sites in project management (PM). Recommendation on the use of web-sites in PM by Southern Africa consultants and contractors have been made (Murray and Mavrokefalos, 2000) and the use of a web site in a large legal project has been described. The use of web-sites in the international construction industry has also been examined (Murray and Lai, 2001) and their use in the integrated design of steel-framed structures, where 3D CAD software would be the core of the system, has also been described (Trincherio, 2000). Process engineering designers and planners have been using 3-D CAD walk-through simulations, to integrate structures and pipe-work in process plants, for a number of years now.

On examining Figs. 1 and 2 it can be seen that very similar items of information are used by most of the role players in a project during the project cycle: the two which stand out are drawings and cost data. Evidently, as the project progresses, the degree of detail increases but the basic components of the information remain the same.

It is therefore suggested that the project promoter could achieve considerable savings in time and money and reduce the risk of erroneous transmission of information by taking two steps.

The first would be for the promoter, or his agent the project manager, to set up a project web-site. This would contain all relevant project information. Confidential information would be password protected, although it is perceived that one of the consequences of increased project web-site use would be increased transparency and the need for trust so that the paranoid habit of some companies of secreting non-sensitive information would have to be discontinued.

The second step would be for the promoter to recommend or specify the use of compatible software on the project so that all stake-holders could easily up-or download information to or from the web-site.

The main consequence of these actions would be that instead of the promoter and his agents distributing information, usually in paper form to the tens or hundreds of project participants, they would all be able to access the information directly on the web-site. Examples of the benefits to be gained from the integration of project information will be given in the following sections.

Design-Construct projects (DC)

It is known that involving the contractor early on in the construction process can lead to economies in time and costs for two reasons. The first is that the contractor provides input on constructability, thereby eliminating unnecessary costs. The second reason is that the project time-frame is streamlined: fast-tracking of the design process is a natural consequence of the process.

The two current ways of involving the contractor are, first, by awarding design-construct contracts and, secondly, by partnering. The lead author has obtained economies of about 10% on total cost on a number of design-construct contracts in the international marine sector. A study of partnering involving a South African contractor carried out under the lead author's supervision (Mkhungo, Mongo and Kakitahi, 2000) suggests that the way forward in this process should be by applying the value engineering concept, that is, for the contractor to obtain a share in the project economy brought about by him.

Build-Operate-Transfer contracts (BOT)

BOT contracts offer three advantages to society ie. to governments. The first is that BOT promoters raise finance which is difficult for increasingly cash-strapped governments to do. The second is that the promoters assume risks previously carried by governments. The third advantage is that they usually carry out the project more efficiently by integrating the finance, design and construction aspects of a project.

Project web-sites

It is suggested that the setting up of a project management system and consequently a project web-site should be widely adopted as standard practice in the industry by project promoters. Promoters should consider the advantages to be gained from the integration of the finance-raising, design and construction processes within the project chain, as exemplified in DC and BOT contracts and as discussed earlier in the paper.

APPLICATION OF ICT IN THE SUB-SAHARAN AFRICAN CONSTRUCTION INDUSTRY

An outstanding benefit of the use of web-based project sites is the minimisation of distance as a constraint on project administration. The use of information and communication technology as described in this paper is relatively inexpensive. Required are a reliable telephone system, servers, software, computers and people trained in the use of ICT: the discipline is knowledge-based and requires limited investment in resources. In sub-Saharan Africa, the unreliable government telephone systems in a number of countries are being rendered obsolete by the introduction of private cell networks. It is necessary to complement this by the introduction of broad-band networks to handle the vast amount of data generated by ICT. It is suggested, however, that for ICT to be successfully implemented in sub-Saharan Africa, governments should focus on the need for education in ICT; the few existing skilled professionals are often being attracted to well-paid work in the US and Europe and need to be motivated to remain if the region is to take part in the ICT revolution. Their numbers also need to be complemented as they are considered to be currently too low for industry requirements, even though some organisations are engaged in training their own staff in-house.

CONCLUSIONS

In this paper the project chain has been examined and it has been seen that there is much duplication and overlapping of activities carried out by project professionals. It is also apparent that there is a bewildering array of specific software available for use by international design professionals. However, an informal survey has led to the suspicion that South African professional firms do not use widely the software available. Furthermore the benefits of using web-based project management techniques do not seem to have become apparent, within the local industry.

An attempt has therefore been made to show how the use of web-based project sites could lead to increased efficiency and economy in the project chain. Recommendations are made that governments in sub-Saharan African countries should maintain reliable telephone systems and/or encourage the setting up of cell phone and broad band networks and should accelerate the implementation of education in ICT.

RECOMMENDATIONS

It is suggested that further research could be carried out in the following areas: the practical use of web-sites in the project chain; the use of commercially available project portals in the project chain and investigation of the economies to be obtained in the integration, using ICT systems, of the design-construct cycle.

ACKNOWLEDGEMENTS

Thanks are extended to the member firms of the South African construction industry which assisted in providing information during the informal survey.

REFERENCES

Cole T, *Electronic Communication in Construction*. Thomas Telford Ltd 2000.

CSIR www.ipros.csir.co.za

Mkhungo M, Mongo L, Kakitahi M. Project Partnering. October 2000. B.Sc Research Report. Department of Construction Economics and Management, University of the Witwatersrand.

Murray M, and Lai A. The Management of Construction Projects Using Web-Sites. *2nd World-wide European Council of Civil Engineers Symposium on Information and Communication Technology in the Practice of Building and Civil Engineering*. June 2001. (Paper submitted)

Murray M, and Mavrokefalos D, The use of E-mail and Dedicated Web-sites in the Management of Engineering Projects. *22nd Symposium on Computers in Engineering*. September 2000. South African Institute of Civil Engineering.

Project Management Institute 1999. *Project Management Software*.

Trincherro P. IT in the Steel Construction Industry. *22nd Symposium on Computers in Engineering*. September 2000. South African Institute of Civil Engineering.