INFORMATION TECHNOLOGY (IT) IN THE CONSTRUCTION PROCESS

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The construction industry is notorious for its reluctant approach to new technologies. IT awareness should be created and directed toward organizations within the built environment to inform and better integrate construction project contributors. Given that IT changes rapidly, it is in the best interest of construction organizations to implement current IT systems and devise a management plan for future updates. In the report *Constructing the Team* Sir Michael Latham reiterates the need to improve the image of construction by adopting high-tech methods that facilitate project communication. Furthermore, recent developments include emerging technologies directed toward mobile computing, and e-collaborations that enable project participants to communicate efficiently from various locations. Although the study reported on determined that IT is rarely used at operations / site management level, contractors are conscious of the potential impact of IT on the traditional project parameters of cost, quality, and time. Further findings include: the increased use of mobile phones for communication at site management level is changing the work environment, and the use of an intranet is a viable method of project management as project managers, designers, and contractors are all able to access 'common' information. Furthermore, 4D CAD has enabled the integration of design and construction management through the ability to link models to project schedules and programmes thus enhancing the construction planning process. Recommendations include: research needs to be conducted relative to the implementation of IT on site; supervision and certain categories of workers need to receive IT training; a transition from desktops to laptop and palmtop is required; software developers need to liaise with the construction industry and develop appropriate software; an intranet should be used on all projects, and contractors should become familiar with 4D CAD.

Keywords: information technology, mobile computing, palmtops, site operations.

INTRODUCTION

IT systems involve the conversion, processing and communication of information. Data captured in digital format is flexible thus, easily revised, adapted and distributed. The combination of quantity and accessibility of information to compress space and time makes computerized information extremely powerful (Day, 1997).

However, the construction industry has evolved technologically at a slower rate than other industries because information components are set in a physical value chain. Furthermore, transformation occurs due to a combination of factors such as globalization, technology advancement, and cultural changes (Scheer, Leusin de Amorim, Santos, Ferreira, and Caron, 2007). To date, the use of IT in construction has been limited and mainly focused on increasing productivity and reducing costs. However, IT continues to evolve in all sectors and the focus on reengineering the

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construction industry promotes a vision of a high-tech level of operations. Furthermore, fundamental changes in the process should occur to better integrate communication between project participants. IT is viewed as a means of solving communication and information management challenges. Once an information system (IS) is implemented opportunities are created for the internal process to improve. Technology implemented at operational level impacts on the development and use of IT at project and organization level. Consequently, the potential implementation of IT at operations level is perceived as a means to solve these challenges. However, this potential is not recognized by all organizations.

Construction projects are specific, unique, and many are complex with varied time constraints and budgets. These factors contribute to the challenge of IT application during the production phase. However, a well organized project grants access to systems software, utilities, electronically stored information or knowledge bases, and other IT resources such as e-mail and discussion forums.

Given the abovementioned a study was conducted among general contractors (GCs) to determine the:

- Extent to which GCs use IT;
- Degree of IT competency;
- Type of hardware used in construction;
- Type of specialized software and intranet use, and
- The impact of design related IT on project parameters.

REVIEW OF THE LITERATURE

The construction process and the need for IT

The production process involves the effective management of resources such as plant and equipment, materials, transportation, personnel, finance, technology and information. Planning and organizing activities are essential functions applied to achieving goals. Short term planning comprizes of a detailed programme that consists of resource and labour schedules. A site manager programmes the work daily or twice daily, therefore programmes that are linked assist in updating schedules. Furthermore, subcontractors and trade supervisors require updated information on a regular basis (Kwakye, 1997).

Site supervisors control labour with the use of time sheets. Targets are set and performance measured and recorded to enable future comparisons. Information is used for remuneration and setting targets. Control in the form of daily planning and site meeting attendance mitigates the outcome of unforeseen events such as subcontractors working simultaneously in the same place.

Quality standards are achieved by implementing a quality system that includes: skilled operatives with experience; materials to correct specification; correct storage of materials; effective planning and programming of resources; supervision and inspection by site management, and adequate protection of completed work (Kwakye, 1997).

Site operations include: materials delivery and storage, procurement of plant and movement of equipment to perform activities. All activities should be coordinated for the process to continue systematically. Task coordination is affected by a reduction in

project duration, delays and alterations to contract programming. Activities are co-dependant, thus a negative effect on one activity could impact others. IT systems support the interaction between subcontractors performing different tasks.

There is a misconception that IT hardware is inappropriate on building sites due to the physical work environment. Resource planning and management improves with the use of appropriate IT. IT applications are designed for specific tasks according to ARUP (2003) as cited by Magdic, Rebolj and Suman (2004):

- Data capture including applications such as time sheets and inspection forms;
- Technical drawings viewed and revised electronically;
- Project management software applications used for project administration, and
- Collaboration software that involves interactive communication systems extended to foremen and site managers through the use of mobile phones and handheld devices.

Decisions are made in project meetings with the design team, consultants and site managers. However, foremen and site supervisors often have the knowledge and experience to evaluate a situation and recommend possible solutions. Foremen and site supervisors are able to communicate on a project using the same software, thus compressing the information gap enabling immediate on-site decisions relative to problems encountered, with the benefit that correspondence is automatically recorded.

Potential use of IT hardware on construction sites

Mobile computing is a key instrument in facilitating the effective use of IT in each phase of a construction project and can be defined as a combination of three components namely (Rebolj and Menzel, 2004):

- Computers that are accessed while the user is in motion such as palmtops;
- Wireless computers with sufficient bandwidth to be accessed while the user is in motion, and
- Mobile applications that support the context or work process in which it is used.

The purpose of integrating mobile computing into an existing IT structure is to reduce the effects of distance between various participants who retain specific information (Rebolj and Menzel, 2004). Very few organizations have implemented mobile computing systems at operations level, thus it is visible that the general construction industry has not recognized the potential use of such systems.

IT is useful in particular construction operations, and mobile workers are intended to input critical information to improve information management and communication for the success of the project. Magdic *et al.* (2004) report on a research project which confirmed that information exchange between project team members and amongst site personnel improve with the use of mobile devices. The second test monitored improvements of document exchange on site with the implementation of a mobile document management system, whilst a third test focused on on-site interpersonal communication whilst problem solving. The findings emanating from the survey conducted by Magdic *et al.* (2004) demonstrate that open project communication enhances project coordination, enabling participants to become more actively involved. The future trend is to move toward the integration of IP telephony, voice

and multimode technology, video-mediated collaborative teamwork, and semantic web based services for intelligent mobile construction.

Use of software and intranet to improve project communication and site efficiency

Software is defined as the set of programs, and procedures and related documentation associated with a computer program, compiled to perform a specific task (Retik and Langford, 2001). Applications software programmes provide a service such as word processing, drafting and data management, for example spreadsheets.

Specialized construction software

A range of specialized construction software is available:

- Construction Computer Software (CCS) - estimating, valuations, planning, and cash flow forecasting;
- JD Edwards - financial management and reporting;
- AutoCAD - design;
- Primavera - project management, scheduling, programming, resource allocation, and costing;
- Buildsmart - estimating, procurement, accounting, and payroll functions, and
- Kwikest - estimating, pricing, and valuing.

Intranet

Organizations realized the need to communicate information within the bounds of their organization. Employees benefit from being able to perform various functions including: access information; receive internal e-mails, and read company policies and newsletters. Intranets that allow selected external access are commonly referred to as extranets. At project level the use of an internet-based network facilitates sharing and exchange of project related information between project participants.

Influence of 3D modelling and 4D CAD on construction projects

The effect of technology on site operations commences at the inception of design. The amount of information increases as operations progress, due to a greater need to coordinate design and the actual construction thereof (Day, 1997).

Designers produce drawings and 3D models by combining relevant information with the initial design to create a realistic perspective. CAD is an important aid to productivity, however few contractors make use of the software applications (Retik and Langford, 2001)

3D Modelling

Modelling highlights the ways in which elements relate to one another. Models are a communication aid that facilitate coordination among trades and integrate architectural components, building services, cladding and other building components (Dawood, Scott, Sriprasert, and Mallasi, 2005). Although more time is taken to create a detailed model, lengthening the design phase, the construction time is reduced. Predetermined parameters assist designers with the selection of suitable materials for a specific component. Furthermore, the design can be communicated easily to the contractors and any adjustments to the model made with ease (Finch, 2000).

Standardization positively influences buildability, productivity, time, and cost. It is possible to relate non-graphical information to elements and components of design drawings with the use of 3D modelling (Day, 97).

4D CAD

4D modelling has evolved from the integration of 3D modelling with the scheduling of construction activities. Models provide project participants with a visual perspective to predetermine possible problems such as sequential spatial process conflicts and temporal aspects of construction schedules (Dawood *et al.*, 2005).

Product data is obtained from specialized design software in either 2D or 3D format and process data is retrieved from programming software. Components are tabulated in a database and linked to relative product information. 4D models make use of start and end dates allocated to activities and those observed to run concurrently and clashes would be highlighted.

RESEARCH

Methodology and sample stratum

General contractors (GCs) were selected from the KwaZulu-Natal Master Builders Association (KZN MBA) membership list using a random sampling selection process. The random sample stratum consisted of 35 GCs extracted from an original sample population of 161. 2 GCs were identified as no longer operating, a single response from a small sized GC was excluded, and 17 responses were included in the analysis of the data, which equates to a net response rate of 52%. The data was captured and analysed using MS Excel.

Findings

Table 1 indicates the frequency of IT use relative to the three levels of management. Given that the mean scores are all above the midpoint value of 3.00, in general the three levels of management can be deemed to use IT. However, the respective mean score ranges provide a more detailed insight. A mean score: $> 4.20 \leq 5.00$ indicates that the use can be deemed to be between often to always / always (middle management); $> 3.40 \leq 4.20$, between sometimes to often / often (top management), and $> 2.60 \leq 3.40$, between rarely to sometimes / sometimes (operational management).

Table 1: Frequency of IT use relative to the three levels of management.

Level	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Middle management	0.0	0.0	0.0	11.8	41.2	47.1	4.35	1
Top management	11.8	0.0	0.0	17.6	35.3	35.3	4.20	2
Operational / Site management	0.0	0.0	23.5	29.4	35.3	11.8	3.35	3

Relative to operational / site management it is notable that in general only two functions can be deemed to use IT - site quantity surveyor, and site manager (Table 2). However, the mean score relative to Site Clerk of Works is on the cut point of 3.00. A mean score: $> 4.20 \leq 5.00$ indicates that the use can be deemed to be between often to always / always (Site Quantity Surveyor); $> 3.40 \leq 4.20$, between sometimes to often /

often (Site Manager); > 2.60 ≤ 3.40, between rarely to sometimes / sometimes (Site Clerk of Works), and > 1.00 ≤ 1.80, never to rarely (GC Foreman, GC SC Supervisor, Store person, and Plant Operator).

Table 2: Frequency of IT use at operational management level.

Occupation	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Site Quantity Surveyor	0.0	0.0	0.0	11.8	35.3	52.9	4.41	1
Site Manager	0.0	0.0	0.0	23.5	52.9	23.5	4.00	2
Site Clerk of Works	6.3	18.8	31.3	6.3	18.8	25.0	3.00	3
GC Foreman	0.0	41.2	41.2	17.6	0.0	0.0	1.76	4
GC SC Supervisor	0.0	58.8	17.6	11.8	0.0	5.9	1.69	5
Store person	0.0	64.7	17.6	17.6	0.0	0.0	1.53	6
Plant Operator	0.0	70.6	17.6	5.9	0.0	0.0	1.31	7

Table 3 indicates that desktops followed by laptops are the hardware devices most commonly used on construction sites – between on average to a near major / near major extent. The mean score relative to palmtops indicates that they can be deemed to be used between a minor to near minor extent. However, mobile phones, which are not hardware *per se*, predominate, and can be deemed to be used between a near major to major / major extent, which suggests they are a popular means of promoting information communication.

Table 3: Extent to which hardware devices are used on site.

Hardware	Response (%)						MS	Rank
	Unsure	Minor				Major		
		1	2	3	4	5		
Mobile phone	0.0	0.0	0.0	0.0	17.6	82.4	4.82	1
Desktop	0.0	11.8	5.9	5.9	41.2	35.3	3.82	2
Laptop	0.0	5.9	11.8	11.8	47.1	23.5	3.71	3
Palmtop	0.0	58.8	23.5	11.8	5.9	0.0	1.65	4

A follow up question investigated the percentage of supervisors that are dependant on mobile phones for resource and task management. The lowest percentage was 40%, the highest 100%, and the mean 83%. Furthermore, 29.4% of respondents surmise that 100% of their supervisors are dependant on mobile phones for resource and task management.

Table 4: Extent to which Supervisors require sources of information whilst working on site.

Information source	Response (%)						Mean score	Rank
	Unsure	Never				Constantly		
		1	2	3	4	5		
Construction drawings	0.0	0.0	0.0	0.0	5.9	94.1	4.94	1
Project programme	0.0	0.0	0.0	11.8	11.8	76.5	4.65	2
Correspondence	0.0	0.0	0.0	5.9	29.4	64.7	4.59	3
Checklists	0.0	0.0	0.0	11.8	47.1	41.2	4.29	4
Schedules	0.0	0.0	5.9	5.9	52.9	35.3	4.18	5

Table 4 indicates the extent to which Supervisors require various sources of information whilst working on site. It is significant that 80% of the information sources have mean scores > 4.20 ≤ 5.00. Therefore, construction drawings, project programme, correspondence, and checklists, can be deemed to be required between often to constantly / constantly. However, schedules has a mean score of 4.18,

marginally below the cut point of 4.20, and thus can be deemed to be required between sometimes to often / often.

Microsoft Excel, Microsoft Word and Microsoft Outlook predominate in terms of the software applications used at site management level (Table 5). Given that the mean scores of Excel and Word are > 4.20 ≤ 5.00, they can be deemed to be used between often to always / always. Excel is used primarily as a spreadsheet programme for information documentation, and financial applications. Word is mainly used to compose documentation and correspondence, as well as agenda and minutes for site meetings. Mean scores: > 3.40 ≤ 4.20 indicate that Outlook and Project can be deemed to be used between sometimes to often / often, and > 1.80 ≤ 2.60 that PowerPoint is used between never to rarely / rarely. Outlook, being an e-mail application is used primarily to communicate, inter alia, to confirm oral communications and transmit documents. Project, a programming application is likely to be used less frequently than a word processing application, and the infrequent use of PowerPoint is likely to be attributable to site management not making frequent presentations.

Table 5: Frequency at which Microsoft office applications are used at site management level.

Software programmes	**Response (%)**						**Mean score**	**Rank**
	Unsure	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**		
Excel	0.0	0.0	0.0	5.9	41.2	52.9	4.47	1
Word	0.0	0.0	0.0	17.6	35.3	47.1	4.29	2
Outlook	5.9	0.0	0.0	29.4	23.5	41.2	4.13	3
Project	5.9	11.8	5.9	23.5	23.5	29.4	3.56	4
PowerPoint	5.9	11.8	41.2	29.4	5.9	5.9	2.50	5

88.2% of the respondents indicated that their organization makes use of specialized construction software. CCS, a programming package, predominates as it is used by 70.6% of these respondents. 11.8% and less of these respondents make use of other specialized packages.

All the respondents indicated that they use IT to perform work activities. Based upon percentage responses to a frequency range of 'never' to 'always', the mean score of 4.47 indicates that the frequency of use can be deemed to be between often to always / always.

23.5% of respondents indicated that an improvement in IT or an increased use of IT would have a major effect on their individual task performance. The mean score of 3.47 indicates that the potential effect can be deemed to be between an effect to near major / near major effect.

23.5% of respondents regarded their computer literacy as extensive, and 0% as limited. The mean score of 3.76 indicates that the degree of computer literacy can be deemed to be between average to near extensive / near extensive. 23.5% of respondents believe the presentation of IT training to site managers and site supervisors is important, 41.2% more than important, and 29.4% very important. The mean score of 3.94 indicates that the importance can be deemed to be between important to more than important / more than important.

Site Quantity Surveyor predominates among functions in terms of the importance of IT competency, the mean score of 4.53 indicating that IT competency can be deemed to be more than important to very / very important (Table 6). Mean scores: > 3.40 ≤ 4.20 indicate that the competency can be deemed to be between important to more than important / more than important – Site Manager; > 2.60 ≤ 3.40 between less than important to important / important – Site Clerk of Works; > 1.80 ≤ 2.60 not important to less than important / less than important – GC Foreman, GC SC Supervisor, and Store person, and > 1.00 ≤ 1.80 – Plant operator.

Table 6: Importance of IT competency relative to various functions.

Function	Response (%)						Mean score	Rank
	Unsure	Not important				Very important		
		1	2	3	4	5		
Site Quantity Surveyor	0.0	0.0	0.0	11.8	23.5	64.7	4.53	1
Site Manager	0.0	0.0	0.0	11.8	58.8	29.4	4.18	2
Site Clerk of Works	0.0	0.0	29.4	41.2	17.6	11.8	3.12	3
GC Foreman	0.0	11.8	47.1	35.3	5.9	0.0	2.35	4
GC SC Supervisor	0.0	29.4	35.3	23.5	5.9	5.9	2.24	5
Store person	0.0	31.3	31.3	37.5	0.0	0.0	2.06	6
Plant operator	0.0	76.5	23.5	0.0	0.0	0.0	1.24	7

Table 7 indicates the importance of access to information sources and IT functions via an intranet. Given that the mean scores of all the sources and functions are greater than the mid-point value of 3.00, in general access can be deemed to be important.

Table 7: Importance of access to information sources and IT functions via an intranet.

Information sources / IT functions	Response (%)						Mean score	Rank
	Unsure	Not important				Very important		
		1	2	3	4	5		
E-mail	0.0	0.0	0.0	6.3	43.8	50.0	4.44	1
Project programme	0.0	0.0	6.3	12.5	31.3	50.0	4.25	2
Minutes of site meetings	0.0	0.0	0.0	12.5	56.3	31.3	4.19	3
Schedules (resource)	0.0	6.3	12.5	31.3	31.3	18.8	3.44	4
Site diary	0.0	0.0	25.0	37.5	18.8	18.8	3.31	5
Digital graphics	0.0	12.5	12.5	43.8	6.3	25.0	3.19	6
Construction drawings	0.0	18.8	12.5	25.0	25.0	18.8	3.13	7
Forum	13.3	0.0	33.3	26.7	13.3	13.3	3.08	8

However, mean scores: > 4.20 ≤ 5.00 indicate that the access can be deemed to be between more than important to very important / very important – e-mail and project programme; > 3.40 ≤ 4.20 between important to more than important / more than important – minutes of meetings and schedules (resource), and > 2.60 ≤ 3.40 between less than important to important / important – site diary, digital graphics, construction drawings, and forum.

Table 8 indicates the impact the use of 3D CAD at design stage would have on five project parameters. Project time, cost, and quality predominate, and given that their mean scores are > 2.60 ≤ 3.40, the impact can be deemed to be between a near minor impact to impact / impact. The mean scores of the environment and project health and safety are > 1.80 ≤ 2.60, and thus the impact can be deemed to be between minor to near minor / near minor. The high percentages relative to the 'unsure' responses is probably attributable to contractors not being aware of the influence of the use of 3D CAD at the design stage on the construction process.

Table 8: Impact of 3D CAD at design stage on project parameters.

Parameter	Response (%)						Mean score	Rank
	Unsure	Minor				Major		
		1	2	3	4	5		
Project time	23.5	11.8	5.9	29.4	23.5	5.9	3.08	1=
Project cost	29.4	5.9	11.8	23.5	29.4	0.0	3.08	1=
Project quality	17.6	11.8	5.9	41.2	17.6	5.9	3.00	3
Environment	35.3	11.8	11.8	35.3	5.9	0.0	2.55	4
Project H&S	35.3	23.5	11.8	17.6	5.9	5.9	2.36	5

Table 9 indicates the impact the use of 4D CAD at design stage would have on five project parameters. As in the case of 3D CAD, project time, cost, and quality predominate. Furthermore, given that their mean scores are $> 2.60 \leq 3.40$, the impact can be deemed to be between a near minor impact to impact / impact. The mean scores of the environment and project health and safety are $> 1.80 \leq 2.60$, and thus the impact can be deemed to be between minor to near minor / near minor. As in the case of 3D CAD, there are high percentages relative to the 'unsure' responses.

Table 9: Potential impact of 4D CAD at design stage on project parameters.

Parameter	Response (%)						Mean score	Rank
	Unsure	Minor				Major		
		1	2	3	4	5		
Project time	41.2	5.9	0.0	29.4	17.6	5.9	3.30	1
Project quality	47.1	0.0	5.9	29.4	17.6	0.0	3.22	2
Project cost	47.1	11.8	5.9	11.8	23.5	0.0	2.89	3
Environment	52.9	11.8	5.9	23.5	5.9	0.0	2.50	4
Project health and safety	47.1	17.6	17.6	5.9	11.8	0.0	2.22	5

CONCLUSIONS

The extent to which GCs use IT

IT is used in various processes within construction and GCs place great importance on improving the extent to which IT is used in each process. It is used at all levels of management; however, to a lesser extent at operational level. Site quantity surveyors and site managers are the predominant users of IT. General foremen and subcontract supervisors rarely use IT, which is likely to be attributable to a lack of IT competency.

IT competency

The importance of access to information sources and IT functions via an intranet, construction drawings included, indicates the need for IT competency at most levels of site management.

The type of hardware used in construction.

Site supervisors require hardware to control resources on a daily basis. Currently GCs make use of desktops and laptops at site management level. Mobile devices are used to store information that supervisors continuously require on site. A large percentage of site managers and site supervisors depend on mobile phones for resource and task management.

Specific software and intranet use

Microsoft Office software applications are frequently used by GCs. However, GCs make use of construction specific software. IT has enhanced communication in terms of project specific intranets connecting the project manager, design team, consulting

engineers, GCs, SCs, and suppliers. E-mail is used as an efficient method of communication.

The impact of design IT on project parameters

The implications of design on construction are highlighted through the use of 3D and 4D CAD. Whilst the literature reiterates the impact the use of 3D and 4D CAD has on the project parameters of cost, environment, H&S, quality, and time, it can be concluded that GCs are not aware thereof.

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