IMPROVING SITE MANAGEMENT PROCESS THROUGH ICT

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ABSTRACT

Purpose of this paper – To identify innovations in information and communication technology (ICT) that have potential benefits for the construction industry. The paper also shows how these innovations, if taken advantage of, can enhance the site management process

Methodology/Scope – The paper uses a purposive sample of specially informative journal and conference published literature on ICT such as 4D CAD and simulation / visualization, Auto IDs, GPS, RFID, Embedded technology, etc. These data sources in conjunction with postulations of uses of mobile communication technology and mobile computing with intranets and extranets in construction, form the basis of extrapolations that could benefit site management.

Findings – Though these are currently propositions, the paper suggests that there is potential for use of ICT in enhancing intra and extra site communications and benefits such as preventative disclosures and 'nipping-in-the-bud' of WMDs, accident causative work processes, enhanced data and materials management – in essence enhanced site management process.

Practical implications – The study is still in developmental stage of a PhD process.

Value – The postulations outlined here show potential to reduce cost of accidents, WMD's and improvement in site management.

Keywords: Site Management Process, ICT potentials, Management ICT tools.

INTRODUCTION

In the past twenty-five years, construction technology has advanced deeper into the gamut of Information and Communication Technology (ICT), with innovations and developments that have far reaching implications for the construction industry. Information and communication technology has continued to develop rapidly ubiquitous applications. The global construction industry boom has fostered research interest in ICT for construction industry. Especially from the dawn of the new millennium construction industry has been accelerated, growing globally and locally with close margins. Volume and value of construction has become a major statistical yardstick for measuring economic activity in any economy. Contribution of construction to Gross National Product (GNP), in different countries at various levels of development reflects appreciable growth.

The new 'construction environment' so created is increasingly more complex and sophisticated, needing more advanced technologies to meet the organisational and operational demands of the day. There is increase in volume and diversity of people on construction sites, with varying levels of literacy and competence. Coupled with these, there has been an influx of new materials and methods, new modes of communication, economic and social changes. This is especially true in

emerging economies of Africa, Asia and South America. This new construction landscape, increased scale and funding of projects, and technological advancement in other areas, among other factors has driven further research effort in construction ICT. Hence appreciable effort has been put into developing ICT systems for construction activities and adapting innovations from other areas. Some of the technologies that have benefited construction include:

Mobile Computing, Mobile Communications, Artificial Intelligence (AI), Automation and Robotics, Global satellite Positioning System (GPS), Geographic Information System (GIS), Embedded Technology, Barcode Technology, Automatic-Identification systems (Auto-ID), Radio Frequency Identification systems (RFID), Four Dimensional-Computer Aided Design (4D-CAD) and graphics, Virtual Reality (VR), Augmented Reality (AR), Extranets and Intranets, etc (Mair, 1999; Retik et al, 1999;Retik and Shapira, 1999; National Institute of Standards U.S., 1998; Flanagan et al, 2000; Jang and Skibniewski, 2007; RFID Centre, 2005; Wang et al, 2007; Stone, undated).

Recently there have been efforts put into integrating the technologies, to achieve better overall performance, in fieldwork. In this regard the following have been investigated: Integrating virtual reality and telepresence, augmented reality with global satellite positioning system (GPS) and mobile communications, embedding barcode and geographic information systems, integrating visualisation with automation and robotics, integrating GPS with smart sensors and wireless networks, virtual reality with surveillance and security applications. These developments in ICT provide potential benefits for the construction industry, construction activities and management of construction activities. It would be logical therefore to expect the construction industry to keep abreast with ICT advancement, and adapting emerging technologies expeditiously, with a view to enhancing communication, visualisation and site management. However, construction industry has been slow in adopting ICT fully, adapting the technologies and properly implementing it. Conservative and non-collaborative tendencies, fear of irrelevancy and loss of jobs, information security and insistence on traditional methods are among the major reasons for this slow response. Where embraced, construction ICT has been targeted more at specific tasks within the set of construction activities, especially operational tasks. In the area of construction management, industry implementation of ICT has been more at policy and strategic management levels. While some technologies have been developed for construction site activities, there is no corresponding level of implementation, and much less is directed at Site Management (SM) and Site Management Process (SMP).

There is a need to investigate recent ICT innovations and developments, within the wide spectrum of information and communication technologies, to determine the potential benefits for the management of construction activities that will enhance the site management process. Against this background, this paper investigates ICT innovations and developments that have potential benefits for construction industry. This paper is part of a wider PhD study still in developmental stage. It will relate sources and literature covered so far in the research work. Being an introductory part of the research effort, this paper intends to show preliminary issues. Site management is a complex field. Thus, ultimately the wider PhD research effort will locate its theoretical framework within the intersections of management and computer science / technology. It is possible also for more light to be shed on what management-oriented approach to construction ICT implementation should be. For the purpose of this paper, focus will be on potential and implications of latest ICT developments for site management process.

CONCEPTS

Wireless – Mobile Technology

Applications based on this concept are diversified in capacity and functionality. They include ability to perform tasks through information interchanges without physical connection, and to move. Mobile / wireless technology is now applied on enterprise scale and grouped according to various factors such as functionality, operational requirements, service categories, etc (RFID Centre, 2005). Mobility has also made it possible to perform mobile computing, undertake mobile office applications and service management involving real-time scheduling and direct information access. It enables frontline data capturing making it possible to enter data at point of activity, making real-time monitoring and control practical (RFID Centre, 2005).

Distributed data collection and centralised management
This involves the control centre approach. An ICT that uses data collecting terminals distributed strategically within a site, and a control centre where transmitted data is collected and analysed (Cheng and Chen, 2002).

Ubiquitous computing
This involves distributing computing power over and around the working environment. This pervasive computing is made possible by wireless mobile communication between embedded systems, handheld mobile devices, stationery devices and bigger terminals, (Flanagan et al, 2001)

Motion planning and tracking
A method used in robotics to predetermine the precise movement of robot arms in 3D environment (Kang and Miranda, 2006). When imported into a 4D virtual environment and linked to a control system on the robot, the movement can be controlled in real-time, especially with real world video monitoring capacity added. This method can be used conceptually for site management where the movement of resources is determined by site design and controlled in real-time.

Real-time computing
This deals with the event and system response (RFID Centre,2005; Wing, 2006; Begh and Kagioglou, 2004; Löfgren, 2007). It talks about generating response from the system as the event happens, within natural response time. It means receiving information and alerts from a system immediately an event occurs anywhere within the system's network.

Contactless transaction
This is enabled by an improvement on smart card technology, where a contactless reader which is able to detect particulars of a smart card without making physical contact, and respond to requests according to access level programmed into the smart card (Card Technology Today, 2007).

Telepresence
It involves using a set of technologies to give the experience of being in a remote location. The user can also affect that location by communicating through vision and sound, or through visually coordinated physical displacement of remote objects by added robotic capacity. It gives remote control capacity to realworld visualisation, providing 4D visualisation. This has become a major research focus for construction ICT. Research has been done on integrating telepresence, virtual realty and mobile communications for planning and monitoring of engineering projects (Retik et al, 1999; Mair, 1999; Stone undated).

TRENDS

Development of these concepts discussed above among others has resulted in many ICT innovations with far reaching implications for the site management process. Initially ICT solutions were targeted at product design, with research concentrated on providing tools for the design stage. Computer aided design software and hardware were among the first implemented. CAD enhanced

the work of architects and design engineers. This effort was followed by ICT solutions for the planning stage of the construction phase, resulting in digital planning and scheduling tools. The design of these solutions was mainly on project management scale. The shift in ICT research to construction site activities came with advancement in automation and robotics in construction. This was borne out of necessity mainly, as in the case of hazardous materials and sites with health threatening features, deep-water construction, subterranean construction, and mega structures. ICT solutions in this regard are isolated, being targeted at specific tasks within construction site activities. Many of these ideas originated from other industries that admittedly have more stability in their basic day-to-day operations than what is found in any construction set up. Thus the success rate achieved in other industries has not been replicated in the construction industry ICT (Wing, 2006; Mair, 1999; Retik et al, 1999;Retik and Shapira, 1999; National Institute of Standards U.S., 1998; Flanagan et al, 2000; Jang and Skibniewski, 2007; RFID Centre, 2005; Wang et al, 2007; Finch, 1998; Stone, undated).

Advancements in mobility, wireless networking, Internet, virtual reality, visualisation, artificial intelligence, embedded systems, and the like have ushered in the present phase of research and development for ICT in construction. Recent developments show an inclination towards integration and the development of hybrid systems with combinations of technologies to perform more tasks or to perform a singular task with more accuracy. Therefore these developments in themselves are still targeted at groups of related tasks and in that sense producing some level of isolation when employed in site management. It seems that requirements of the construction site are not taken into consideration, as much as performing a task in the construction site (Löfgren, 2007). The level of awareness of site staff concerning their ICT requirements is low (Löfgren, 2007).

ICT has been applied extensively in pre-construction stage, in product design, production planning and scheduling. Site management as a distinct part of the fieldwork or construction phase seems not be in proper focus. Research focusing on site management has been limited. It can be argued that there is lack of adequate awareness of ICT potential for management of construction site activities. Moreover a proper evaluation of present ICT developments, innovations and infrastructure has not been conducted to any large extent. Management oriented construction ICT research, focused on the site management process is required to identify these ICT potentials.

RECENT INNOVATIONS AND DEVELOPMENTS

ICT research efforts examined so far fall under the following classifications which are discussed below:

Embedded systems – Auto-IDs - smart sensor networks

Smart card technology

Smart cards, which make use of smart electronic labelling for automatic identification, have continued to soar in adoption and demand across other economic sectors. With added capacity of cyber agents, access control can now be centralised through TCP/IP-enabled local IT networks. An Internet based smart card payment and information access system has been highly adopted among New York City taxis for passengers since June of 2007, which makes use of a contactless reader and a Passenger Information Monitor (PIM) (Card Technology Today, 2007). A new smart sensor system is claimed to allow scripting and real-time management of cards in the field. The ANDiS4EMV system by BELL ID (Card Technology Today, 2007), gives enormous access control power in the hands of management, which can be applied to any resource on site. It has potential for mobile machinery such as cranes. BELL ID smart cards can be disabled totally or partially, blocked or unblocked, and all these while the card is mobile in the field (Card Technology Today, 2007). Next generation smart cards are programmable optical memory cards with numerous customisable

features. As smart card technology evolves and interoperability improves, the cost of operating these systems is reducing and access is increasing. The RP40multiClass transparent contactless reader from HID Global (Card Technology Today, 2007) is one of such that can read cards using old and new technologies. The ability to customise is increasing with software development kits (SDK) being produced for card manufacturers. So for a project site, certain unique feature can be programmed into cards to be used during the project life cycle. Some of the current research fields in this area are Near Field Communications (NFC) and RFID solutions for mobile handsets. One such breakthrough is in bringing about Mobile TV. MTN South Africa is now offering mobile TV service based third generation mobile technology standard (3G), and Digital Video Broadcast-Handheld (DVB-H) technology (Card Technology Today, 2007). The smart card being used for this purpose is the UpTeq mobile TV USIM cards type, which has Conditional Access System (CAS) application built in and is customisable.

RFID

Radio Frequency identification (RFID) can be viewed as advancement from barcode technology, enabling automation to further increase labour productivity (RFID Centre, 2005). This high impact has given RFID systems wide acceptance in various sectors worldwide, especially in the tracking of goods and assets. RFID lends a high level of practicality to mobility, where it is commonly referred to as 'contact-less technology' and 'distributed databases'. RFID is an advanced Automatic Identification (Auto-ID) system made up of radio tags (transponders) that collect and transmit information through a reader or scanner, by Radio Frequency (RF), to a host computer for processing (RFID Centre, 2005). When integrated in field support systems, RFID terminals can be used to remotely detect and measure temperature, pressure, orientation, identify and geographically position objects. They facilitate batch processing because of the ability of auto-identification and using RF, which eliminates the need for visibility. There are up to three frequencies for RFID transmission that are suited to different applications of the technology. The computational capacity in recent RFID products has increased, making it possible to use ubiquitous computing more. RFID has been adopted extensively in retail business. It can be applied to access control for all kinds of resources and in product security. RFID in other research work has been integrated with other allied technologies with far reaching results. There has been integration of RFID and Geographic Information System (GIS) to monitor construction progress, using the Archsched system (Cheng and Chen, 2002), Combining RFID with Ultrasound, using ZigBee networks, in the AMTRACK system, for tracking and monitoring of construction materials (Jang and Skibniewski, 2007). RFID technology now includes cyber-agents or software components, which make independent decisions and actions in the field, without human intervention possible (Wing, 2006). It is now possible to add Internet connectivity to embedded systems, and programme them while in use. This synergy between electronic labelling, tracking features and Internet connectivity through software component eliminates the need for data collection by human intervention, consequently an information laden embedded system can continue with a resource through its transformation as it is used on site (Finch, 1998).

Mobile computing and communications

Mobile communications and mobile computing involves three features; mobile device, mobile networks and mobile services (Rebolj, 2002). Mobile devices are intended to experience displacement while maintaining functionality. Therefore, quality of mobile device and wireless application service is vital (RFID Centre, 2005). Mobile devices have developed at a tremendous rate. These devices have increased in style, functionality, capacity, application areas, features, usability etc. The same has been the case with wireless application service. Today there proliferation, and this is creating room for universal systems. Mobile devices range from Laptop computers, Notebooks, Personal Digital Assistants (PDA), Portable Data terminals (PDT), Tablet personal computers, to Smart phones. Integrating these features has accelerated development of

various mobile devices. Mobile technology has grown through many standards. First Zero-to-Half Generation (0G - 0.5G), through First Generation (1G), and Second Generation (2G – 2.7G). Then Third Generation (3G – 3.75G), which can transfer voice and non-voice data simultaneously making features like videophone call a reality. The next frontier is Fourth Generation (4G) mobility technology standard which has global applicability as one of its major research objectives (RFID Centre, 2005). The coming into existence of Internet Protocol (IP) has given tremendous capacity to wireless and mobility technology. IP offers one of the most affordable and versatile communication means for the job site with room for future adaptations (Begh and Kagioglou, 2004). Internet Protocol is an ICT enabling solution. It enables convergence of technologies on its framework. This makes IP a good choice for ICT implementation in construction sites. It comes with different modes of communication like Pc-to-Pc, Pc-to-Phone and Phone-to-Phone. Other concepts have developed on its framework like Voice over Internet Protocol (VoIP), Integrated Sound and Data Network (ISDN) etc (RFID Centre, 2005; Begh and Kagioglou, 2004).

Visualisation / Simulation

Visualisation has developed rapidly from simple two-dimensional (2D) computer graphics representation (2D CAD), through three-dimensional (3D) computer aided design (CAD) and graphics to four-dimensional CAD (4D CAD). Experience of virtual worlds, and interaction with 3D CAD models in virtual environments, Simulating and visualising passage of time and its implications on cybernetic versions of our real world data in 4D CAD have become regular applications in many fields of work today (Wing, 2006; Mair, 1999; Retik et al, 1999;Retik and Shapira, 1999; National Institute of Standards U.S., 1998; Flanagan et al, 2000; Wang et al, 2007; Finch, 1998; Stone, undated). Research interest areas in visualisation include:

Four-Dimensional CAD
Adding the element of time to 3D virtual environment had created 4D CAD applications with which time passage in projects are simulated and visualised, enabling more efficient planning scheduling. It also enables updating according to progress of work (Mair, 1999;Retik and Shapira, 1999; Flanagan et al, 2000; Wang et al, 2007).

Virtual Reality (VR)
This uses Virtual environments (VE) (Retik and Shapira, 1999) offers an immersive and interactive 3D environment to work in. The user is able to interact with a computer-generated environment, which can be created or the modelling of a real world situation (Flanagan et al, 2000; Wang et al, 2007; Stone, undated). Construction scheduling and its effect on work can be simulated thereby giving a virtual experience of the construction process. Understanding of the design concept and a good knowledge of site eventualities are possible. It offers a graphic medium for both process design and progress monitoring. VR is a convergence of knowledge gained from simulation, visualisation and animation (Retik and Shapira, 1999). Virtual environments generated with computer graphics gives the experience of natural situations in virtual space, using virtual objects and related data. Virtual Reality technology engages the visual senses in order to get the most accurate deduction from the experience. Some VR applications now include the sense of sound and some advanced systems simulate touch by applying motion and vibrations (Mair, 1999; Flanagan et al, 2000; Stone, undated).

Augmented Reality (AR)
Also called Mixed Reality (Graz University, 2007), means taking virtual 3D CAD objects into the real world environments by superimposition. This is opposed to VR, which is simulating real world environments in cyberspace. Augmented reality has different approaches (Retik et al, 1999). It can also be manual or automatic. The real world environment is the base environment while virtual objects are placed in their future real world positions. This is done through a system combining

Global Satellite Positioning System (GPS), Tracking system and Video camera. Outdoor AR is especially good for construction because it is non-restrictive, and augments the reality in conformity with the user's location, position and orientation (Behzadan and Kamat, 2006). Thus the real situation on site can be augmented with virtual CAD models, to simulate and visualise an augmented reality of non-existent situation on site. The user can determine the fit of the imagined with the real. A handheld version this system exists currently.

Telepresence

This is made up of combined technologies. In principle it aims at giving the end user the experience of being physically and completely in a remote or virtual environment by engaging the five classical senses. Telepresence (TP) goes beyond VR to putting the end user in the environment and synthetically giving a real world experience. TP can also be of a non-immersive mode, where the user's senses are not completely engaged to the point of non-awareness of the immediate environment, however the user is able to view a virtual or remote real site situation through monitors (Retik et al, 1999). The idea of teleoperation developed from the concept of Haptic Feedback, Teleoperators and Remote Manipulators, which had appeared in publications by late 1960s (Stone, undated). It has developed by usage in different areas including aviation and space, nuclear energy industry, manufacturing, military and medical practice. Research effort for Telepresence (TP) in construction has culminated in hybrid systems, convergence of even more of technologies (Retik et al, 1999; Mair, 1999). Advancements in video image compression and decompression, wireless networks and mobility have impacted positively on the development of TP systems. A mobile hybrid VR and TP system integrates three modules namely virtual reality module, real world video module (camera platforms), and communications module (Retik et al, 1999). As reported in (Mair, 1999) the hybrid VR, TP and mobile communications concept had home / office site equipment, and site hardware for the remote site. The remote site hardware had both fixed and mobile types. Stereoscopic cameras were used and the communications relied on Internet Protocol TCP/IP through mobile handsets. Research has continued on incorporating audio, mechatronics aspect of this area, in manufacturing, hazardous sites and overcoming problems of application on construction sites, which are dynamic by nature.

DISCUSSION

Various issues of interest arise as the study evaluates the wide range of ICTs available for construction currently and in the near future, and the possibilities come to light. For example, it is foreseeable that the future of satellite TV is in handheld mobile communication devices. That singular possibility holds a lot of benefits for SMP. Satellite based construction support systems like SABARECO and COSMOS have been tried successfully. If powerful systems like that were linked seamlessly and automatically to mobile handsets, communication speed would be tremendously improved.

Very critical SM situations can take place smoothly, seamlessly and timely. For instance a TV broadcast system integrated into a company's intranet can be used to broadcast critical information to supervisors and foremen on the ground. Site management-coordinated remote directing of critical installations in real-time, by both design and construction teams in teleconference mode, with full operation / subject visualisation is possible. In same way, RFID potential can be applied to site management process. If RFID is integrated with allied technologies, it could give the remote and real-time capabilities. The management of the site, human resource, material / equipment / plant, health and safety etc can all benefit from ICT. Site management functions, especially monitoring, directing and control can be highly improved. Technologies employed in all generations of mobile devices still have potentials for construction management today. For instance the Push-To-Talk (PPT) from OG Technology, regarded as obsolete, can still be exploited today. Global System for Mobile communication (GSM) phones on site can be turned into two-way radios, locked on to site intranet through their read / write sim cards, so that site management can simultaneously monitor

and control site activities in real time. Many, if not all existing types of mobile devices are used by construction personnel in one form or the other. They are not utilised to their full potential. Therefore much remains to be done in taking advantage of mobile and wireless application technology for site management process.

CONCLUSION

Terms such as project management team, construction management team and design team are familiar in construction. Site Management (SM), Site Management Team (SMT) and Site Management Process (SMP) on the other hand seem to be lost in the vastness and strategic nature of project management and construction management. While SM comes under construction management, it plays a pivotal role in the production phase of construction process. SM is a complex field, so there is a wide array of potential benefits in utilising ICTs for process enhancement. SMP involves the major stakeholders in construction at various levels of engagement. Therefore simply innovating ICT based solutions for specific tasks in construction process will create more islands of technology. That will not adequately serve for full realisation of ICT potential benefits in SMP. Implementation of ICT in SMP ought to have a multi-stakeholder approach, which seeks to understand the ICT requirements of various aspects of SM and the appropriate nature of their interfaces.
There are appreciable and latent potentials for the enhancement of SM, the SMT and SMP. Even so preventive measures that will nip WMDs in the bud remain an issue. The ideal communications situations on construction sites have not yet been achieved and site management in general is still pressured and stretched over adequate monitoring and control. These potentials should be studied with the backdrop of, what ICT requirements for SM should be and, what ICT toolset and nature of implementation would serve SM best and be inclusive of stakeholders.

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