CONTEXT AWARENESS IN CONSTRUCTION MANAGEMENT - KEY ISSUES & ENABLING TECHNOLOGIES

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ABSTRACT

The use of Information and Communication Technology (ICT) is critical in managing construction projects as the right information needs to be delivered to the right person, at the right time, and at the right place. This paper reviews the challenges and issues in the delivery of information in construction management and explores how context-aware computing can help in managing information and services in a construction project. The key issues in context-awareness in construction management are discussed and the enabling information and communication technologies described. The context of a user (such as role, location, time, preference, etc) may be utilised to provide personalised information. Wireless communication technologies allow computing and communication devices to be used virtually anywhere in delivering information and services. The discussion in the paper focuses on the potential application of context-aware computing in construction management using wireless devices. Conclusions are drawn about the possible implementation of these emerging context-aware computing technologies for Construction Programme Managers.

Keywords Context-Aware Information System, Construction Management, Location Based Services, Wireless devices

1. INTRODUCTION

Construction management involves various contexts which include communication, risk, human resource, procurement, quality, cost, time, scope and integration management. A Construction Programme Manager may be responsible for managing multiple construction projects which may involve various activities, people, companies, suppliers, construction sites, offices and locations. From the inception of a project through to its design, construction, and operation, all parties involved are dependent on information and services. Researchers have estimated that if this information could be managed effectively then savings of up to 25% in the construction cost could be achieved (Baldwin et al. 1990). A Construction Programme Manager's roles and responsibilities involve complex management of planning, scheduling, monitoring, reporting and control of multiple projects. Thus, instant delivery of information and services through an intelligent system can play a crucial part in his or her day-to-day managing activities.

Construction activities are widely dispersed and the site location frequently changes (Magdic et al. 2002). It has been suggested by researchers (Aziz et al. 2006a) that by using wireless communication technologies, the information, communications and

services delivery between project team members in the field and the office can be enhanced. Thus rapid decisions can be made by the construction programme manager. Researchers (Aziz et al. 2006a; May et al. 2005) however claimed that the existing mobile applications in the construction industry only support the communication of static information (such as project data, plans, drawings, etc.), and are unable to take into account the construction worker's changing context and the dynamic project conditions. Similarly, most of the commercially available mobile applications for construction management are designed primarily to deliver pre-programmed management tools without any consideration of the project manager's context. This often leads to a contrast between what an application can deliver and what the data requirements of a user are.

Context-aware computing is an intelligent system that uses environmental characteristics such as the contextual elements of a user's location, time, identity, and activity to inform the computing device of its current context (Burrell and Gay 2001). Context-aware computing applications examine and react to a user's changing context in order to help promote and mediate people's interactions with each other and their environment (Schilit et al. 2002). In addition, some have the ability to provide highly specific data and services by intelligent interpretation of their context (Aziz 2005). It is suggested that awareness of a user's context (such as user role, task, preferences, location, site condition etc.) in mobile construction applications will enhance the effectiveness of programme delivery by providing information and services relevant to a particular context.

This paper reviews the issues and challenges in construction management and explores how context-aware computing can help construction programme managers in managing construction projects more effectively. The next section discusses specific challenges and issues in construction management. This is followed by a review of the enabling technologies for context-aware computing. The potential applications of context-awareness in construction management are then presented and a number of conclusions drawn.

2. CHALLENGES & ISSUES IN CONSTRUCTION MANAGEMENT

The construction industry is not a homogeneous industry. It is made up of a diverse and competing organizations and professional disciplines such as architects, surveyors, contractors and suppliers, the majority of whom are brought together for one project, before transferring to the next. Each construction project is unique with its own environment, resources, scope and timescale, and may require different information, communications and management techniques.

Modern project management methods have evolved tremendously in order to overcome problems in construction management. However, with the growing complexity of single and multi-project management, the traditional methods of construction management need to be revised. The high degree of complexity results from the number of different companies, organisations and professionals taking part in single or multiple projects. People and resources are at the same time part of two (or more) organisations: their company and project organisations. Therefore, effort is required for coordination and communication, since the volume of information and

service delivery is high. In addition, there may be a large distance between the project sites, programme management offices/regional office and the company headquarters.

It is well understood that the use of mobile information and communication technologies (ICT) is critical in managing construction projects as the right information needs to be delivered to the right person, at the right time, and at the right place (Bowden et al. 2006; Magdic et al. 2002). However, the delivery of static information and services to the construction programme manager is inadequate given the growing complexity of construction projects. Mobile applications not only need to be intelligent to the user's changing context (user location, task, profile, etc.) but also to the programme management methodology.

It has been estimated that as much as 30% of project cost is wasted in the construction process (Zou et al. 2006). The problems lie in three main areas:

1). Information history, access and delivery:

- **Poor information and history** – the information passed on is often wrong or inaccurate (Barber et al. 1999), differences in the interpretation of the information, information available is overlooked (Vries 1996), the frustration in not having enough input at the design stage of new-build projects (McAndrew et al. 2005) and lack of information from previous project data.
- **Huge volume of information** – huge volume of project information especially in the multiple project environment, which makes filtering important in order to avoid information overload. Thus, solutions to determine the information relevant to the mobile construction workers current context (Aziz et al. 2006b) are needed to overcome this problems.

2). Communication and collaboration:

- **Poor communication** – senior management often do not know what is happening on site (Barber et al. 1999),
- **Ineffective collaboration** - defects in construction works are often due to poorly detailed drawings, operatives being given incorrect instructions, or technical information not being available (Stupart 2003).

3). Construction Organisational Operation:

- **Complexity and inefficient operation** – complexity factors owing to industry-specific uncertainties and interdependencies. These include the inefficiency of operations in construction management (Dubois and Gadde 2002) such as the number of technologies used and interdependences, rigidity of sequences between the various main operations and overlap of stages or elements of construction.
- **Inaccurate planning** – wrong assumptions are made as to where the project is going in terms of completion date, low technological input, unfavourable clients' attitudes towards projects and lack of support from senior management (Barber et al. 1999).

The problems outlined above becomes more complicated when the construction management firm is involved in a multi-project environment. Researchers (Elonen and Artto 2003) have classified and identified the six relevant problem areas in managing multiple projects: (1) Inadequate project level activities, (2) Lack of resources, competencies and methods, (3) Lack of commitment, unclear roles and

responsibilities, (4) Inadequate portfolio level activities, (5) Inadequate information management and (6) Inadequate management of project-oriented organisation.

In summary, the main problems faced in construction management today are the delivery of fast and accurate information, and good communication amongst various parties in the industry. Therefore, the delivery of effective context-specific information and services for Construction Programme Manager's is very important for the success of construction projects. The use of wireless communication technologies and context-aware computing technologies will enhance information flow in more timely manner between the users at fields and office.

3. ENABLING TECHNOLOGIES FOR CONTEXT-AWARE COMPUTING

There has been considerable interest in human-computer interaction and mobile computing research recently. The increasing availability of cheap mobile devices, wireless technologies and free access to GPS data (that enable the detection of elements of the user's current context, specifically their current location) has created an increasing interest in *context-aware applications*: applications whose behaviour are governed by the user's current context (Brown et al. 2000) and *location-based services*: whose behaviour are governed by the user's current location (Ferscha et al. 2001). A system is context-aware if it can extract, interpret and use context information and adapt its functionality to the current context of use. There are various terms used for context-aware applications, such as context-aware computing, situated computing, context-sensitive computing and situation-dependent computing (Aziz 2005). These terms however, refer to the same concept which is the ability of the applications to respond to their environment. The enabling technologies for context-awareness are presented below:

3.1 Wireless Networking Technologies

Wireless networking technologies allow computing and communication devices to be used virtually anywhere. Table 1 shows comparisons of the available wireless technologies, which is divided into four categories as the Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN) and Wireless Wide Area Network (WWAN). The table shows that the WLAN and WMAN technologies are in a better position than WPAN and WWAN to be adopted in future research. This is due to the data transfer rate capabilities in providing documents and drawings to the programme manager (which required bigger data transfer rate) at an acceptable coverage area for construction site (maximum coverage area of 100m for WiFi and 31 miles for WiMax). Although WPAN is able to transfer data up to 1 MB, its limited range will be the disadvantages, whereas WWAN is unable to transfer large data with its wide area coverage.

The introduction of Mesh networking (a networks that employs one of two connection arrangements of WiFi) that enables WiFi providers to go beyond the limitations of hotspots and offer a broadband service in a wider coverage area (outdoor and indoor deployment), may be the key enabler for the adoption of context-aware computing in construction site management in the near future.

Table 1: Comparison of Wireless Networking Technologies (Adopted from Tropos Networks 2004; Wiggins 2006)

Parameters	Bluetooth (WPAN)	WiFi (WLAN)	WiMax (WMAN)	3G (WWAN)
Frequency Band	Varies (Typical 2.4 GHz)	2.4 GHz	2-11 GHz	Varies
Range	10-100 meters (Class 1 – have 100 meters range)	100 meters	31 Miles	>1000 miles
Data Transfer Rate	Up to 1 Mbps	11-55 Mbps	70-500 Mbps	256 kbps
Number of users	Dozens	Dozens	Thousands	Thousands
Key Advantages	Low cost, Support for ad-hoc networking and intra-device communication	Low cost, easy to deploy, wireless broadband support	Very high bandwidth and high range	Ability to access Internet (Mobile IP based)
Key Disadvantages	Difficulty in configuring the network, security issues, limited range, limited data transmission	Limited range, security issues	A developing standard, expensive and market availability is still limited	Limited bandwidth and expensive

Nonetheless, the development of an application for context-aware computing in construction management should not just rely on wireless communication technology to function, other technologies such as the mobile device capability, web services and location-based services are crucial in supplying the right contextual information. Web services and location-based services technologies will be adapted into the mobile devices with the now widely available GPS PDA-phone, thereby increasing the potential for new communicative operations in context-aware computing.

3.2 Mobile Devices

There are two aspects of mobility in mobile communication. First is the user mobility where one communicates (wireless) “anytime, anywhere, with anyone”. Secondly there is the device portability in which devices can be connected anytime, anywhere to the network. With a move towards a world in which communications and computing are ubiquitous, mobile phones and pocket PCs are ideally positioned to be a core element in this move. With their existing widespread use and familiarity, the deployment of more complex functionality through wireless technologies has the potential to turn the conventional mobile phone and pocket PC into a multipurpose piece of equipment. There are many types of mobile ICT hardware currently used in construction. These include PDA (Personal Digital Assistants), PDA-Phone (combined PDA and mobile phone), handheld computer (a laptop in a small package) and tablet PC (Bowden et al. 2006). They, however, are not efficiently used in delivering information between the construction personnel due to problems with different application platforms in the device applications. Therefore, futher research is needed to develop suitable applications for mobile ICT software to make it more user friendly and able to communicate with different platforms.

3.3 Web Services

A web service is a technology that describe an interface that consists of a set of operation that can be accessed through XML message over the network (Bonsor

2006). The interface provide all details of a web service such that other web service can interact with this web service. This technology supports machine-to-machine interaction over a network, allowing applications written in various languages and running on various platforms to work with one another. Web services enable Windows and Linux applications platforms to function together and exchange data. According to Aziz et. al. (2006a), a major problem in the existing mobile communication application in the construction industry is that they are based on multiple technology platforms (e.g. PDA, Palm, Pocket PC, Tablet PC). This creates problems in the integration of applications that come with different interfaces, programming languages and out-of-sync information. For example, project management applications files in a windows-based PDA will not be able to run or even open in similar applications in a Palm platform. Web services are Web-based enterprise applications that use open, XML-based standards and transport protocols to exchange data with calling clients. They provide simple services that can interact with each other in order to deliver sophisticated added-value services. Therefore, the use of Web services technology may solve the problems related to interaction complexity.

3.4 Location-Based Services

One of the most important dimensions in context-aware computing is based on location. In many mobile computing research efforts (Pagonis and Dixon 2004; Pashtan 2005), location is often used as a parameter to approximate context and to implement context-aware applications. Mobile computing devices that are operational and operated while on the move, can significantly benefit from a context location. Services built on the location awareness capabilities of mobile devices and/or networks are usually referred to as Location Based Services (LBS) (Pagonis and Dixon 2004). The support for this technical capability in mobile devices presents a great opportunity for application developers to create compelling services that are widely used and highly valued. Location information can be used for a variety of purposes in construction management such as to monitor the locations of construction materials and equipment, thus reducing construction waste and improving construction efficiency (Li et al. 2005).

3.5 Technologies for Location Tracking

Location tracking involves several technologies that are combined to produce a system that can track people, materials or equipment. Current technologies used to create location-tracking and location-based systems (LBS) include: Geographic Information Systems (GIS), Global Positioning System (GPS), Radio Frequency Identification (RFID) and Wireless Local Area Network (WLAN) (Bonsor 2006). Any location tracking or location-based service system will use one or a combination of these technologies. A node or tag has to be placed on the object being tracked. For example, the GPS receiver in a cell phone or an RFID tag on a DVD can be used to track these devices with detection systems such as GPS satellites or RFID readers. Nonetheless, LBS can use different principles for acquiring user location data (Nokia Corporation 2005). These are cell ID (a system identifies the cell site in which a user is currently connected, mapping it to coordinates for an estimate of the user's location.), Global Positioning System (GPS - a system that uses a network of 24 satellites to triangulate a receiver's position and provide latitude and longitude coordinates.) and Assisted GPS (A-GPS - a system that uses a combination of cell ID and GPS technology).

The only problem with GPS technology is that it is useless indoors (Hesseldahl 2001). This is because the satellite signals are not all that strong and coverage can be spotty in cities with tall buildings. Therefore, to overcome this obstacle, A-GPS seems to be the solution. A-GPS offers better performance than stand-alone GPS because of superior accuracy, quicker time-to-first-fix, and heightened sensitivity, which leads to better performance in challenging or blocked environments.

4. POTENTIAL APPLICATIONS OF CONTEXT-AWARENESS IN CONSTRUCTION MANAGEMENT

The construction programme manager is at the heart of the Programme Management Office (PMO). The PMO is the organisation that provides the infrastructure and supports necessary to manage multiple projects. Its main responsibilities include: project portfolio management, capacity planning, scope management, inter-project coordination, overall project oversight, cost estimation, contingency planning, quality assurance, subcontract management, project managers' development, process management and tool support. There are many applications that are required to effectively manage a programme management office. The PMO is an operational functioning office, not a policy making office. It is normally led by a Construction Programme Manager who acts as an agent for senior management, providing advice, coordination and overall project oversight.

In managing construction projects, construction project managers typically spend 70% of their time dealing with (generating, managing, sending, collecting and analysing) project data (Fisher et al. 1992). Therefore, a Construction Programme Manager who manages multiple projects may be deeply burdened dealing with huge volumes of project data. The ability to quickly convert data into information, while at the same time reducing the administrative tasks may improve the Construction Programme Manager's efficiency. Context-aware project and programme information and services delivery may be undertaken by intelligently converting and delivering relevant project data (such as project planning, resources, cost, etc) and services based on the Construction Programme Manager's current context.

Having location based services (LBS) allow the application to present information and services that are relevant to the Construction Programme Manager's current position, especially when he/she makes multiple site visits. The LBS application may supply information about the Construction Programme Manager's current location by using tracking technologies such as A-GPS or WLAN technologies. The values are then transmitted from the handheld (PDA-phone) to the server so that it can automatically send appropriate information to the Construction Programme Manager (such as project information required, issues to be resolved at the project site, advice, coordination or overall overview of the project) based on his location. This flow of project information and services can be utilised by the Construction Programme Manager in monitoring a programme plan, progress reports and efficiently managing a multi-project environment. Thus, it increases the efficiency and productivity of the construction project delivery process in a multi-project environment. This section explores the potential applications of context awareness in construction management, particularly with respect to the duties and responsibilities of a Construction Programme Manager.

The potential applications of context-aware computing for programme manager can be developed to have the following functions:

- ***List of tasks and status*** – information such as project progress, contractual information, unfinished tasks and relevant information to the programme manager's current context can be automatically updated on his/her mobile device. For example, when he/she needs to make on the spot decisions about variation orders in certain project, he/she may be able to get the current information (such as project cost, progress, effect of the delay to the programme, etc) and contractual arrangements that are relevant to the current project. This may enhance the judgement and reporting process for Construction Programme Manager's in managing the multiple projects.
- ***Resource usage*** – graphical display of resource allocation over time where the Construction Programme Manager may be able to see the resource allocation, which are busy or free from any task based on the current context. An application can then be developed to trigger the Construction Programme Manager awareness of the current usage of resources on a certain project that is not utilised, so that he/she can relocate the resources to other projects. This may enhance the utilisation of staff in resource management at multi-projects environments.
- ***Context-aware searching*** – the intelligently searching of relevant information for programme or project which is based on the general idea of using contextual information as one of the criteria to search for information. This could be the time of the day when he/she is looking for suppliers near to the project location. For example, the nearest concrete batching plant for concreting works. This may help the Construction Programme Manager in making fast and accurate decisions about selecting the supplier.
- ***Context-aware browsing*** – navigating project information based on the programme manager's physical context (e.g. location). This allows programme manager to browse information or documents that are related and relevant to his/her current context (such as project location and task). Context-aware browsing may reduce the time and enhance the effectiveness of the system in providing efficient browsing information for Construction Programme Manager. The combination of context-aware searching and browsing may overcome the problems of information overload by filtering the information required especially when dealing with mobile devices with limited user interface, where the current browsing quickly becomes tedious. For example, when the user have to gone through multiple layers of menus or list.

Based on these applications, context-aware computing in construction management offers the following benefits:-

- Delivery of relevant data having a context-based filtering mechanism (Aziz et al. 2006a);
- Enhancement of construction collaboration (Aziz et al. 2006a);
- Improvement of health and safety management in construction (Aziz et al. 2006a);
- Reducing the overall cost of construction management by providing only relevant information and services to team members;
- Fast and real time access of information in single or multi-project environment;

- Reducing in the project risk in decision making by tackling the issues based on the user's current context (project type, time and location) and with current information on the projects;
- Improved communications between team members;
- Improved resource usage and allocation based on real time tracking of requirements; and
- Improved overall control and management of single or multiple projects based on intelligent supply of information or services to the right person, at the right time and at the right place.

5. SUMMARY AND CONCLUSIONS

In this paper, the challenges and issues with respect to timely information in construction management are discussed and the enabling technologies for context-aware computing described. Then the potential applications for context-aware computing in construction programme management are discussed. The complexity of multiple-construction projects with dynamic site conditions and multi-layered communication amongst project team members may cause information overload to the Construction Programme Manager. These result from poor communication and service delivery, poor collaboration and inefficient organisational operation. This creates an uphill task for the programme manager in effectively delivering the portfolio of projects on time, within budget and with an acceptable quality. In conclusion, the practical solution to this complex management, dynamic site condition and multi-layered communication problem may be the use of context-aware computing applications. However, in order to determine the most appropriate approach to the adoption of context-aware information and service delivery in construction programme management, the current information needs and flows must be first be understood. This is being explored as part of the next stage of the research and involves interviews with experienced programme managers, and case studies.

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