# AN INNOVATIVE MOBILE APPLICATION FOR CONSTRUCTION PROGRAMME MANAGERS

**Mohamad Syazli Fathi**

*syazli@ic.utm.my*

*Department of Civil Engineering, College of Science and Technology, UTM International Campus, Jalan Semarak, 54100 Kuala Lumpur, Malaysia*


**Chimay Anumba**

*anumba@engr.psu.edu*

*Department of Architectural Engineering, The Pennsylvania State University, University Park, PA 16802, USA*


**Patricia Carrillo**

*p.m.carrillo@lboro.ac.uk*

*Department of Civil and Building Engineering, Loughborough University, LE11 3TU, United Kingdom*

**Abstract**

Construction programme management is a complex and information-intensive environment. The construction programme management team requires access to construction information in real-time and when needed. The current increasing use of mobile devices offers an opportunity to meet this need. The efficient management of construction programmes is one of the major factors for improving stakeholders' satisfaction. An innovative tool is needed in accessing the right information at the right time, especially when spontaneous and urgent decision-making is needed. To this end, the innovative use of a mobile device in delivering information and services to the management team in real-time and based on their current context offers significant benefits.

This paper discusses context-aware computing, the enabling technologies for geolocation and the development of a prototype, mobile, context-aware application for construction programme management. The prototype system developed is based on the findings from an earlier study of user requirements which showed that the ability to provide relevant information and services at an appropriate time and at the most appropriate location has the potential to improve the monitoring and control of construction programmes. The prototype system demonstrates the provision of context-specific information and services to construction programme managers using a mobile device. The benefits and limitations of the proposed approach are discussed and conclusions drawn about the potential impact of enhanced information delivery for the efficiency of the construction programme managers.

**Keywords**

Construction Programme Manager, Context-Aware, GPS, Mobile Application, Programme Management.

# 1. INTRODUCTION

The management of construction programmes was known to be experiencing unprecedented changes and challenges resulting from their complexity (Aritua *et al.*, 2009) and information-intensive nature (Anumba *et al.*, 2008) and, as such, information delivery is the key to better management, survival and success. 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.*, 1999). Furthermore, construction activities are widely dispersed and site locations are frequently changed (Magdic *et al.*, 2002) complicating the management of the projects. Modern project management methods and tools have evolved tremendously in order to overcome problems in construction management. The uses of these tools and methods have been widely known (Milosevic, 2003). However, with the growing complexity of single and multi-construction projects, the traditional methods of construction management need to be revised by using construction programme management. Construction programme management deals with the integration and management of multiple-construction projects involving complex resource utilisation with the intent of achieving benefits that would not be realised if they were managed separately.

It has been suggested by researchers (Aziz *et al.*, 2006) that by using wireless communication technologies, the information, communication 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. However, researchers (May *et al.*, 2005; Aziz *et al.*, 2006) 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 project management tools without any consideration of the construction programme manager's context. This often leads to irrelevant and inadequate information being supplied to the construction programme manager.

Context-aware computing is an intelligent system that uses environmental context (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 applications have the ability to provide highly-specific data and services by intelligent interpretation of their context (Aziz *et al.*, 2006). It is suggested that awareness of a user's context (such as user role, task, preferences, location, site conditions, etc.) in mobile construction applications will enhance the effectiveness of construction programme delivery by providing information and services relevant to a particular context.

Firstly, this paper reviews construction programme management. Secondly, it discusses context-aware computing in terms of the enabling technologies for location-tracking and data transfer. It goes on to present and discuss the development of a prototype mobile information system for construction programme management which includes the system architecture and the features of the prototype application. Finally, a number of conclusions are drawn.

# 2. CONSTRUCTION PROGRAMME MANAGEMENT

A construction programme requires an expanded scope of construction management services, which is commonly referred to as construction programme management. Construction programme management services normally focus on managing the planning, design and construction of a building programme involving multiple projects and multiple phases on either single or multiple sites. The Construction Programme Manager (CPM) is responsible for the overall projects (within the programme), including awarding contracts, procuring materials, monitoring performance (including costs and schedules) and managing the necessary reporting and communications.

Construction project and programme management have been used to build some of the greatest engineering achievements, from the Burj Khalifa tower in Dubai to complex structures such as the Beijing Olympic Stadium. In part, this success can be attributed to the construction project managers' focus and the discipline inherent in project management, and the integration and coordination of such complex initiatives facilitated by the construction programme manager in a programme management framework, as suggested by the Project Management Institute (2008).

Programme management provides a bridge between projects and the organisation's strategy, they must be both adaptable and forceful, absorbing shocks and discontinuities yet ensuring that progress is achieved (Pellegrinelli, 2002). The construction programme manager needs to act like a strategic manager, using a wide range of skills and competencies to realise lasting organisational changes in the face of vested interests and cultural diversity. From a strategic management perspective, an organisation requires flexibility to shape and respond to its own environment.

The fact is that today's construction programme manager must execute a programme effectively with two drivers that are in a constant state of change: (1) people and (2) technology.

- People (for a variety of reasons), come and go in today's business or construction environment. Therefore, the organisation must have the ability to expand and contract on a rapid basis and react to changes in the marketplace. The ability to acquire people rapidly and to enable them to make a valuable contribution quickly is a necessity for survival in today's marketplace (Brown, 2008).
- Technology that changes rapidly. The programme manager must also deal with constant changes in technology and innovation. As technology changes, every company has opportunities to improve operations (Archibald, 2003).

A core element of programme management is tracking the progress of projects and taking action (Pellegrinelli, 1997). Effective and efficient project deliverables are creating competitive advantages for an organisation (in monitoring and controlling the construction programme). Therefore, tools are needed to support construction programme managers in monitoring, controlling and making an informed decision in construction programme management. The rapid developments in mobile and wireless ICT and mobile devices have now enabled the new possibilities of portability and on-demand access to information systems and communication tools that construction organisations are requesting (Löfgren, 2007). However, the existing tools in construction programme management only support the delivery of static modes of information. They are pre-programmed and thus not able to take into account the construction programme managers' context. This support can be provided

through the innovative used of context-aware computing technology that has the capabilities to supply specific information in real-time and as needed, so that decision makers can make informed decisions based on the most important relevant facts.

# 3. CONTEXT-AWARE COMPUTING

Context is a powerful and long-standing concept in human-computer interaction (HCI). Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use in a social context, and with the study of the major phenomena surrounding them (Ghaoui, 2006). Interaction with computation is by explicit acts of communication (e.g. pointing to a menu item) and the context is understood (e.g. default settings). Context can be used to interpret explicit acts, making communication much more efficient (Ghaoui, 2006).

The use of context-aware computing technologies enables mobile applications to deliver context-specific information and services to the user. According to Aziz (2005), the use of context-aware information delivery is able to eliminate distractions for the users (related to the volume and level of information). Context-aware computing also enhances the use of mobile information systems in construction programme management by not just providing a filtering mechanism (to deliver information relevant to the task at hand) but also by increasing efficiency and integrity (being able to make an informed decision). Context-aware computing also has the potential to increase usability by decreasing the level of interaction required between a mobile device and the user (Aziz *et al*., 2005).

One of the most important dimensions and commonly-used context attributes in context-aware computing is based on location. According to Smailagic *et al*. (2001), many frameworks have been developed utilising the location context. In published mobile computing research (Pagonis and Dixon, 2004; Pashtan, 2005), the location parameter is most often used to approximate the context and to implement context-aware applications. Mobile computing applications, characterised by devices that are operational and operated while on the move (e.g. PDA-phones, mobile phones), can significantly benefit from a context location. The following section presents, classifies and reviews the enabling technologies to determine the context location. It also compares the technologies for location-tracking and data transfer to determine their applicability to the research.

## 3.1 Geolocation

Geolocation involves geographically localised information or, in other words, associating digital resources with a physical location. According to Bonsor (2001), a location-based service system will use a combination of Geographic Information Systems (GIS) with any location-tracking technology such as a Global Positioning System (GPS), Radio Frequency Identification (RFID) and/or a Wireless Local Area Network (WLAN). Geographic data is an important aspect of any location system. Geographic Information Systems (GIS) provide the tools to provide and administer base-map data such as manmade structures (streets, buildings) and terrain (mountains, rivers). GIS is used to manage point-of-interest data such as the location of petrol stations, restaurants, hotels, etc. GIS information also includes information about the radio frequency characteristics of the mobile network. This allows the system to determine the serving cell site of the user.

A variety of different location tracking technologies can be found with significantly different characteristics, infrastructure and device requirements. Location-tracking technologies can be classified as micro (location-tracking in an indoor environment), macro (location-tracking in an outdoor environment) and hybrid (a combination of micro- and macro-location-tracking technologies). The competing location-tracking technologies are briefly reviewed in Table 1.

**Table 1: Location-tracking Technologies**

| Technology | Brief Description |
|---|---|
| Wireless Local Area Network (WLAN) | Network of devices that connect via radio frequency, such as 802.11b. These devices pass data over radio waves and provide users with a network with a range of 70 to 300 feet (21.3 to 91.4 meters). |
| Global Positioning System (GPS) (Oloufa *et al*., 2003) | Global Positioning System (GPS) receives signals from multiple satellites and employs a triangulation process to determine physical locations with an accuracy of approximately 0.5 - 5m (commercial use). |
| Time Difference of Arrival (TDOA) (Aatique, 1997) | The Time Difference of Arrival (TDOA) technique is one of the position location techniques for cellular-type wireless communication systems. TDOA techniques are based on estimating the difference in the arrival times of the signal from the source at multiple receivers. |
| Active Badge Infrared (Want *et al*., 1992) | An Active-Badge system uses infrared emissions from a small infrared badge carried by the object of interest. A centralised server receives the emitted signals and provides the location information. |
| Radio Frequency Identification (RFID) (Bahl and Padmanabhan, 2000) | RFID is a small and battery-less microchip that can be attached to consumer goods, animals, equipment and other objects to track their movements. RFID tags are passive and only transmit data if prompted by a reader. The reader transmits radio waves that activate the RFID tag. The tag then transmits information via a pre-determined radio frequency. This information is captured and transmitted to a central database. |

## 3.2 Coverage Area and Data Transfer

Table 2 shows the advantages and disadvantages of the technologies in terms of the coverage area and data transfer capabilities for use in developing an application.

**Table 2: Competing Technologies**

| | WLAN | GPS | A-GPS | Passive RFID | Active RFID | TDOA | Infrared |
|---|---|---|---|---|---|---|---|
| Global | X | √ | √ | X | X | X | X |
| City-wide | X | √ | √ | X | X | X | X |
| Campus-wide | √ | √ | √ | X | √ | √ | X |
| Indoor, room level | √ | X | √ | √ | √ | √ | √ |
| No need for antennas/readers | √ | √ | √ | X | √ | √ | X |
| No need for line-of-sight (travelling in a straight line) | √ | √ | √ | X | X | X | X |
| High Data Transfer Capabilities | √ | X | X | X | X | X | X |

The comparison of technologies in Table 2 also shows that GPS, A-GPS and WLAN technologies have better features and great potential for utilisation as technologies for

mobile-application development. This is due to the coverage area and enabling features, such as there being no need for either an antenna or line-of-sight (where the signal is not required to travel in a straight line to function), which is important for mobile applications where users are moving back and forth from an indoor to an outdoor environment. Moreover, only WLAN is able to provide the high data transfer capabilities that are required to transfer huge amounts of programme management data.


# 4. PROTOTYPE DEVELOPMENT

The concept of supplying specific information and services to the construction programme manager has become technically and financially feasible because of the capability of integrating mobile devices, context-awareness, data, voice and positioning technologies. Although on a small scale, research works by Aziz *et al*., (2006) proved that the concept was achievable. The prototyping process was chosen for the developers to design and build a scaled-down functional model of a desired system, which allows the developer to demonstrate the working model to the user. The prototype gives the users an 'early feel' of the system through showing what the application will do, how a user will interact with it and what it will look like. Furthermore, by using the prototyping approach, what the user wants from the system will be discovered exactly, as well as what it is feasible for the system to deliver. The prototype system developed was based on the findings from an earlier user-requirements study (Fathi *et al*., 2007) which showed that the ability to provide relevant information and services at an appropriate time and at the most appropriate location has the potential to improve the monitoring and control of construction programmes.

## 4.1    System Architecture of the Prototype Application

Based on the literature (Abowd *et al*., 1997; Imielinski and Viswanathan, 1994), the design goal and user requirements identified in Fathi (2009) allowed the researchers to develop a system architecture for the design of a context-aware information and services tool for the construction programme manager, as shown in Figure 1.

The context-aware information system (C-aIS) architecture consists basically of four main components: -
1. The **Positioning System** – using GPS and WLAN to determine the current location;
2. The **Mobile Client** – a mobile device will receive location coordinates from GPS and WLAN, then transmit them to the application server. The mobile client will also receive information or data from the server;
3. The **Context Information Network System** – the wireless network environment for transmitting contextual information and data to the users; and
4. The **Server System** – the context-aware server engine will process the location data gathered from GPS and WLAN and intelligently choose the right information and services from the servers available in the system (Database server, the GIS server and the Enterprise Project Management server).
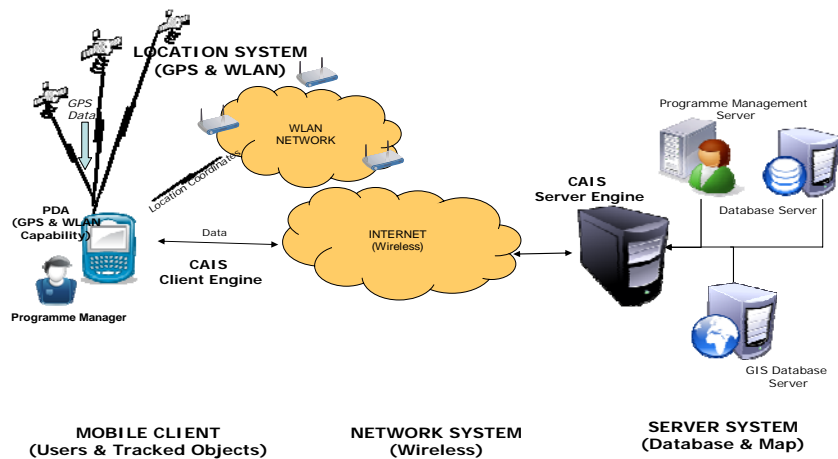
**Figure 1: Context-Aware Information System (C-aIS) Architecture**

The context-aware application supplies information and services based on the construction programme manager's current location by using the Global Positioning System (GPS) for the outdoor location coordinates and a Wireless Local Area Network (WLAN) for the indoor location coordinates. The location coordinates (latitude, longitude and altitude) are then transmitted from the mobile client (PDA-Phone with GPS and WLAN capabilities) to the C-aIS application server through a wireless network.

The C-aIS application server registers the query issued by the mobile client and then performs the following operations until the query is active:
1. Retrieve information associated with the current context together with its scope and load information to the user's device (based on selected context information); and
2. Periodically monitor the current user's context and check whether it belongs to the current information scope. If an out-of-scope condition is detected, the service manager restarts.

The C-aIS application server will process the coordinates received based on the context defined (such as location, time, activity, task and project). This process will involve the programme management servers, database servers and GIS servers, so that it can be programmed to automatically send specific information and services to the construction programme manager (such as the project information required, issues to be resolved at the project site, advice, coordination or a full overview of the project) based on the current context. This flow of project information and services can be utilised by the construction programme manager to monitor a programme's performance and progress, thus a multiple-project environment will be efficiently managed.

## 4.2    Features of the Prototype Application

The prototype application has been developed to have several key features (Figure 2) such as a real-time, context-aware, project and programme dashboard, real-time information on the status of materials and issues on sites, context-aware services and context-aware searching capabilities. The context-aware project and programme dashboard was designed to display the operational status of all projects or the performance of a programme. The application helps manage project interdependencies, especially when construction programme managers

are making multiple site visits. Information such as programme performance, project progress, contractual information, unfinished tasks and information relevant to the construction programme manager's current context (location and activity) can be automatically updated on his/her mobile device. This may enhance the real-time visibility of the status of projects and programmes, and allow accurate judgement and effective reporting processes in construction programme management



**Figure 2: Features in the prototype application**

## 5. ANALYSIS & DISCUSSION

The construction programme manager will be provided with, or can get immediate access to, the central repository of project data that grows as information about the project or programme is developed by the team members. Various programme information such as feasibility studies, budgets, approvals, minutes, KPI, etc., can all be viewed or supplied through the mobile device. Thus, the construction programme manager can use up-to-date and relevant information to make an informed decision.

It is important to note that the management of a construction programme (or multiple projects) presents challenges that are different from those of single-project management. The situations are complex (unpredictable and non-linear) (Aritua *et al.*, 2009) and information requirements are huge (to cover the macro- and micro-levels) (Fathi *et al.*, 2007). Thus, designing and developing mobile, context-aware, construction programme management applications is challenging and demanding. The technology itself is rather complex and involves several fields and technologies that contribute to the final outcome (such as integration, system architecture and interaction design).

The concept delivers benefits to the organisation through a new way of managing projects and programmes, which in turn delivers to the construction programme management the benefits of high efficiency, good visibility and good governance. However, this research is still in the early stages. There are concerns about security, privacy and the reliability of the network, which will be the focus for future research.

## 6. CONCLUSIONS AND RECOMMENDATIONS

This paper has given an overview of the context-aware computing and location-tracking technologies. The review also shows the potential of context-aware computing for construction programme managers. The findings show that to develop a mobile context-aware application, a system should be able to integrate multiple technologies such as context-aware computing, mobile devices, GPS, WLAN and an enterprise project management system.

Based on the reviews and understanding of the construction programme manager's role in construction programme management, a mobile context-aware application may be able to address the following:

1. Improvements in terms of a more timely decision-making;
2. Improvements in managerial tasks in terms of better project planning, scheduling, monitoring and control;
3. The provision of a tool or a system that enables construction programme managers to monitor, control and get access to a specific project information across all projects (for health checks, progress reporting, issues management and risk management) to ensure that the programme stays aligned with the overall strategic objectives of the organization; and
4. The ability to make an informed decision based on instant access to information.

Technology itself would not guarantee success if the project management system fails to meet the needs of the user. Therefore, it is important to understand the relationship and interaction between the user (human) and the application (computer) before developing any computer application. The success of an application depends on the right research philosophy, methodology and techniques. This will also be the focus of future research.

## ACKNOWLEDGEMENT

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