MOBILE COMPUTING IN CONSTRUCTION PROJECTS; ASSESSING FEASIBILITY

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Mobile computing along with the latest developments in mobile telecommunications and mobile devices has emerged as a new potential for efficient execution of distributed collaborative teamwork in AEC industry. However, a research study conducted in Turkish Construction Industry revealed that the mobility support is not effectively used in the construction projects. This study investigates the state of the art collaboration in construction projects and latest mobile technologies as a revolutionary means of support in order to integrate wireless connectivity and mobile computing in construction industry core business processes on site. Wireless solutions are discussed to improve information flow, quality of data, control and coordinate business processes in construction companies. Investment required and benefits gained by the contractors are analyzed. This study investigates and seeks to eliminate the barriers on the way to integrating mobile technologies in the construction industry business processes.

Keywords: Construction, Mobile computing, Wireless communication.

INTRODUCTION

In the global business environment of 21st century, efficiency of work processes, collaboration between geographically distributed teams, reducing cost, and increasing the quality of product are the main concerns of not only construction sector but all sectors. Working teams in distributed business environment demand a high degree communication infrastructure for collaborative working (Dustdar& Gall 2003). A new collaboration model called mobile collaboration has been developed and uses the latest mobile and wireless technologies at anytime-anyplace. Wireless and mobile communications allow people to be more productive and more accessible (DTI 2004). Mobile technologies are essential for many businesses who require flexibility of personnel in terms of location and time. Wireless devices have ability to synchronize with real time data in a more efficient manner than traditional methods.

Parallel to the developments in mobile computing and wireless networking, various communication service providers have begun finding new business areas to enter. New innovative services and technologies has changed the existing business processes in many sectors already.

Construction industry has many parties such as design firms, contractors, subcontractors, consultants, and suppliers involved in business processes. Much research concludes that information technology has the potential for saving considerable time during the business processes by improving the quality of communication between these parties (Rebolj et.al.2000). This leads to great advantages in speed of operation, consistency of data generation, accessibility and exchange of information.

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Mobile technology can be an effective tool to enhance field force operation. Moreover, mobile computing along with the latest developments in mobile telecommunications and mobile devices has emerged as a new potential for efficient execution of distributed collaborative teamwork in AEC industry. The aim of integrating wireless connectivity and mobile computing into construction industry is to improve quality, competitiveness and profitability and to increase the value to clients. However, construction organizations using traditional approaches to evaluate their IT are unaware how to measure the benefits of the IT investments (Love& Irani 2001). For this reason, IT costs must be identified clearly before the determination of benefits.

Nowadays, the most important and prestigious construction project for Turkish government and contractors is Marmaray project. This project includes different types of tunnelling methods and a variety of construction site activities. An industry survey in Turkish construction sector revealed that mobile technologies and wireless communications are not used for improving collaboration and communication in site activities. Marmaray project is a potential prestigious project for Turkish construction where the benefits of mobile computing and wireless communications on site can be theoretically evaluated.

MOBILE COLLABORATION IN CONSTRUCTION

Collaboration is a process of participation through which people, groups and organisations work together to achieve desired results. Collaboration defines a process of value creation that traditional communication and teamwork infrastructure can not achieve (Attaran 2002, Lang et.al. 2002).

Electronic collaboration is the interaction of groups or project teams where the communication for business processes and project delivery are integrated within virtual “real-time” environment (CIRIA 2003). The main collaborative technologies on the market today are based on: Local area networks, Internet, intranet, extranet, mobile and wireless networking technologies.

As projects become larger and more complicated, construction project time scales continue to contract. Effective communication has a key role to control of information, and the execution of business processes. The construction site is a key area where money is made or lost and through the appropriate deployment of collaborative working technology solutions, there is considerable opportunity for improving efficiency, productivity and quality performance (Construct IT 2004).

Mobile technologies are now widely available to enable the construction industry to work collaboratively. However, their adoption and use by the construction industry is still very limited. The main reason for the limited adoption is the traditional structure of the construction industry (Avanti 2004). Real benefits will be determined when all parties involved in the construction process are able to communicate effectively (CIRIA 2003, Hamilton 2004, Construct IT 2004).

Construction site activities can benefit from real-time wireless communication integration in the field, just as any other work activity. By enabling instant wireless connectivity in site with the necessary handheld devices, decision making and problem solving can be made quickly reducing the need for time-consuming face to face meetings. Moreover, tedious paper work will decrease after the integration of mobility into construction site activities and communication and information flow between the site and the office become more accurate and efficient. With the right

information at the right time leads to save time and make workers more productive at site. Wireless solutions and connections enable workers to achieve these applications at the construction site:

- Transfer electronic data to other site or main office by using wireless connectivity.
- Record field data on a mobile device such as PDA, Pocket PC and Tablet PC.
- Instant access to the corporate information.
- Solve problems on site related with the project documents.
- Virtual meetings and instantaneous decision making.
- Real time audio, video and data communication on site.

Mobile business solutions are used for the above applications and these applications can be used for construction site activities listed below:

- Material management
- Quality control
- Daily jobsite record keeping
- Resource allocation and control
- Health & Safety
- Cost and schedule control
- Design document management
- Design problem resolution

There have been some real applications in construction industry (Table1). These applications include the deployment of mobile computing and wireless communication on site. One of the most important point for the integration of mobile collaboration into construction business processes is to measure the benefits of investments. For this reason, costs must be identified clearly before the determination of benefits. Investment costs are divided into direct and indirect costs. Direct costs are classified as: Hardware costs, software costs, installation and configuration costs, maintenance costs and fees for service providers. Indirect costs are classified as: training costs, employee motivation, salary changes, salaries of engineers & technicians for technical support (Love 2001).

Table1: Examples from real mobile IT applications in construction (Comit Project 2004)

Process	Users	Hardware	Software	Location
Monitoring Piling Activities	Workers and Engineers	Cisco Systems	Bespoke web-based	Wembley Stadium, UK
Monitoring Piling Activities	Workers and Engineers	Cisco Systems	Bespoke web-based	Kings Cross, UK
Asset Management	Hilti Technicians	Rugged laptop	Hilti Design Software	Osram Factory, Germany
Safety Audits	Site Agents	Handheld computer	In house system	Bottisham, UK
Maintenance of Fixed assets	Maintenance Engineers	Wearable Computer	Windows, Speech/Touch Rec.	Ontario, Canada
Asset Management	Inventory Staff	Dolphin 7400RF	Houndware Onsite	Fort Saskatchewa, USA
Asbestos Management	Property Surveyors	Xybernaut MA-V	Asbestos Management System	Nationwide, UK
Snagging/Defect Management	Site Engineers	Symbol SPT 1700	MSC Snagging Software	Century Wharf, Cardiff Bay
Collection of Time Sheets	Maintenance Division	Siemens SX45 PDA	Concept 500	Nationwide, UK
Snagging	Project Managers	Digital Pen and Paper, PC	Handwriting Recognition	Glasgow Harbour, UK
Site Monitoring	Site personnel	Compaq Tablet PC	MS Office	Edinburgh, UK
Input of survey data	Building Surveyors	Tablet PC computers	AutoCAD 2002	USA
Asset Management	Earthworks Engineers	Pocket PC	Gismo	National, UK
Building Inspections	Inspectors	Pen based Tablet PC	Sybase SQL	Edmonton, USA

There are many different mobile devices and technologies used on the market today. Data protocols over mobile networks are predominantly GPRS, EDGE and WCDMA (UMTS/3G). Moreover, some of the existing technologies such as wireless local area networks (WLAN), Bluetooth, 3G(third generation mobile technology) and upcoming

technology called WiMAX (Worldwide Interoperability for Microwave Access) are gaining importance. Mobile devices are getting smaller and more integrated. Latest Pocket PC and Tablet PC versions have both integrated WLAN ad Bluetooth capabilities, and WiMAX-integrated chipsets have recently been announced by major manufacturers. Some mobile phones of 'communicator' types have integrated WLAN. These new developments in wireless industry show that hardware and communication protocols which will be deployed in construction industry will face very minor shortcomings during the integration period into daily jobsite business processes. On the software side however, things become more trade-specific. Different software applications for CAD, data capturing, project management, quality management, health & safety, resource allocation and control, material management, etc. are used in construction sites (Table1). All these applications have to be centralised by using collaboration software which is not used in common by engineers on site (Figure1) (Comit Project 2004).

Collaboration software consists of intranets, extranets and different knowledge management applications. Collaboration software enables organizations to centralize electronic documents and allows users from different organizations to work in a more collaborative manner (Figure1). The main objective is to move away from traditional paper-based business processes and breaking down barriers in front of the effective communication (Attaran 2002, Compagnia 2003).

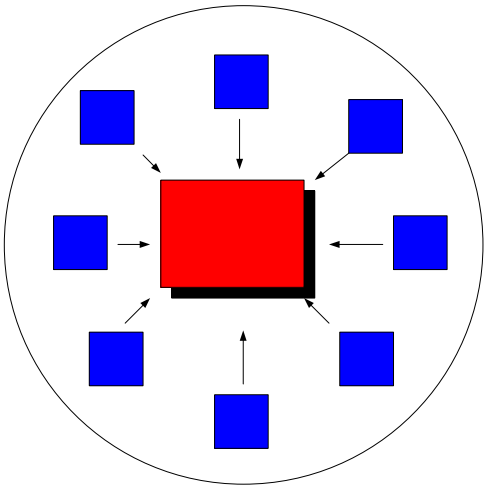

Figure 1: Centralization of applications and electronic documents (Compagnia)

Mobile computing and wireless communications are hot topics in communication environments. Technology is continuously developing, more and more people are using wireless communications during their daily life. Business sectors such as retail, health, education, manufacturing, etc. are using these technologies extensively. However, construction industry is waiting for more real applied projects. Large international projects can be the best ones to be applied due to their needs to mobile collaboration on site, easier evaluation of benefits and investment opportunities. In this study, Marmaray project in Turkey is used for theoretical configuration of wireless communication in construction sites and potential benefits were outlined in the light of experienced professionals who will be involved in the project.

MARMARAY PROJECT: ASSESSING FEASIBILITY

The Marmaray Project provides an upgrading of the commuter rail system in Istanbul, connecting Halkalı on the European side with Gebze on the Asian side with an uninterrupted, modern, high-capacity commuter rail system (Figure 2&3). This Project is one of the major transportation infrastructure projects in the world at present, and is a prestigious project for everyone involved; Turkish Government, consultants and contractors. The entire upgraded and new railway system will be approximately 76 km long. The main structures and systems; include the immersed tube tunnel(under Bosphorus at world-record depth), bored tunnels, cut-and-cover tunnels, at - grade structures, three new underground stations, 37 surface stations (renovation and upgrading), operations control centre, yards, workshops, maintenance facilities, upgrading of existing tracks including a new third track on ground, completely new electrical and mechanical systems and procurement of modern railway vehicles (Marmaray website 2005, Construction proposal 2004).

Figure 2: Marmaray project location in the World map(Marmaray website 2005)

Construction will continue simultaneously in different parts of European and Anatolian side. This fragmentation result in development of five different construction sites and these construction sites have to be coordinated with each other and with site offices (Figure3). Moreover, instant information sharing and communication have great importance on the coordination. Tunnel projects under the ground have difficulties due to distances between the site office and construction site. Especially, in Marmaray, there will be construction sites in both sides of Bosphorus.

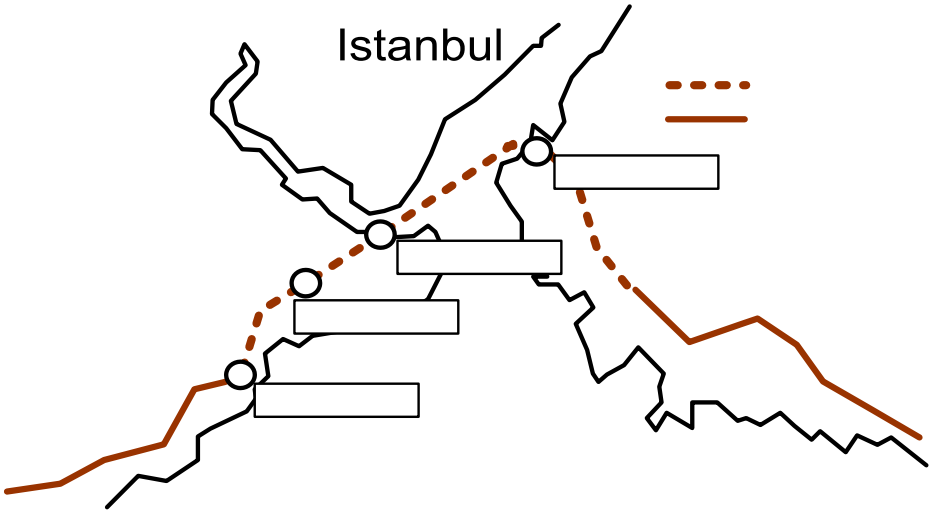

Figure3: Map of Marmaray showing both underground and surface construction area (Construction proposal 2004).

The contractor for Contract section BC-1 is a joint venture consisting of TAISEI (Japan), KUMAGAIGUMI (Japan), NUROL (Turkey) and GAMA (Turkey) and the

employer for the project is Republic of Turkey, Ministry of Transportation General Directorate of Railways, Harbours and Airports Construction (DLH). A groundbreaking ceremony took place on May 9, 2004. However, due to Istanbul's being a historical site and some other reasons construction started in April 2005. Project duration is nearly fifty months and the project cost is estimated nearly one billion dollars and financed by Official Development Assistance (ODA) loan from Japan Bank for International Cooperation (JBIC) and partially from national budget.

Wireless Local Area Network is designed for the tunnels between Kazlıcesme-Yenikapı (1,870m),Yenikapı-Sirkeci (3,343m), Üsküdar-Sögütlüçesme (4,620m) and over the ground for construction sites (Figure3). A wireless LAN was designed according to the project details.

There will be five construction site offices and a main site office. In every site office, construction company will have computer servers and the wireless network will be connected to these servers. In the underground tunnels during the project execution, there will be at least 50 users. 10 users will be between Kazlıcesme-Yenikapı, 20 of them will be between Yenikapı-Sirkeci and 20 users will be between Üsküdar-Sögütlüçesme. By evaluating the cost of these items, mobile computing and wireless connectivity cost can be calculated in Marmaray Project:

- WLAN equipment and installation cost: 25,000-30,000 $(according to technical design).
- Mobile Device Cost: At most 25 users are assumed for the mobile computing during the project. Mobile device cost includes the Pocket PC and Tablet PC cost which is nearly 30,000$ for 25 users (20 Pocket PC& 5 Tablet PC).
- Software Cost: Collaboration software which is also used for the mobile computing can be useful for the development of database which builds the project-specific web page. For mobile computing, combined and detailed software can be used in the construction site activities. This software may include resource planning, progress control, quality control and etc. By this way, contractor may use the software for all of the operations in construction sites and for all projects. The software cost may have benefits beyond the Marmaray project; the contractor may order development of a general software which is designed for the construction project control and management in construction sites. As a result, several construction projects can be controlled and coordinated over the internet and local networks. Users can reach any information at any time about the current or past projects by using the database and the proposed software which is designed for mobile computing in construction sites.
- IT Team Cost: At least two engineers have to be employed by the construction company for Marmaray project in order to develop a collaboration software, integrate the mobile computing into business processes and inform the end users with the proper training sessions. The estimated IT team cost for the whole project duration is 200,000$.
- Maintenance and depreciation: Marmaray project lasts for 4-5 years and during this time devices and network need some maintenances and most of them may be changed, or upgraded due to the technological developments during construction period or demand for capacity increases. For 4-5 years

time, due to the breakdown and technological development estimated cost is 50,000$.

- The total estimated cost for the whole integration of wireless communication and mobile computing in Marmaray project is nearly 400,000$, an estimated 0.04% of total project budget. Moreover, the results of the meetings with contractors revealed that mobile site applications will improve business processes, quality of information, communication, control and coordination of construction sites.

CONCLUSIONS

Mobile technologies bring new potential to businesses. However, success of implementation does not depend on the technology itself alone but the way it is integrated into our existing work processes. Effective usage of mobile technologies depends on correct scenarios. Information technology is developing rapidly and especially wireless communication and mobile computing continue to improve business processes in sectors such as marketing and manufacturing. This research focuses on the integration of wireless connectivity and mobile computing into construction site activities in order to gain efficiency and quality. Construction sector is a suitable domain for adopting mobile technologies due to its specific characteristics, such as field work at distant locations, unique characteristics of each project, different project partners with different cultures, less standardization in processes and specifications.

Strategic management of IT has an important role on the future of construction companies for competitiveness. However, in the vast majority of Turkish construction companies, there are no real strategies for the integration of information technology for gaining competitive advantage. Construction sector has to follow new technological developments, develop appropriate usage scenarios and integrate into the construction business processes. With the appropriate training, understanding, efficiency and effectiveness of the employees will increase as well.

The construction sector has numerous kinds of information flow between the parties involved in the business processes. Many of these information channels can be handled by the use of IT and telecommunication tools. By developing the necessary infrastructure, construction sites in different locations can be coordinated from the main office and real-time data flows between the site office-construction site and site office-main office can be developed. When making IT investments, it has always been problematic to quantify the benefits in monetary values. However, tangible and intangible benefits may be summarized as:

- Improved record keeping and developing historical database
- Increasing efficiency and effectiveness according to decrease in paper work and time consumption
- Accessing real, accurate and instant information
- Cost saving due to printing and delivery and disposal of documents
- Decreasing the trips to construction sites and travel costs
- Competitive advantage due to better coordinated organization
- Reputation due to the application of latest technological developments

- Cost saving due to better resource planning (material, equipment, labor)
- Better controlling and decrease cost of rework during construction
- Increasing the ability to complete project on time and within the budget according to improved control, coordinating and planning.

Certain cultural barriers which are often related to the organisational structure must be overcome before the integration of mobile computing and wireless connectivity in the construction business. Step 1 could be forming an IT team must consist of engineers having experience in the construction and IT sector. The team will help the firm investing in IT tools in the most effective way and avoiding allocation of unnecessary budgets to IT. The second step is making the necessary investments. Managers in the construction sector must be informed about the latest IT integration in construction and the company must develop a long term strategy with the coordination and cooperation of IT team and other departments. After developing the strategies, necessary investment can be shaped. The third step is the application of technology. At this stage, users have to be informed and receive the necessary training. In the development of new systems, users show a well-known resistance. Out of habit, the traditional systems are considered more effective. However, with management back-up, and if users are informed in a professional way by the IT team, resistance will be lowered.

The case study includes a preliminary cost analysis for implementation of wireless networking on site. For this scale of project, a wireless network covering the whole construction area represents a very minor cost item. The WLAN design and mobile computing in the case project is considered as feasible and applicable. Existing research, as well as the conducted interviews suggest that mobile computing and wireless connectivity investment on the case project will improve business processes, quality of information, control and coordination of construction sites.

In the long term, the target must be to develop strategies to use mobile IT in the most efficient and effective way, in order to increase the quality of project communication in construction sector, increasing quality of processes thereby driving down waste and costs.

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