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Mobile Application Prototype for On-Site Information Management in Construction Industry

Abstract:

Purpose:
This paper presents the results of a study aimed at investigating the information requirements for broad use mobile applications for construction projects. It also presents the results of usability testing of a mobile application prototype for improving information management in construction projects.

Design/methodology/approach:
To achieve the research objectives, the information required to properly design the mobile application was collected by distributing an online questionnaire among construction professionals. Then a server-based application prototype was developed based on enterprise content management concepts. The mobile application was tested in a laboratory by setting a group of construction management postgraduate students who had experience on working in construction industry.

Finding:
This study determines and ranks the critical on-site information artifacts, considered highly important from the perspective of clients, consultants, and contractors. The study also illustrates the development of a mobile application prototype and results of a usability test. The test results demonstrate that the application is well designed, user friendly, and meets user requirements.

Practical implications:
The results of this study are useful for developing a functional mobile application to manage on-site information in construction projects.

Originality/value:
The paper makes an original contribution of investigating information requirements of a mobile application for on-site information management.

Key Words: Mobile Application, Information Management, Usability Test

1 Introduction

Information and communication technology (ICT) has contributed significantly to the construction industry. It supports traditional tasks, eases communication barriers, speeds up processes, and manages information. Unfortunately, the construction industry remains behind other industries and it is still relatively in the early stage of adopting modern Internet technology (Klinc et al., 2010, Shen et al., 2010). Most construction companies, for instance, rely on manual processes and traditional communication tools such as emails, faxes, and phones (Dave et al., 2010). A survey conducted in small- to medium-sized construction companies in Taiwan revealed that almost all respondents used e-mail as the internal and external communication tool (Chien and Barthorpe, 2010). Thus, there is no centralized repository for all project data among the type of surveyed companies. Such a repository, if existed, can be used as a form of communication between the project participants and for the integration of project information. This issue has been discussed for two decades, yet the problem still exists in the construction industry (Dave et al., 2010).

The construction industry is known to be labour-intensive and generates large amounts of information. This information ranges from drawings, which are produced in the design stage, to different project reports, which are prepared during the construction stage. Information is obtained from all stages until the end of the project. Thus, the fusion and management of construction information are crucial due to the diversity and intensity of the information (Chen and Kamara, 2008a, Soibelman et al., 2008). This is a real challenge in construction projects, and is a primary step in productivity improvement (Bjork, 2003).

On-site information management is critically important because it is the fundamental element of successful project management (Tsai, 2009). For accurate and efficient information management, information and communication technology (ICT) tools are used in the construction industry. Although, the development of the information technology (IT) gives the construction industry a powerful potential to increase the efficiency and effectiveness of the information exchange (Chen and Kamara, 2005), the IT application for collecting, accessing, and using of the information has not grown properly (Irizarry and Gill, 2009). For instance, there are plenty of commercial products for IT application, but they are very specific and lack simplicity and functionality (Forcada et al., 2007).

Current information and communication technology support has been extended to site offices. The advances in affordable mobile devices, increases in wireless network transfer speeds, and improvements in mobile application performance provide a profound potential for enhancing on-site information management (Chen and Kamara, 2008b). Consequently, developing a simple and functional mobile application, which can benefit the construction industry by streamlining on-site information flow, is crucial. In this context, the research described in this paper is carried out with the aim to develop a prototype mobile application for improving information management in construction projects.

2 Literature Review

2.1 Information Needs in Construction

On-site information management is vital for success of the construction projects. This information has been investigated for two decades. Different researchers had different perspectives and divided the information from general view into technical, commercial, management and control (British Telecom, 1995) to detailed view. For instance, Scott and Assadi (1999) proposed three main categories for construction information, namely finance, quality and progress. Prior to this research, De La Garza and Howitt (1998) classified the information into 10 main groups which are requests for information, material management, equipment management, cost management, schedule means and methods, jobsite record keeping, submittals, safety, quality control (QC) /quality assurance (QA), and future trends. Tenah (1986) had different point of view and found that the information needs of each personnel have an inextricable link to their roles and responsibilities. It can be concluded that, based on Scott and Assadi (1999), Tenah (1998) and De La Garza and Howitt (1998), there is no unique category of information classification and it differs based on researchers' point of view. It conforms to the nature of the information in construction projects where every construction site has its own information classification, and it differs from one to another.

However, even though the job site information is discussed in the early research studies, information needs and the priority of the information for developing a multifunctional mobile application have not been investigated properly.

2.2 Developed Mobile Application Systems for Managing On-site Information Flow

Usage of affordable mobile technology such as personal digital assistants (PDAs), smart phones, and palmtops alongside the latest generation of communication infrastructures such as third generation of mobile communication system (3G), wireless local area network (WLAN), and general packet radio service (GPRS) could benefit the construction process and cause the re-valuing of construction (Bowden et al., 2006). Based on Chen and Kamara (2008b), there are three types of mobile applications that have been used in the construction industry.

1. Mobile CAD Applications for interacting with drawings in construction sites.
2. Data Capture Applications for managing on-site information. This type of application can be subdivided into three categories, namely capturing data, the bar code system, and wireless sensor system.
3. Project Management Applications for dealing with project schedule in construction sites.

There is a variety of research on the adoption of mobile applications in construction projects. In early studies, Nathwani et al. (1995) designed a PDA-based data collection application for maintenance inspection, Repass et al. (2000) proposed a mobile schedule tracking system for progress monitoring, and Baldwin et al. (1994) improved material management through the bar-coding system.

Table 1 summarizes some of the research on mobile application development in recent years. Kimoto et al. (2005) developed a mobile system to manage on-site information by using a PDA device. The system was used for work inspection, managing checklist, position checking and monitoring of the work progress. Menzel et al. (2004) designed a prototype for a PDA application for solving issues regarding mobile usage on construction sites.

Irizarry and Gill (2009) developed two mobile applications based on the situation awareness (SA) approach. The first system, Construction Equipment Finder (CEF), searched for the closest piece of equipment based on the user's location. The second system, Be Safe, displayed safety-related information in an iPhone application.

Table 1: Developed Mobile Application Systems for on-site Information Management

Author(s)	System Function	Main Information	Application Fields	Tools
(Cox et al., 2002)	Field Inspection	Proposed	Proposed	
(Kimoto et al., 2005)	Inspection System, Checklist and Reference System, Position Check System Progress Monitoring System	Proposed (They extracted the formalized unit jobs in data input from some outdoor ones that are suitable for the use of the mobile computing)	Proposed	PDA
(Wang et al., 2007)	PDA- and RFID-based dynamic supply chain management system	Survey (Found four functions: Control, Record, Communication and Reference)	Proposed	PDA, RFID
(Vilkko et al., 2008)	Progress monitoring through monitoring status of precast concrete	-	-	PDA
(Chen and Kamara, 2008a)	They proposed a model for process of selecting mobile computing technologies in construction	-	-	
(Dong et al., 2009)	Defect Management: Capturing digital images or movies of the defects, annotating a note regarding each defect, defining the locations of the defects, as well as sending the above information to an off-site database to be accessed from the design office.	-	-	Nokia N80
(Irizarry and Gill, 2009)	1) Construction Equipment Finder 2) Access to safety-related information	Literature and SA (situation awareness)	SA	iPhone
(Venkatraman and Yoong, 2009)	A mobile collaboration tool which was functioned as a phone, fax, e-mail, canvas for drawings, etc.	Performed a survey for investigating construction constrains	Solution based on constrains	
(Yammiyavar and Kate, 2010)	A self-managed information system on mobile phone for informing workers about job openings	Adopted	Adopted	Nokia N73

Based on Table 1, the developed mobile applications for construction projects usually concentrate on a specific task. Thus, the function of the proposed systems is limited to a certain job and does not embrace general construction projects. Therefore, development of a functional mobile application which has a profound potential to be used broadly for managing the most common information in construction projects is crucial.

3 Research Methodology

Research methodology of this study is subdivided into three sections as follows.

(1) Exploratory Phase
(2) Application Development Phase
(3) Testing Phase

3.1 Exploratory Phase

This stage was conducted to identify problems in construction projects. Based on the critical literature review, some interviews with construction professionals, and online communication through professional networks and forums, a questionnaire was designed in order to determine the mobile application's information requirements. The interviews and online communication were conducted to ensure that the list of the questions is up to date with regards to rapidly changing of the information technology. In addition, an open question was considered to collect the respondents' idea about the information that is not listed on the questionnaire. The questionnaire consisted of three parts: Background Information, the Current Status of Adopting On-Site Information Management, and the Information Requirements of a Mobile Application. After the questions were arranged, a pilot survey was conducted with number of construction professionals to review the clarity, coherence, and relevance of the questionnaire. Then, the necessary amendments were performed to ensure that the final survey fulfilled the objectives of the study. For instance, the number of questions was reduced, the type of the questionnaire changed from the PDF format to the online survey format. Finally, the web link to the questionnaire was sent to 883 construction professionals between the months of May 2010 and January 2011 via their personal email addresses and also through social and professional networks.

The data obtained from the questionnaire were analyzed with the Statistical Package for Social Science (SPSS). Some statistical tests such as, Cronbach's Alpha Test, Kruskal-Wallis Test, ANOVA Test, and Post Hock Multiple Comparison Test were performed to analyze the data.

3.2 Application Development Phase

The main concern of the application design phase was to illustrate the viability of a mobile application prototype for enhancing communication and managing on-site information in construction projects. The required information of the mobile application was selected from the data analysis. Figure 1 depicts the process of developing the mobile application prototype based on the System Design Life Cycle (SDLC) methodology.

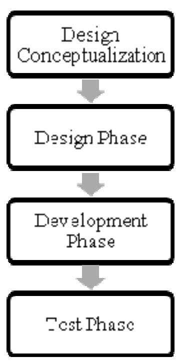

Figure 1 Mobile application prototype development process adopted from Fox and Sheldon (2008)

3.2.1 Design Conceptualization

The first stage was research on design requirements for developing the application. Some programming languages such as Windows Mobile and Java were selected for developing the mobile application in the preliminary phase. Then several interviews were conducted in order to select the best platform alternatives for the study. The platform could be application-based meaning to be used at discrete mobile phones. It also could be server-based meaning the application is connected to a server and project data will be transferred to the server and vice versa. The main objective of this phase was to make a road map for better development and testing in following phases.

3.2.2 Design Phase

This phase included the design of the system architecture. In this phase, overall structure of the system should be drawn. Moreover, the number of layers of the system, such as application server, web server, database server, firewalls, and etc., should be decided. Design of the database and map of the development phase were the most important outputs of this stage.

There are number of construction forms that being used for recoding information in construction projects such as accident reporting form, project progress form, and so on. Each form comprises some fields. For instance, accident form is consisted of accident date, accident location, type of injury, and etc. The fields of construction forms should be considered in design of the application. Therefore, after selecting information requirements of the prototype resulting from exploratory phase, many examples of forms used in construction sites were gathered to find the necessary fields for the mobile application. Forty-two emails were sent to some of the survey's respondents. They were asked to send the selected construction forms. The fields of the application were collected from the forms to be included in the mobile application.

3.2.3 Development Phase

The paper-based map for application design should be translated into machine language in this stage. Microsoft® SharePoint® has the capability to convert website components, such as tables, formatted texts, menus, etc., into programming codes. To develop the application, a mobile version of the SharePoint website was designed. This allows the website to be accessible through both mobile devices and desktop web browsers.

3.3 Test Phase

Usability is defined as "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO, 1998). Usability is critical to the success of mobile devices and acceptance of mobile technology (Urbaczewski and Koivisto, 2007). Thus, a usability test is essential after the development phase. The testing phase investigated the overall look, performance, and usability of the constructed mobile application in a laboratory setting. This study focused on laboratory test because conducting a time-consuming field test may not be worthwhile when searching user interface flaws to improve user interaction. In spite of this, it is possible that field testing is worthwhile when combining usability tests with a field pilot or contextual study where user behaviour is investigated in a natural context (Kaikkonen et al., 2005). In addition, the added value of conducting usability evaluations in the field is very little and that recreating central aspects of the use context in a laboratory setting enables the identification of the same usability problem list (Nielsen et al., 2006).

The laboratory usability test took place at Construction Technology and Management Centre (CTMC) in Universiti Teknologi Malaysia (UTM). The participants were postgraduate students in construction engineering and management from various cultures and work experiences. This group of respondents had previously worked in various construction organizations. The test used 12 participants in order to achieve statistically relevant results sufficient for a formative usability evaluation (Bevan et al., 2003).

A performance test was conducted using four tasks: sending a short message, filling an accident report, delay, and change order forms. All four tasks had 70 characters, including a space. The reason for using the same 70 characters for the tasks was making sense of comparison between the tasks' duration after completing. All of the participants completed their tasks at the same location, but not at the same time. This was to avoid feeling of competition among participants to achieve the best record if they were completing the tasks at the same place. The usability test was carried out after using the system and through the aid of a structured questionnaire.

Though all participants owned mobile phones, for a level playing field, a Samsung SGH-i780 was used. This phone has a 320 x 320 pixel screen and an onscreen QWERTY keyboard. All of the participants used the QWERTY keyboard instead of typing with the phone keypad.

While performing the tasks, the respondents sometimes asked for help in dealing with the mobile phone and its applications. The number of the help requests and the time it took to do the tasks were recorded to investigate the overall performance of the mobile application.

At the end of the test, the overall usability of the mobile application was graded by a questionnaire adopted from Vuolle et al.(2008). The testers answered questions related to learnability, ease of use, user satisfaction, and system efficiency.

4 Analysis and Results

This section includes analysis and results of the exploratory, application development, and usability test phase.

4.1 Analysis and Results of the Exploratory Phase

To achieve the objective of this study, which is to investigate the information requirements for broad use mobile applications, an online survey was established. A total of 233 construction professionals from 22 countries responded to the survey. From those, 182 completed and reliable responses were selected for analysis. This sample included 101 contractors, 50 consultants, and 31 clients.

The reliability of the Likert scale was tested using Cronbach's alpha coefficient. According to Pallant (2001) the coefficient more than 0.7 would be considered as a reliable scale. The obtained alpha score, using reliability analysis, is 0.955, meaning highly interrelated data and consistency of the scale with sample size. Other studies such as Wu and Ding (2008), Narang (2011), and Pajek et al. (2011) achieved 0.97, 0.96, and 0.96 respectively.

4.1.1 Findings from Respondents Profile

Almost half of the participants have more than 15 years' experience (53.3%, n=182), and about 70% have more than 10 years' experience. Construction professionals from 22 countries participated in this survey. The largest number of respondents was from the United States of America, which had 26 participants. Canada, India, and the United Arab Emirates respectively accounted for 24, 24, and 22 respondents each. The least number of responses came from Indonesia, Kuwait, Slovakia, and the Central African Republic with only one respondent from each. Almost half of the participating construction companies (47.8%) were small- to medium-sized, while 52.8% were large companies.

About 81% (n=143) of companies captured the information at construction sites, using traditional and digital tools Among those, 52% were from large companies and 48% were from small- to medium-sized construction companies (SMSC). About 44% (n=182) of construction companies did not have a system for managing information, while 56% of them did. 57% of the companies are not satisfied with their current information management systems; of those, 60% are from large companies and 40% are from SMCS. Even though larger organizations are better equipped or motivated to adopt mobile IT to enhance productivity and to stay ahead of the game, they have a higher demand to implement or improve their information management systems.

Figure 2 reveals several tools that are currently being used for managing on-site information. The functions of these tools were explained in the survey and the respondents were requested to select these tools if only they use it for on-site information management. Out of 99 responses, cell phones account for 39.4%, while PDAs and computers make up 23.2% and 15.2%, respectively. Other tools such as cameras, voice recorders, walkie-talkies, etc. comprised another 22.2%. Since the cell phone is the most popular tool for managing on-site information, this study focused on developing a prototype for mobile phone.

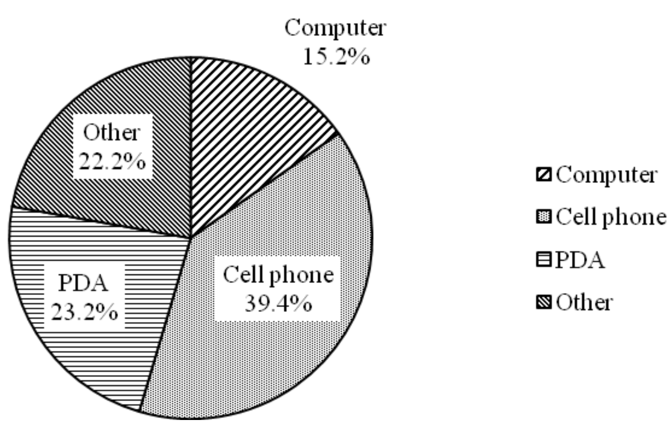

Figure 2 On-site Information Management Tools

4.1.2 Findings from Mobile Information Requirement

In order to evaluate the demand for information for mobile applications, the questionnaire responses were transformed to important indices using equation (1).

$$Relative\ Important\ Index\,(RII) = \sum \frac{W}{A \times N} \qquad \text{(Equation. 1)}$$

where w is the weighting given to each factor by the respondent, ranging from 1 to 5 in which "1" is the least important and "5" the most important; A the highest weight, in this study A = 5; N the total number of samples; and RII the relative important index, 0 < RII < 1 (Tam, 2000).
Three important levels using relative important index, high (0.8 < RII < 1), medium (0.5 < RII < 0.8) and low (0 < RII < 0.5), are then transformed from the RII values (Tam et al., 2007).

Table 2 illustrates the results of the analysis. The descriptive analysis of the client group reveals that there are eight important information categories highly required to be included in the mobile program. The RII ranges from 0.80 to 0.557in the contractor group. The most important information for contractors' perspectives is "Schedule Update", followed by "Violation Report". The consultants' information needs ranged from "Design Intent and Clarification" to "Employee Training", with a RII of 0.840 to 0.596. Consultants' requirements focus on designing part or giving instructions when contractors demand work progress, and client achieving project objectives.

[Place Table 2 here]

4.1.2.1 Difference between Information Needs of Contractor, Consultant, and Client

An ANOVA test and a Post Hock Multiple Comparison test were conducted to compare the mean score of the information among client, contractor, and consultant. Results show that apart from design intent and clarification, there is no significant difference (ρ>0.05) in information demands from contractor's and consultant's point of view. However, perspective of client is different from contractor and consultant in such categories as material order status, visitor's log, as built records, variation order, and reporting violations. Based on Table 2 and statistical analysis, it can be concluded that the information needs of construction parties are different, depending their roles and responsibilities where consultant designs the project, contractor realizes the design, and the client focuses on overall project performance.

4.1.2.2 Information Needs of the Different Countries

A Kruskal-Wallis test was conducted to investigate any significant difference between locations of the respondents. The result reveals that, apart from productivity information (ρ=0.024), there is no statistically significant difference in the distribution of the sample in these countries, because in all cases ρ>0.05. Therefore, the data gathered are independent of the location of the respondents. It demonstrates that the methods of construction and the requirements of the construction professionals are the same in different countries.

4.1.2.3 Selected Information for Design of the Prototype

The above results prove that the selected information can safely be used in the development phase. The highly demanded information (0.8 < RII < 1) are considered for developing the mobile application. The selected information from the client's, consultant's, and the contractor's group is as follows.

- Design intent and clarification
- Reporting violations
- Report QC/QA problems
- Accident reporting
- Productivity information
- Report inspection results
- Progress Photo
- Change Order
- Daily Report
- Delay recording
- Schedule updates
- Site instructions
- Variation Order

4.2 Analysis and Results from the Application Development Phase

The application development phase had three phases, namely the design conceptualization phase, the design phase, and the development phase. The results of these phases are presented next:

4.2.1 Results from the Design Conceptualization

This stage involved research on the design requirements for developing the application. Microsoft® Office SharePoint Server (MOSS) was selected as a fundamental element for designing the prototype. MOSS provides some templates for organisations to easily develop their websites. Basic customisation of these templates can be done in MOSS; however, advanced customisations need the knowledge of programming and should be made in Microsoft® Office SharePoint Designer (MOSD). MOSD is a part of Microsoft® SharePoint family to create, customise, and manipulate existing features of SharePoint sites. The reason for selecting SharePoint was not just adoption of ECM. The lack of IT expertise personnel is one of the barriers when it comes to IT implementation in small and medium-sized enterprises (Tan et al., 2010, Jones et al., 2003). A simple, yet functional, professional system, which can be controlled by non-technical personnel, allows companies to handle their projects efficiently. Microsoft® SharePoint products have been developed to address this issue in organizations. This software allows non-technical personnel to easily manage and customize organizational processes (Microsoft, 2006).

4.2.2 Results from the Design Phase

The system has five different layers (see Figure 3). The first layer is the interface, which can be seen by system users. The next two layers are the switch layer and the firewall layer. These provide physical security for the system. The forth layer is the web server, which includes Microsoft® SharePoint Server and Microsoft SharePoint® Service. The final layer of the system is a database server. Microsoft® SharePoint Server's database is Microsoft® SQL Server.

A review of construction forms was conducted to investigate information subcategories. The main information categories consist of 13 information groups, which are the fundamental functions of the construction mobile application (CMA). The sub information groups are the system fields. Under the Schedule Update menu, for example, are the fields Date, Task Name, Actual Work, Actual Cost, and Actual Duration.

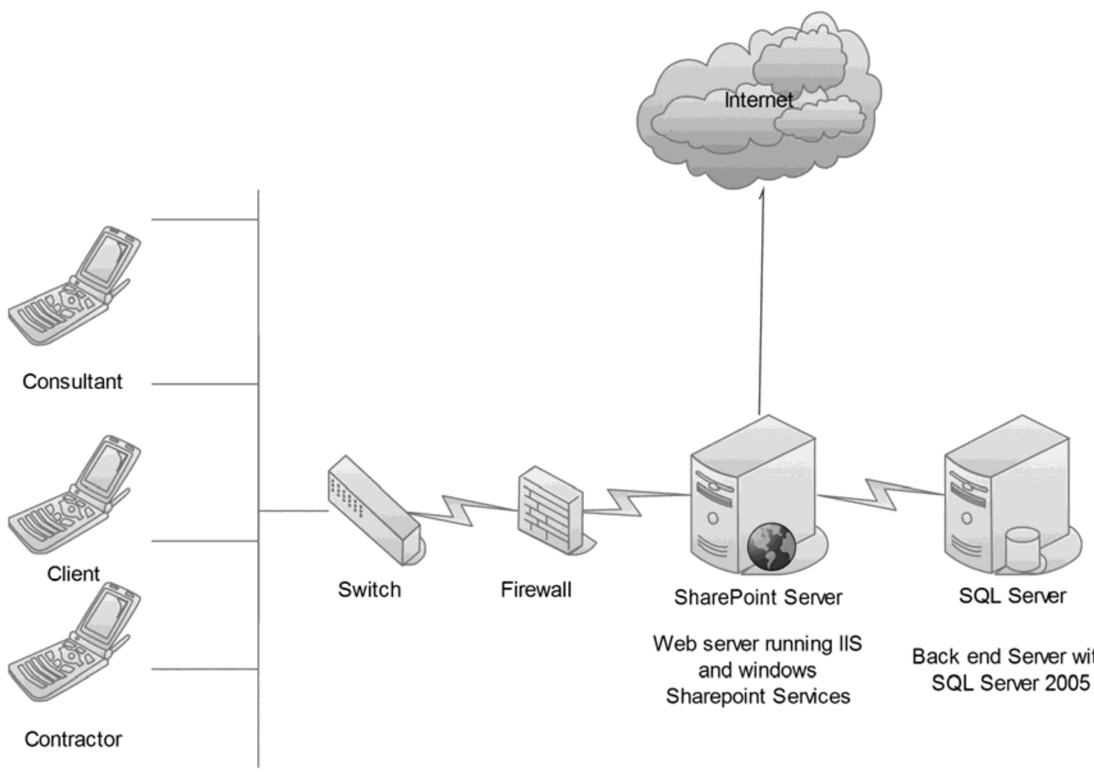

Figure 3 Network Diagram of the CMA

4.2.3 Results from Development Phase

The server-based mobile application was designed with MOSS, and advanced customisations were then made with MOSD. Even though the existing software, namely Microsoft Office SharePoint family, was used, the mobile application was developed using Active Server Page (ASP).NET framework and C# programming language in the MOSD environment. Coding in MOSD provided new features that do not exist in MOSS (e.g. creating new web parts). This is to ensure that the final product suits the objective of this study as well as construction industry. It is based on the main information, which was selected from the survey, and on the information's subcategories, which were collected from different construction companies. Figure 4 shows a sample screen of the developed mobile application.

Figure 4 Construction Mobile Application (CMA)

The system architecture is shown in Figure 5. In the first step, the application asks for user permission, which allows authorized individuals to enter the system. The users access different parts of the application based on their roles and responsibilities, which are settled via authorization rules. For instance, senior managers can view, edit, and approve the information, but junior managers can only view and edit.

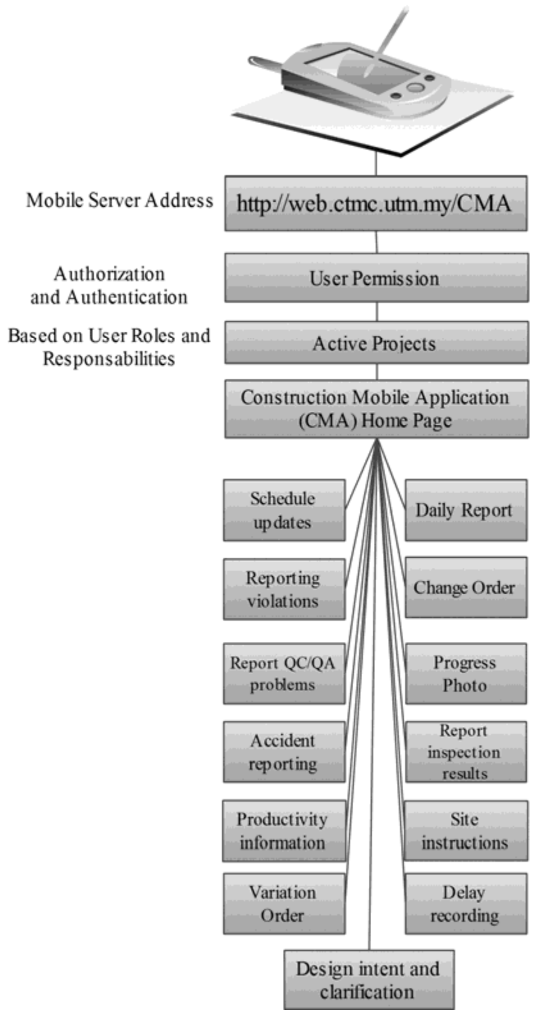

Figure 5 Architecture of the CMA

In real construction projects, various data are generated by the consultant and submitted to the contractor, while some data are generated by the contractor and delivered to the consultant. For instance, Inspection Report, QA / QC report, Design Intent and Clarification, and site instruction are the data generated by the consultant. Schedule Update, Accident Report, Violation Report, Productivity Information, Progress Photo, Daily Report, and Delay Recording are data produced by the contractor. The data flow between contactor and consultant as a part of the conceptual framework of the CMA is presented in Figure 6. The data generated by contractors are labelled from one to 14 while consultants' data are labelled from 15 to 24. First, for example, a contractor enters the 'Schedule Update' data into the CMA. Second, the data will be transferred to the online database of the system. The CMA organizes the data into information (Garvin and Berkman, 1995) by storing them in its database. On the other hand, when on-site data are imported into the system, the unstructured data become structured by storing in the CMA database. After that, the information is organized in relevant directories for better information management. These directories are available for consultant team based on their roles and responsibilities. This is how the data flow from contractor to consultant and vise versa in the CMA.

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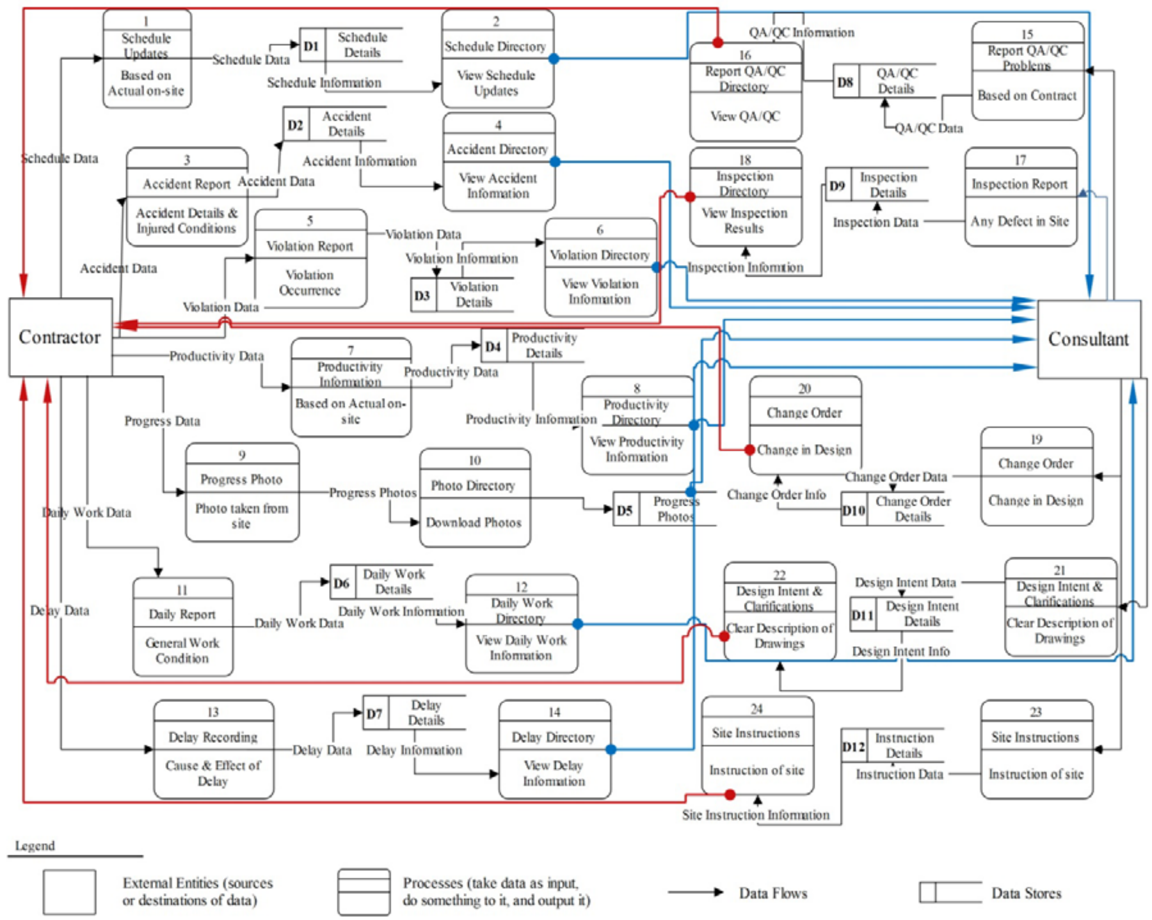

Figure 6 Conceptual Framework of CMA between Contractor and Consultant

4.3 Analysis and Results from the Testing Phase

Interviews with 12 test subjects were conducted to assess the usability of the CMA system. The mean age of the subjects was 28 years, with a standard deviation of 3.5 years. The subjects had an average of 1.7 years of work experience, using cell phones for almost eight years.

4.3.1 Results from the Performance Test

The aim of performance test is to quantitatively measure the ease of using the system, either by speed of performance or error rate (Lee, 1999) and users' required assistance. Four tasks were carried out to assure the accurate performance of the system.

Figure 7 and demonstrates the testers' results; it can be clearly seen that, apart from only two participants' results, most of the results were close in the first task. This means that the testers were familiar with the first task, because they had been sending short messages for about eight years. The respondents had a different performance in the second task when they were interacting with the application for the first time. It was observed that some of them solved their problems quickly, while others relied on asking questions instead of trying to find the solutions themselves. The overall increase of the time it took to complete the tasks was due to the testers' unfamiliarity with the system. In the next task, the results were closer, because they were more accustomed to the application, and in the forth task, the results were as close together as in the first task. This means that all of the respondents were familiar with the system and they could use the system as easily as sending a short message; this proves the simplicity of the mobile application.

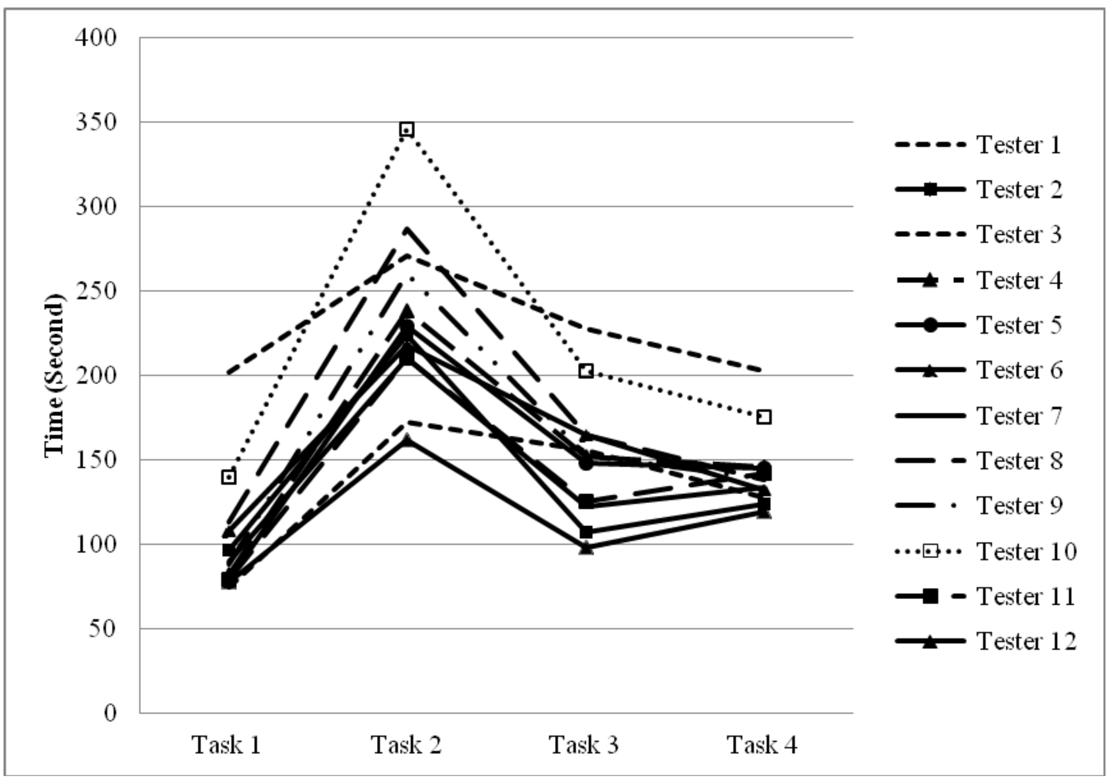

Figure 7 Performance Test Result

Some of the participants asked about the function of the QWERTY keyboard while sending the short messages, because it was the first time that they had used a QWERTY keyboard and they could not find some of the letters. In the second task, when they were doing the accident reports, some of them asked about the function of the CMA and some of them needed instructions.

Figure 8 demonstrates the participants who required assistance. Most participants learned to use the CMA in the first two tasks, and there was almost no assistance required in the last two tasks.

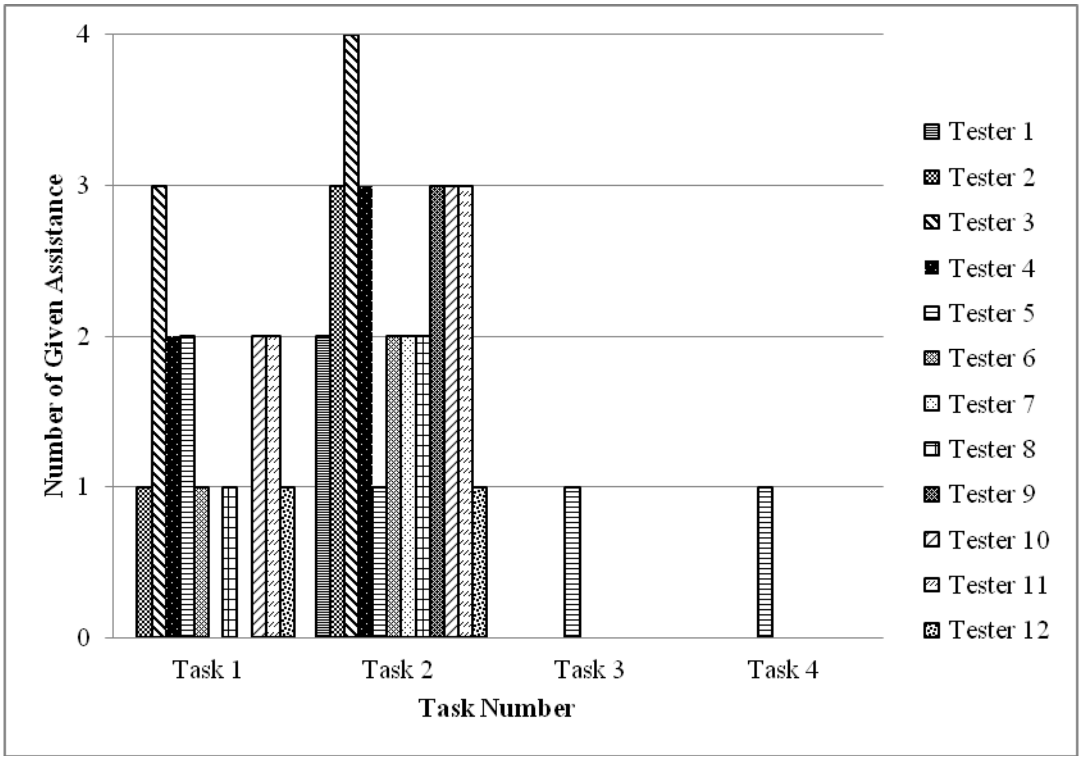

Figure 8 Testers' Required Assistance

Table 3 demonstrates the results of usability test. The results are summarised as follows.

[Place Table 3 here]

Learnability is user's ability to operate the system to some defined level of competence after some predetermined amount and period of training (Rubin and Chisnell, 2008). Almost half of the participants strongly agreed that the CMA is easy to learn, while the other 25% agreed. Moreover, About 70% stated that they would not need to learn many things before beginning to use the CMA. About 50% strongly agreed, while about 40% agreed, with the statement that their experience with other mobile services made the CMA easier to operate. This shows that the CMA's interface is not unique. Rather, it is based on common mobile applications, which makes its users feel confident. It is important for the success of service because the learning phase may be expensive for both company and service provider (Vuolle et al., 2008).

Almost half of the participants accepted that it was easy to move from one part of a task to the next with the CMA. The easiness of use is an important motive for using mobile services. This is because only if the mobile services are easy to use users are able to take advantage of all possible benefits of the services (Nysveen et al., 2005).

Efficiency is the quickness with which the user's goal can be accomplished accurately and completely (Rubin and Chisnell, 2008). Over 80% of its testers agreed that it responded quickly to their actions. They also agreed that by using the CMA, they could quickly complete their work. This is due to design of navigation and categorisation of the content which has a great impact on efficiency (Quesenbery, 2003).

Users are more likely to perform well on a product that meets their needs and provides satisfaction than one that does not (Rubin and Chisnell, 2008). Investigation on the user satisfaction reveals that over 90% of the respondents recommend the CMA to others who do similar work, while about 60% were pleased to use the CMA to perform work tasks. Moreover, About 70% of the participants felt confident when they used the system.

The results of testing phase indicate that most respondents found the CMA efficient, user-friendly, and easy to learn. Although some of the participants had never used an on-screen keyboard or had difficulty using touch screen cell phones, they learned the CMA after performing just three tasks. The usability test revealed the validity and usefulness of the CMA.

5 Conclusion

This study investigated the information requirements of a mobile application that can be used broadly in construction projects. It looked at what information would be most important from the perspectives of consultants, contractors, and clients:

Clients highly need eight information categories as follows.

1. Delay Recording
2. Site Instructions
3. Schedule Updates
4. Productivity Information
5. Change Order
6. Variation Order
7. Daily Report
8. Report QC/QA problems

Contractors want work performance and progress as well as safety. The highly demanded information is as follows.

1. Schedule updates
2. Reporting violations
3. Report QC/QA problems
4. Accident reporting
5. Productivity information
6. Report inspection results
7. Progress Photo
8. Change Order

Consultants also want the same information as contractors but also with a focus on design and instruction. The highly required information from consultant point of view is summarized as follows.

1. Design intent and clarification
2. Daily Report
3. Report QC/QA problems
4. Change Order
5. Schedule updates
6. Site instructions
7. Accident reporting

Statistics shows that apart from design intent and clarification, there is no significant difference in the information demands of consultants and contractors; however client’s needs are quite different comparing the two. Moreover, although different countries have different cultures and different adoptions of IT in construction projects, there weren't significant differences in the information requirements of the respondents from different countries.

To develop the mobile application, some construction forms were collected to investigate the appropriate fields of the selected information. Then the mobile application was developed using Microsoft® Share Point which is the best alternative for those companies lacking IT experts. Microsoft® SharePoint allows non-IT personnel to develop IT applications in construction projects and customize them according to project objectives.

Usability is critical to the success of mobile applications which are being used in construction projects due to variety of personnel and low sophistication of users in this industry. The personnel demand easy to learn, easy to use and effective devices to satisfactorily fulfil their job requirements. Thus, the mobile application was tested in the laboratory at the Construction Technology and Management Centre of Universiti Teknologi Malaysia. Twelve master students of construction management participated in the test. They performed four tasks and completed three construction forms in the CMA. The results reveal that they got familiar with the system after doing the first task. They found CMA effective, easy to learn, easy to use, and efficient. They also were satisfied with using CMA.

This study could be a platform for developing a functional mobile application that can be used broadly in construction projects. The required information is collected and ranked based on the points of view of clients, contractors, and consultants. Future research can investigate the required information fields of the mobile application and elaborate in detail in order to design and develop the mobile application.

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