THE ROLE OF USING A TABLET COMPUTER FOR MOBILE COMMUNICATION ON CONSTRUCTION SITES

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ABSTRACT: The coordination and control of construction projects is vital if a project is to be a success. Almost all analysis has shown that these can only be achieved if good quality communication can be maintained on a construction site. This research focuses on the role that tablet computers could play in enhancing this communication. The following points are investigated in this paper: (a) Whether a tablet computer can enable users to monitor project progress more efficiently than traditional methods, (b) How the tablet computer fits within the project management iron triangle in construction, (c) The two different psychological impacts of information transmission for the end user using a tablet computer (i) The expectancy to transmit information frequently and rapidly from tablet computer users to project members whilst working onsite (ii) The mode of information transmission to the cognition of the transmitted information to the tablet computer. Through the use of structured interviews and questionnaires, the opinions of individuals within various disciplines in construction were canvassed. The approach adopted in this paper deals with understanding both the soft and hard issues for deploying such a system. This research enabled the authors to develop a base framework incorporating the key factors which are relevant for implementing a tablet computer based on information flows primarily.

Keywords: *Information management; Information transmission; Project management; Communication; Construction site office; Construction site staff; Tablet computing.*

1. INTRODUCTION

Coordination and communication are major activities in any construction project. The entire construction process relies on large volumes of information being generated, transmitted and interpreted to enable a project to be developed, executed and for project assets to be maintained. Construction personnel tend to focus on information transfer, exchange, dealing with drawings, specifications, cost, data and other information management requirements to successfully complete a construction project.

The current systems in construction site offices present difficulties for site-based personnel in gaining easy access to office-based information systems. The use of tablet computing technology, aims to eliminate information flow difficulties between fieldworkers during core working time and the design team located off the construction site. The combination of poor communication, lack of consultation, and inadequate feedback are the prime causes of defects in most construction projects (Emmitt et al. [1]). The construction industry faces challenges in achieving faster and more accurate information communication and exchange on construction work sites.

Elvin [2] claims that mobile computing on actual construction work sites will ensure real time data flow between the construction work site and office; using wireless communication.

Löfgren [3] argues that mobile computers should not be used at the expense of other activities, such as project management, leadership, social collaborations and work practices. The authors would argue that there is a need to investigate the implementation of mobile tablet computers from a project management perspective in alignment with the iron triangle and examine related soft issues. Over the past years the growth of information communication technology has increased, thus; reducing the cost of transferring information, while increasing both efficiency and effectiveness.

The purpose of the research is to investigate if such devices have the potential to improve information flows and communication onsite. The research is particularly geared towards those who are involved with the construction phase of the project, and the long term implications this would have for the construction industry.

The specific objectives of this paper are to examine (a) whether a tablet computer can enable users to monitor project progress more efficiently than traditional methods, (b) How the tablet computer fits within the project

management iron triangle in construction, (c) The psychological impacts of information transmission for the end user using a tablet computer.

The key aspects of this research comprise of the literature review, semi structured interviews and questionnaires. The literature review initially gives an overview of current challenges in managing information on site. The next section of the review aims to identify methods to manage construction information and provide a framework for the interviews and questionnaires. Finally the current idea of a tablet computer is explored. In the results and discussion the authors examine the qualitative and quantitative data from the interviews in conjunction with the literature to answer the papers specific objectives.

2. THE DIFFICULTY IN MANAGING INFORMATION FLOWS ON CONSTRUCTION SITES

2.1 Overview of the Problem

Participants are increasingly finding it difficult to share information in the construction industry. Zeng et al. [4] identifies the following barriers which hinder the flow of information:

- Organisational structures
- Technical characteristics of information in the industry
- Behaviours of individuals involved with information management

Information must be able to flow seamlessly between every component of an organisation (Laudon and Laudon [5]). Sub-contractors require easy access to detailed instructions for the tasks that needs to be carried out. This includes both the engineering specification of the relevant tasks, and then progress reports to the project management office before the client or contractor can be finally invoiced (Ziestman [6]) depending on the nature of the instruction.

A study undertaken by BT [7] highlights that there are needs to identify, compile and accurately transfer information among relevant project members throughout the complete project lifecycle.

A major inefficiency encountered in construction projects is the transmission or flow of construction information. Research by Tucker and O'Connor [8] has shown that over a fifth of the problems that arise on a construction site are directly related to the communication of design information. Furthermore, they estimate that around 30% of the cost of a building project involves obsolete processes and communication of the architecture, engineering, construction and facilities management industry.

2.2 Current State of Information Flows on Construction Sites

The current main form of information that onsite construction personnel receive are transferred through paper based documents, which construct a constraint boundary for onsite information communication exchange. These documents include drawings, data collection forms, correspondences, progress information and specifications (Bowden et al. [9]).

Paper based documents lead to slow and inefficient information retrievals and searching, causing unwanted delays. This can lead to ineffective on site management which causes problems for those overseeing important issues that require rapid responses. This often causes onsite decisions to be delayed, (Singhvi and Terk [10]) as production management personnel have to travel unnecessarily to the site office. One of the causes for delays can be linked to uncertainty, which is critical in information management (Winch [11]).

The co-ordination of activities and management of operations on a construction site must be resolved effectively and efficiently to minimise downtime, rework, waste and cost overruns (Miah et al. [12] and Löfgren, [13]). As a result a large part of the management team uses their computers several hours per day. This can cause a loss of onsite production leadership, coordination and organisation, which can result in delays and deficiencies. Furthermore, no efficient interfaces exist between departmental systems to access the information directly by electronic means (Gyampoh-Vidogah et al. [14]). Löfgren [13] emphasises the unnecessarily busy schedule of construction management staff undertaking administrative work associated with construction site activities whereby, certain administrative tasks are processed "twice", leading to significant reduction in staff productivity.

The following factors are typical issues which take place on a construction site related to construction information management and communication:

- Speed of information transfer;
- Unexpected site conditions and/or rapid changes in the environment;
- Supply chain management;
- Inaccuracies in plan or layout design.

Zarli and Richaud [15] indicate the fundamental challenges in resolving the above problems:

- Homogeneity - Solutions tend to be 'one size fits all' and not open, as such this holds back on more innovative technologies and systems.
- High Entry Level - Many solutions are too expensive to be invested in currently. Therefore there is a need for lower entry levels offering a greater range.
- Lack of Scalability - The current solutions offer limited growth both in hardware and software.
- Application centric - Introducing information technology application to the organisation.

2.3 Current Challenges in Managing Information Flows

Understanding how tablet computing can benefit information flows on the construction site requires an understanding of the limitations of current approaches to managing information (Wetherhill et al. [16]).

- A large volume of construction knowledge is tacit and resides solely in the minds of individuals working within the domain;
- Decisions are often not recorded or documented since it requires complex processes to track and record the numerous messages, phone calls, memos and conversations that comprise a large volume of project information;
- Individuals who are responsible for collecting, gathering and archiving data do not necessarily understand the specific needs of those individuals who would be potentially using it. (Such as maintenance workers);
- The data is usually unmanaged during its creation. Thus, the data is usually captured and archived at the end of the construction stage;
- The lessons that have been learned are not identified, captured, or stored well and their details are difficult to retrieve. As a result it is difficult to compile and disseminate useful and purposeful knowledge to other projects;
- By adapting to new approach to the management of knowledge within and between firms imply major changes in individual's roles and organisational processes.

The limitations described by Wetherhill et al. [16] emphasise the importance of categorising the problems into *hard* and *soft* issues. Hard issues deal with innovations and technological advancement. Whilst soft issues include training, education, organisational culture, user values and beliefs.

3. MANAGING CONSTRUCTION INFORMATION AND IDENTIFYING KEY ISSUES FOR QUESTIONAIRRE AND INTERVIEWS

3.1 Classification of Construction Information

Construction information can be classified into three categories (Mead, 2001 [17]) as shown in Table 3.1:

Technical Information	Designs, technical evaluations which reflects the project
Commercial Information	Contract details, which states responsibilities such as delivery of project
Management and Control Information	Project management information which is required to control the project and develop reports. Information developed by the project manager ranging from as built drawings to safety information

Table 3.1: Classifying construction information

Broadly speaking construction information can be decomposed into:

- Construction product and contract documentation
- Site information and site records

3.2 Framework for Questionnaire using Construction Site Information and Site Records

Construction site information is organised into the ten categories (de la Garza [18]) shown in Table 3.2:

1. Request for information
2. Material management
3. Equipment management
4. Cost management
5. Schedule and means and methods
6. Jobsite record keeping
7. Submittals
8. Safety
9. Quality control/ quality assurance
10. Future trends

Table 3.2: Categorising site information (de la Garza [18])

Site records exist in a wide range of formats, they include minutes of meetings, correspondence, file notes, materials delivery invoices, photographs, plant and labour return and personal diaries. This requires key personnel to file the relevant information for future records; otherwise this may become misplaced or lost which can result in disputes (Craig and Sommerville [19]).

The study questionnaire will use the above categories as a reference for the types of information required by personnel on site.

4. THE CURRENT TABLET COMPUTER

4.1 Main Components Resembling the Tablet Computer

Mobile tablet computers provide great flexibility for onsite personnel to be moved and carried around onsite. The device is physically tailored for construction environment practices such as the ability to absorb vibrations and hard impacts; because of its rugged all weather material construction. For further reading on hardware properties of a tablet computer the reader should refer to Kimoto et al. [20].

At the highest level, mobile computing consists of three major components (Rebolj et al. [21]):

- The Mobile (tablet computer) hardware
- Mobile software designed for construction (mobile applications)
- Wireless networking and communication

These factors are classed as the dependent factors as they need to work flawlessly to prevent users from distracting from their main site job, which otherwise could lead to additional stress, whilst working onsite.

Research undertaken by de la Garza and Howitt [18] emphasise the relevance of using a tablet computer with wireless networking capabilities. This brings two benefits; rapid information flows and the ability to communicate without leaving the actual construction site.

According to Chen's [22] research the above elements are related to produce the top-level framework (Figure 4.1).

In this framework, the concept of mobile computing is associated more closely with construction and includes the relevance of human computer interaction for onsite users. The importance of construction information can be closely related to the psychological impact tablet computing bears.

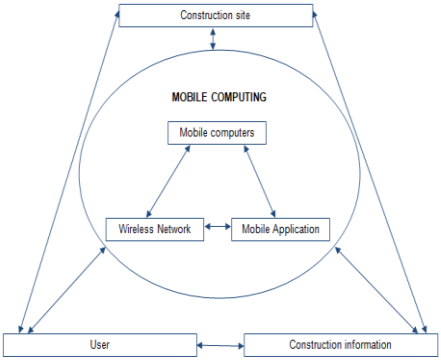

Figure 4.1: Top level framework (Chen, [22])

5. METHODOLOGY

This multisite study used the literature review as a framework to gauge perceptions to mobile computing. The study was based on questionnaires and semi-structured interviews. Participation in the study was voluntary and was restricted to personnel who had worked on a construction site for at least one year. Ten different construction sites around London were approached and personnel who met the selection criteria were interviewed.

Using the literature review a questionnaire was developed to analyse the categories of information required outside the site office. This was primarily divided into types of personnel requiring the information and modalities of access currently used onsite for each information subtype. The semi structured interviews involved a series of open-ended questions mainly as shown in Figure 5.1. Open ended questions gave the researcher the opportunity to develop the anticipated framework further by incorporating their experiences.

Both the interviews and questionnaires focus on information requirements both off and on the actual construction site, the medium in which information is received and transmitted to the destination source.
Furthermore, the questions focused on the risks and benefits associated with the device and thereafter respondents had the opportunity to discuss certain aspects of the device in alignment with the iron triangle in project management.

Both quantitative and qualitative data were obtained. The results and discussion outlines whether a tablet computer can enable users to monitor project progress more efficiently than traditional methods using quantitative data. Qualitative responses are extrapolated from interviews to address applications to project management and the psychological impacts of mobile computing. Here a framework is developed to address how the user can benefit from the device without creating disruptions to their onsite proceedings.

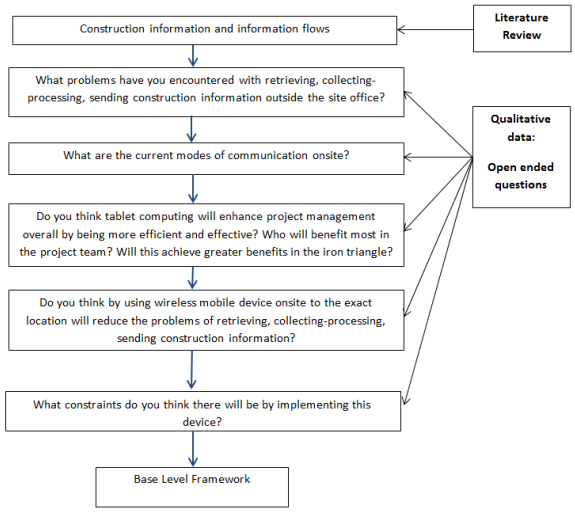

Figure 5.1: Methodology to develop base framework

6. RESULTS AND DISCUSSIONS

From the 10 construction sites 8 separate respondents were obtained for the paper based questionnaire and 10 different personnel participated in the semi structured interviews. Figure 6.1 indicates the roles of the participants in this research. Most of the participants are professional workers.

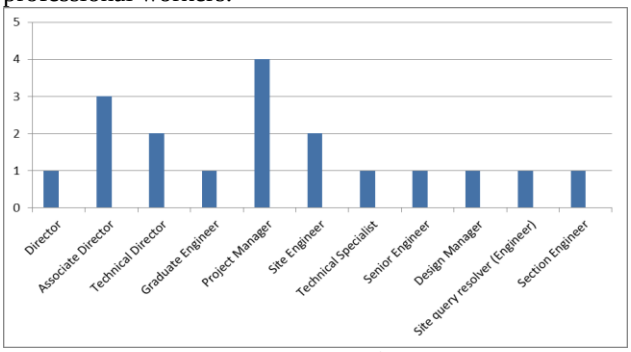

Figure 6.1: Bar chart displaying the roles of participants in this research

The design of the tablet computer is dependent on the data or information required by the end user. Table 6.1 summarises the specific data requirements onsite depending on the type of user.

Much of the cost related information was required by the project manager, whilst the site managers and technical engineers would focus on the health and safety statements which link with the construction methodology statements in most cases. "Quality" and "design clarifications" are seen to be crucial for both site engineers and project managers which resonates the importance of the quality of the tablet computer display.

Project managers indicated that the tablet computer should feed information wirelessly into their main desktop or laptop in the site office. Based on these results, the project manager requires unrestricted access to information transmitted from other users. Other construction personnel will be restricted to the type of information received by the tablet computer. As such information flows need to be controlled.

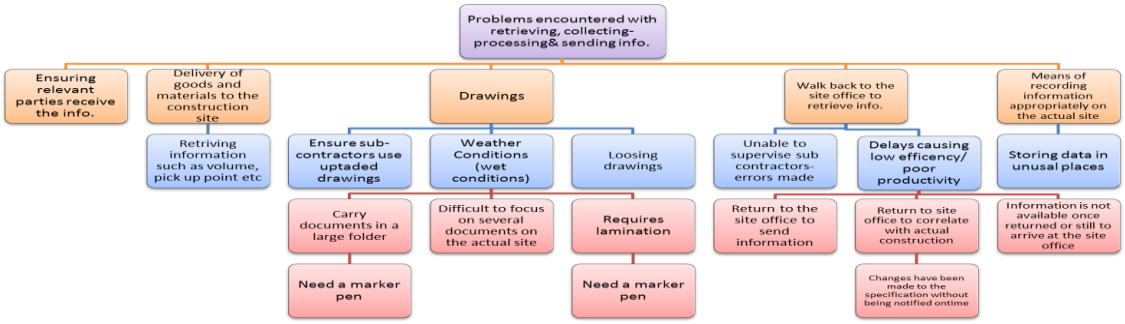

Fig 6.2: Problems encountered on the construction site based on communication

	Plant information	Scheduled progress	Quality information	Equipment information	Construction method statements	Contractual information	Design clarification	Labour information	Sub-contractor information	Material information	Site visit records	Other
Project manager	1	1	2	1	1		3	1	1		1	2
Site engineer	1		1				1			1		
Technical specialist	1						1					
Senior engineer		1							1			
Design manager		1	1				1	1		1		1
Site query resolver	1	1		1						1		1
Section engineer	1		1		1		1			1		

Table 6.1: Construction information required outside the site office by key construction personnel

	Design refinements or design clarifications	Contract information	Schedule and progress management	Drawings	Supply chain information	Sub-contractor information	Method statements/ construction methods	Equipment/ plant management information	Information on quality control	Safety record	Specifications	Other
Mobile phone	3	2	2	1				1				
Return to site	4	5	3	5	2	2	4	2	2	3	5	
Retrieve information from digitial device												
Take documents to site itself	1	1	1	1	2	2	2	2	2	2	2	
Retrieve information from memory												
Use a notepad												
Project extranet												1

Table 6.2: Modalities used to access information outside the site office

The medium used to access construction information is not only critical to the overall quality of the information received but also in terms of productivity as summarised in Table 6.2.

According to Table 6.2 the majority of the participants returned to the site office to access information, which results in poor Efficiency. Based on this data it can be deduced that a tablet computer could improve efficiency by reducing the need for personnel to return to the site office. Most of the construction information from Table 6.2 can be retrieved from the database management system, which provides real time updated information.

To complete site related tasks it is essential that construction personnel can work on the move. These individuals on site require a large volume of information ranging from technical design drawings to recording all job tasks on their personal log books. As a result, there is a clear need to address the issues in Figure 6.2 which was based on the questionnaires. Figure 6.2 indicates the difficulties encountered by onsite personnel.

With regards to productivity a tablet computer will eliminate the need to laminate drawings, carry a large folder and misplace drawings which reduces paper. It can also be deduced that site personnel return to the site office to check construction progress and to send information, which indicates poor efficiency as discussed in the literature review also. Additionally, site personnel emphasise the importance of real time information flow, such as ensuring subcontractor receive updated drawings which can minimise both cost and time of the project.

6.1 Applying the Tablet Computer at the Project Management Level

The outcome of the semi structured interviews identified three distinct areas which the tablet computer enhances project management, which is also in accordance to Bowden et al. [23]. These areas; quality, cost and time reflect the iron triangle as depicted in Figure 6.3.

Quality was closely associated to reduction in defects and accidents. With regards to reducing defects, it was understood that the tablet computer should allow construction personnel to collect data electronically through a systematic process and transmit the data to the central database in real time. Similarly accidents can be minimised by collecting and transmitting problem notification to subcontractors via the wireless network.

Figure 6.3: Associating the iron triangle with the tablet computer

Another factor which can optimize the quality of the project is to minimize waste through monitoring the plant or materials entering the actual construction site using the tablet computer.

Another factor which can optimize the quality of the project is by minimising waste through monitoring the plant or materials entering the actual construction site using the tablet computer.

Costs are saved primarily through reducing repetitive tasks such as eliminating rewriting/ retyping and reducing multiple visits to the site office to retrieve or transmit information, enabling the personnel to focus at the task level.

Furthermore, the use of a tablet computer can also minimise operational costs in the maintenance of plant or equipment.

Productivity is considerably increased by automating tasks and enhancing collaboration. Automated tasks include the transmission of data through wireless communication, whilst enhanced electronic collaboration eliminates paperwork, reentry of data, reduces delays.

Predictability can be increased by providing accurate real time progress and cost information as the project progresses. This will be channeled to the project participants. Broadly speaking four elements of the 'time' factor can be associated with the tablet computer:

- Decision making processes
- Information retrieval
- Co-ordination of tasks
- Managing information

6.2 The psychological impact of information transmission using a tablet computer

The qualitative data collected from this research made direct associations with the psychological impact tablet computing has based on the type of information flow.

6.2.1 The effect of information transmission to tablet computer users' onsite

Information transmitted from the sender can be classified as "intentional" and "unintentional". Retrieving information is vital for most participants in order to increase productivity. Retrieving information is suitable for confirming information that has been reviewed previously or known information.

An example of a particular benefit is when site managers and engineers working on large construction sites are not generally aware of the pickup point of their delivered materials. Such information can be sent from the logistics manager to the section engineer. This form of information can be classified as "intentional information" from the section engineer as they are "aware" of this delivery. Equally "unintentional information" exists, which should be differentiated into, "notification of unintentional information" and "expected response- unintentional information". This is categorised in Table 6.3.

Expected response-unintentional information	*Notification of unintentional information*
Design refinements or design clarifications	Schedule and progress management/ progress update
Detailed sectional drawings	Supply chain information
Subcontractor information	Equipment/Plant management information
Method statements/construction methods	Information on quality control
	Safety Records

Table 6.3: Differentiating types of unintentional information

The interviewees indicated that "expected response-unintentional information" would be a popular command by personnel's who require further confirmation by liaising with other individuals before a decision can be made. This form of information was not deemed suitable to be received to the tablet computer. In contrast "notification of unintentional information" is a message which provides warnings for risk mitigations.

6.2.2 The mode of information transmission to the cognition of the transmitted information to the tablet computer

A minority of the respondents from the interview indicated that processing information would divert attention away from site issues and engage the personnel with the device. Figure 6.4 shows the levels of transmission received from a tablet computer. At the highest level, information is classified as "high risk", decision to take onsite based on the information received to the Tablet Computer. The sender of such information would be anticipating a response from the recipient to act "immediately" on the construction site. An example would be to clarify a drawing for a tablet computer user onsite who is restricted in terms of size and quality of the display. This may prevent the user from providing the exact response and potentially 'keeping your eye off the construction site during that time can cause problems, which are eventually picked up by the client' as identified from the interviews.

Access to such connections would inevitably lead to a culture where responses that ought to be carried out on the site office are instead made instantaneously on the

actual construction site.. These effects can portrait the tablet computer as being counterproductive.

6.2.3 Base framework and Recommendations

As discussed, three categories of information can be received by construction personnel using a tablet computer onsite; unintentional, expected response unintentional and intentional information. Figure 6.4 represents a base framework incorporating the key factors which are relevant for implementing a tablet computer based on these information flows. As such this research addresses the need to manage these categories of information effectively. It was indicated that the use of tablet computers could increase 'stress levels' and distort personnel from carrying out their duties onsite.

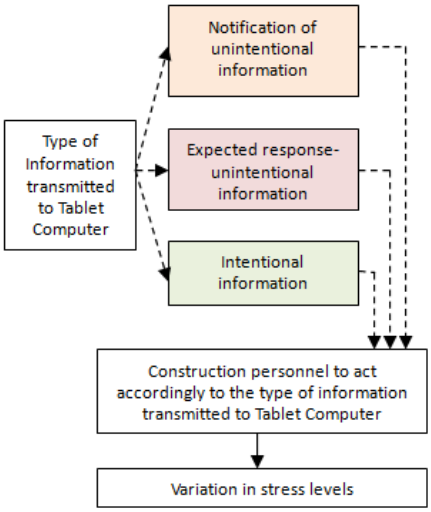

Figure 6.4: The base framework

This research recommends managing and filtering specific information which construction personnel require whilst working onsite. The two types of information which would benefit users are notification of "expected response unintentional information" and "intentional information"

6.3 The Challenges Involved in Implementing such Technology in Complex Projects in Construction

Respondents were keen to point out that the greatest barrier would be related to the change in organisational culture. The results indicated that personnel who have been working in the construction industry for 7 years or more are resistant to change. This was followed by "no organisations in the industry are ready to carry out the first trial". In contrast the recent graduates or those who are akin to linking innovative systems with the construction industry are open to trialing or using a tablet computer to support their requirements and foresee the potential benefits.

Those who gave consideration for the device stressed the need for an excellent user interface, ease of use and sufficient training for end users. Figure 6.5 provides the challenges involved with integrating the device with the project coalition team:

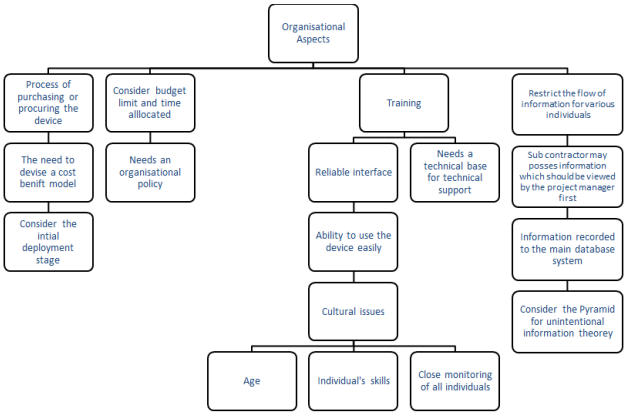

Figure 6.5: Soft issues as pointed by respondents for implementing the Tablet Computer

7. CONCLUSION

This research has examined the impact of tablet computing for construction users' onsite, more particularly based on the soft issues.

In summary tablet computing can enable users to monitor project progress more efficiently than traditional methods through various means, including reducing the number of visits to the site office. The tablet computer has the potential to reduce operational cost, increase quality by reducing site accidents and increase productivity.

The base framework was developed based on the interviews held and represents three types of information which are transmitted to the tablet computer. Of these it was established that users would benefit greatest from "expected response-unintentional information" and "intentional information".

The type of information transmitted to the device needs to be restricted accordingly; otherwise the tablet computer may also adversely interact with psychological factors influencing decision making onsite. If the device is unable to deliver key requirements and does not seamlessly integrate with the industry, then it might be considered obstructive to effective construction operations and project delivery thus not adding value to the project (Löfgren [3]).

This research has indicated that tablet computers could be beneficial. However, this research recommends a non-complicated device which allows capabilities to improve coordination; reporting issues immediately onsite, especially those related to health and safety and retrieving information for those who work on the actual construction site.

Site engineers and managers also pointed out that key decisions had to be made within the site office rather than being rushed on the actual construction site, which indicates the need to control information transmitted to the tablet computer.

It is the authors' view that soft issues play a critical role (interconnected to hard issues). Irrespective of how

well the device integrates with the construction site, the real benefits from each organisation would only come through user familiarity with the device through trial and error.

To understand the capabilities and seek the optimum benefits it is necessary to understand beyond the context of tablet computers functioning onsite and focus on their pitfalls and quality of communication overall, in comparison to the current method of communication in a project.

This research has aimed to underpin this to an extent. There is further difficultly as each individual/ organisation has their own set of skills with ICT coupled with other cognitive factors, hence this soft issue approach provides scope for future research.

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