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Developing mobile technology for construction sites

Michael Er
Faculty of Design Architecture and Building
University of Technology, Sydney

Abstract

An attribute of construction workers operating on a construction site is the necessity to be mobile, a feature that results in their disconnection from the information hub which is physically located at the site office. This means that these workers functioning at the point of work are often faced with an information system which is fragmented and prone to inefficiencies, resulting in decisions being made on the basis of inaccurate information. It has been suggested that mobile technology offers a solution to this problem however to date the construction industry has failed to take advantage of this technology. This paper reflects on the decision making process which is currently being employed on construction sites, identifying the shortfalls in information access and the ways it is overcome by site personnel. Highlighted is the role which site personnel worked in a networked manner, using such practices as informal meetings and collaboration to extend their knowledge. This network attribute forms a major component of the information system of these mobile construction site workers and potentially has a substantial influence on the adoptability of a mobile technology.

Key words: Mobile technology adoption, construction sites, information systems

Introduction

The worldwide value of the building and construction industry runs into hundreds of billions of dollars per annum, with the construction industry's annual turn-over contributing approximately 10 per cent of annual GDP for most nations. (Olomolaiye et al, 1998, quoted in Farin et al 2001). The involvement of complementary industries means the inclusion of many other sectors of the economy, from financial services to materials supplies and highlights the importance of this industry to the economy. Construction is however an area which is plagued by inefficiency. Bowden and Thorpe (2002), report that "65% of contractor rework is attributed to insufficient, inappropriate or conflicting information" on construction sites. This provides a clear indication of the deficiencies of the information system on construction sites and the adverse outcomes which can result.

Bowden and Thorpe note the need of construction personnel to be mobile in order to fulfill their work. Perry et al. (2001) compared office workers to mobile workers, such as construction site workers, and observed the many difficulties with gaining information faced by the mobile worker. "When people work in an office they have greater familiarity and certainty about their environment and resources... They structure the information

documents around them to suit their needs and they know who to ask for particular kinds of information. Such familiarity with their environment affords them greater freedom over the way they organise their work... Contrast this resource-rich view of the office work with the difficulties encountered by a mobile worker... they do not have the access to colleagues or knowledge of who to seek to get support... mobile workers have less control over the configuration of their environment and therefore the way they manage their work." (p.324)

In the case of the construction industry, the mobile workers such as the foreman make many crucial decisions at the point of work. Er and Kay (2003) identify the information deficiencies on construction site are a result of a disconnection between the point of work and point of information storage and access which are either stationed in offices off site or in the site office. The identification and subsequent resolution of issues is often subject to the dynamic nature of the construction site and can only clearly be manifested in the minds of participants when on site. The information required to solve problems at the point of work is unfortunately often stored in detail in the site office. This is particularly the case for the larger more complex construction projects on which information hubs are physically inaccessible from the point of work.

Compounding this situation is the collaborative nature of work. The modern construction site operate on a collaborative system involving many independent contributors in the work process, some participating on site while others such as consultants (eg architects or design engineers) are off site and office based. Participants off site often engage in a virtual manner and having a limited view of the actual conditions on site potentially inhibits their ability to contribute.

It has been suggested by Sun and Howard (2004) that the use of mobile technology can be developed for use on construction sites to assist in project management, data capture (and access) and collaboration, all of which would be beneficial in addressing the issue of information access faced by construction workers on site. This information model has yet to be successfully applied.

Technology Adoption

There have been many instances of less than successful attempts to introduce technological innovation into a work process. Attempts to establish mobile technology for data capture and access have met with limited success. Luff and Heath (1998) report on an instance where a laptop was introduced into the construction site context to replace a paper based process used to monitor workers. Having this information recorded directly into a digital form had the intension of reducing time wasted associated with double handling (the previous system required the foreman to type into these details into the computer). It should have also allowed instantaneous access to the information by administration staff based in the office. "The development of a mobile technology for foreman may have seemed straightforward" (p.309) however the adoption of this new

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system experienced difficulties as "rather than transforming the foreman's task to be more proactive and involve more planning and management, the foreman became more involved in bureaucratic activities... It is not surprising, therefore, that the team decided to continue using paper sheets and employ someone else to enter and code the information from them."

Considerable research into innovation adoption has been undertaken within the area of technology development, with many researchers developing theories dedicated to solving the problems associated with technology adoption and diffusion. A well recognised innovation framework of Rogers (1983), proposes that the diffusion of innovation is heavily dependent upon such elements as communication, time and the change agent. This theory makes the assumption that the innovation (technology) is useful. It outlines a broadly linear diffusion process moving through the following stages: Knowledge (exposure to its existence, and understanding of its functions); Persuasion (the forming of a favorable attitude to it); Decision (commitment to its adoption); Implementation (putting it to use); and Confirmation (reinforcement based on positive outcomes from it). An issue identified by Rogers is that although an introduced innovation does have positive attributes, it may inadvertently create problems. "Change agents usually introduce innovations into a client system that they expect will have consequences that will be desirable, direct and anticipated. But often such innovations result in at least some unanticipated consequences that are indirect and undesirable for the system's members." (Rogers, 1995, p, 31)

Like the research of Rogers, Luff and Heath have identified the issues surrounding unanticipated consequences. "These difficulties suggest some misunderstandings by the proponents of the system concerning the nature of the collaborative activities on the site and the technology required to support the... Serious attention has to be paid to the ways in which personnel interact with colleagues whilst on site and use various objects and artifacts to accomplish their work with others." (Luff and Heath, p308-309)

Interaction design is a technology development methodology which also emphasizes the user as well as the way they do work in overcoming unanticipated consequences. Preece (2002) describes 'interaction design' as a shift of the development focus away from the technology to highlight the concerns of the user through investigation of "the artifact's use and target domain by taking a user-centred approach to development. This means that users' concerns direct the development rather than technical concerns." (Preece, p.166) Focusing attention on the user of a technology at an early stage of development improves the possibilities of adopting it. Shneiderman (2002) writes, "The challenge for technology developers is to more deeply understand what you, the user, want. Then they can respond to this challenge by creating products that are more useful and satisfying to more people."

In a bid to develop a useful technology for construction site personnel a holistic understanding of these workers and their information needs is developed. This paper considers the construction workers as they operate in a mobile sense on site and the way they make decisions. How these workers gather information to resolve problems is closely examined. This paper is set out as follows: The qualitative methodology

employed to explore this research is outlined next, followed by a description of findings and discussion. Finally this paper draws a conclusion and outlines the potential for further research.

Methodology

To develop an insight into the operations of the construction site personnel and their ability to make decisions a qualitative research approach was utilised. Myers points out that "Qualitative research methods are designed to help researchers understand people and the social and cultural contexts within which they live." The work being performed on the construction site cannot be reproduced with any real accuracy within the confines of a laboratory. Further, "Qualitative methods can be used to uncover and understand what lies behind and phenomenon about which little is yet known."

Taking into account the exploratory nature and "real life context" of this research, a case study method was developed (Yin (2002), Preece et al. (2002) and Benbasat et al. (2002)). Data collection in constructing the case study was composed through interviews. Walsham (2002) argues that "interviews are the primary data source, since it is through this method that the researcher can best access the interpretations that participants have regarding the actions and events which have or are taking place, and views and aspirations of themselves and other participants." The interviews were undertaken in the place of work (on a construction site) to assist with the integrity of data collected. We note Preece et al. (2002) "If interviewed in their own work or home setting, people may find it easier to talk about their activities by showing the interviewer what they do and what systems and other artefacts that they use... In requirements activity, interviews are good at getting people to explore issues..."

The focus of this research considered the way the site workers performed while moving around the work area with particular attention on how they made decisions and how they gathered information to assist their decisions.

All interviews were digitally recorded and transcriptions were made. The data was then analysed using a thematic analysis.

The Case study site

Selection criteria applied to finding an appropriate subject for developing a case study was based upon finding an operational construction site with several physical points at which work was taking place. Site personnel, such as the head contractor's foreman and subcontractors at these locations were physically isolated from the site office. Mobile technology offers the potential to deliver pertinent information to site personnel in an "on demand" manner from remote locations (such as these isolated points of work). An identification of where the main issues in the current information system exist is firstly considered. The case study explores the way in which site workers currently make decisions and how they overcome the information shortfalls in information.

A suitable case study site which met the mobile workers isolation criteria was identified as a new 13.5 million dollar sports complex. The complex consisted of indoor swimming pool, "water play area", two indoor basketball courts, caretaker's residence and landscaping works. The substantial footprint of the development meant that there was considerable distance between the work areas and the site sheds.

Case study data developed through the use of interviews with the construction company's site staff. 4 staff members were interviewed and included the Project Manager, 2 Foremen and a Sub-Foreman (Leading Hand). All the interviewees had substantial experience in the construction industry (see table 1 below).

Participant	Experience (years)
Project Manager	15
Foreman 1	15
Foreman 2	21
Leading Hand	7

Table 1: Interviewees and work experience in the construction industry

Findings and discussion

Sources of information

Paper forms are an integral part of a projects' information system and is used by on site staff for planning, issuing instructions, record keeping and information transfer. They contain / record essential information which informs the foreman about the works including plans, the site diary, site instruction, safety instructions, request for information, purchase orders, contracts and specifications. These paper forms are central to guiding the construction process and assisting the site staff (such as foremen) in making decisions. On most construction sites, all documentation for a particular project is stored in the site office.

Another component of the construction site information system is the use of digitally stored information. This electronic form of information allows for documents such as plans to be stored and accessible in the head office as well as the site office. Further, the use of digital information permits communication of information to be passed expeditiously using electronic means such as email. "For instance if you got plans, before you used to use hard copies but now basically everything is being emailed form one place to another." (Project Manager)

The use of mobile phones and walkie talkies form another element used in the communication of information. Since their inception, the mobile phone has become a pervasive part of communication. An example of this is their use in contact between site staff and off site stakeholders such as consultants. Foreman 1 noted that "things to move a lot faster... You get things done then rather than years ago you would write things down and come back into the office to call them from there, possibly an hour or two hour later". The Project Manager agreed with the usefulness of the mobile phone stating "Its

great for emergency situations where valuable time is saved instead of running out to the shed you got a phone handy, and its critical you get the response."

Shortfalls at the work face

Plans are a particularly important paper form used by site staff such as the foreman and subcontractors. There are however several issues identified by the interviewee's with regards to this information source. Firstly, because plans are stored in the site office, when the foreman needs to consult with the documentation they leave the work face to view the plans or documentation. Further other paper based documents face the same inaccessibility, for example to officially issue a site instruction, the foreman is also required to leave the work area to retrieve the forms which are stored in the office. Foreman 1, relies on "memory of details while walking around site".

Taking plans to the work area is a premeditated exercise by the foreman. For example, if the foreman know there is a certain trade (such as an electrician or plumber) working in a particular area, a copy of the drawings pertinent to that work might be carried by the foreman however the manifestation of problems may be presented as site staff move around the various work areas on site. The opportunistic nature of problem identification makes it difficult to determine which plans are necessary form day to day and the size and number of plans makes carrying all the plans impossible. To overcome this, some construction companies provide foremen with smaller sized copies of the plans (A3 size sheets) however the ability to read the reduced details off these plans is often impaired. The Project Manager notes "Everyone likes to see a big drawing and how the detail works and looks say on an elevation".

Another issue with associated with the paper plan is that the plan on site is often "marked up". That is notes are made by the foreman on the paper plan such as minor changes. These notes, if made on the plan which the foreman has (A3 plan) then this information has to be transferred to the main copy kept in the site office as well as the copy held in head office.

During the lifetime of a construction project the plans are amended to reflect approved changes or elicit details which were neglected in the original documents. An issue associated with these changes to plans is that different versions of a plan may be used by different stakeholders. When changes are made the plans and documents associated with the changes need to be revised to reflect the changes and then reissued. Unfortunately, there is often a breakdown in the dissemination and use of these revised plans, often resulting in inaccuracies in the finished product.

The problem of "versioning" is further compounded as often details of changes are not made to the main drawings. Instead sketched details are made and ensuring all the affected workers are informed is a difficult task. "A lot of architects issue file notes but between them and the revised drawings there causes a whole lot of confusion." (Project Manager) The leading hand noted, "A subbie may ask me a question out on site and I might have gone over the plans and told them to go ahead but little do I know a variation

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has come through, and it happens all the time where things get changed. But they (site managers / foreman) obviously can't keep me up to date every single time they have a meeting on what's going on." The Leading Hand often felt frustrated and embarrassed when he tells the subcontractor to do something and then the foreman comes out and tells them something different which "makes me look stupid".

Associated with the versioning is an issued identified by the Project manager and foremen, the communication process and the time which it takes for official approval of a change. This includes the process used for "requests for information" (RFI) to consultants and the client. For example, the work by consultants may need to be redesigned / adapted to address a latent condition and represent a slow turn around time even though the site workers know what has to be adjusted. "Very frustrating especially when they propose a detail and everyone is waiting on the architect's approval and to issue the new plans. Everyone knows which way to go but they can't do it until they receive the plans and it could take a couple of days for someone to drive out and issue the plans so potentially we could loose half a week." (Project Manager)

Marked up changes are required to also be made to the digital copy. Attempting to make the changes and read off the digital copy itself presents problems as identified by the Project Manager "you can't get 10 blokes into a small office all looking at a 10 inch screen and try and coordinate the project. It's not going to work. You can't mark up a screen."

Assisting decision making

The foreman is the decision maker at the point of work. Issues associated with decision making centre on their ability to access appropriate and up to date information. To overcome issues of information isolation at the point of work the site workers make use of good planning. The project manager noted that both formal and informal meeting were organized with site workers including subcontractors. The informal meetings are "toolbox talks" where specific parts of a project are discussed by the participants in a specific work area. The formal "co-ordination meeting" allows the passing of information at scheduled points. The co-ordination meetings involve all the stakeholders allowing information to be shared by all. The Project Manager further noted that "a lot of the architects don't like updating their drawings they issue file notes and its up to the builder to coordinate. In most cases if there is a file note we try to issue it through the coordination meeting so that everyone gets a chance have a look at it and give their feedback. That's our main way of coordinating. A lot of the subcontractors on site are here to do their work, they're not here to think. It's their bosses in the office that try to coordinate and think and they come to the coordination meeting and then go out and organise their guys and hopefully give them the up to date information."

Good planning is essential for a construction site to function efficiently, however, it is limited in that the construction site is a particularly volatile workplace and even the best of planning will need to allow for some flexibility. Plans are continually adjusted and decisions made "on the spot" as issues become apparent. To cope with this dynamic

nature of the site every morning the heading hands go for a walk with the foreman and the foreman in an opportunistic manner will pass on information to the leading hand such as the various things that need to be done, what is being delivered and when and who is working on site.

Collaboration plays a major role in dissemination of information and decision making. Although the foreman is officially the main decision maker at the point of work, they often rely on a group effort including interacting with the subcontractors for contributing expert information. The foreman will take advantage of the specialist knowledge that the subcontractors possess to assist in their decisions. It was noted that the foremen built up relationships with those they interact with, allowing them to develop unofficial forms of communication to overcome the lack of information. The foreman will make informal commitments with the sub-contractors as part of their decision making. The relationship with the subcontractors is emphasized in resolve held by the foreman. "My word is my bond" (Foreman 2).

The importance of the collaborative relationship is further highlighted by Foreman 2. He notes, "I sell cans of drink for a dollar (cheap), I don't make money... they have to come to me... every person who wants a drink, which is 90% of the people on site, has to walk past me to get it. At that point I'm not talking to them about what they're going to get with that can of drink, I'm asking them how you going, getting an update on what they're doing and at that point and (check) have you got the latest drawings." The need to exchange information on site has led to the development of informal communication system specifically aimed at information exchange between collaborators (the foreman and subcontractors).

Future research

Further research needs to be conducted into the potential affect that the introduction of a mobile device could cause to the existing information system.

If a new device was developed which did offer a solution to information isolation which a foreman or other decision makers on site, such as versioning, it may (as noted by Rogers1995) cause unanticipated consequences. For example a new mobile device may mean that access to all the up to date documents however, the foreman / leading hands may only look for information as required. Opportunistic dissemination of information (such as the daily walk rounds) would be interfered with (ended). The site manager may be freed to concentrate on office duties at hand and leave the leading hands free to be at the work face with all the required information with which to make decisions however through its opportunistic nature, other information is also passed in these daily walk rounds, information which may not directly influence one leading hands work area but could cause problems indirectly.

Another consideration for further research is the potential affect upon the collaborative nature of work between the sub-contractors and the foreman. Consideration of the

opinions of the sub-contractor could become of less importance to the foreman initiating a more hostile work environment resulting in further negative work performance.

Conclusion

There have been several failed attempts in introducing mobile technology to mobile workers such as construction site decision makers. This paper undertakes research in a qualitative review which considers the way in which construction site staff operates. The isolated nature of decision makers with regards to information access and the methods of overcoming this are highlighted. Of particular note, the existing information system used on site appears to rely on informal dissemination of information (such as the toolbox meeting and foreman walk-around), collaborative between participants and where possible good planning. Future research needs to be undertaken in order to observe how a potential mobile device can adversely affect the efficiency of information dissemination as well as considering it potential benefits.

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GROUP WORK IN CONSTRUCTION EDUCATION – HOW TO AVOID THE 'FREE RIDE' SYNDROME AND OTHER PROBLEMS.

Mary Hardie, School of Engineering, University of Western Sydney

ABSTRACT: If Construction Management education is to effectively mirror construction industry practice then group work needs to be as much a part of the experience of the student as it is of the practitioner. Group activity has many positive aspects for student development. It is essential, however, that academics are aware of the pitfalls that can result from personality clashes, group dynamics and equity in assessment. This paper compares academic literature on group work in several disciplines with the author's experience teaching in a construction management program. Several points are raised for further discussion among construction academics.

KEYWORDS: Group work, assessment, checking process.

INTRODUCTION

Construction undergraduate programs usually involve some level of group work. With the exception of very small building projects, such as the proverbial 'log cabin', buildings cannot be delivered by one person. It is, therefore, important that construction training includes an element of participating in group activity. The dynamics of group formation, personality types and whether compatible or complementary groups perform better are all significant issues. In addition, a major problem for construction educators is one of ensuring that group work is equitably assessed. There needs to be a robust checking process in place to ensure that individuals do not get a 'free ride' at the expense of their more conscientious fellow students. Whether the management of underperformers should be left to their fellow students or be dealt with by their academic leaders is another question. This may vary according to the level of experience and maturity of the students involved. A further problem exists in dealing with those individuals who find group work does not suit their style of learning. Is it possible to design projects with a fair alternative option for these 'lone wolf' individuals who are to