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# Facilitating Collaboration for the Construction Industry: Designing an Appropriate Interface

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## ABSTRACT

*Large construction projects involve multiple participants who need to collaborate in order for the project to be successful. To date, the collaborative process on construction sites has failed to take advantage of communications technology developments. This paper will discuss the results of empirical research in three contexts with regard to the adoption of new technologies in order to propose an acceptable system for collaboration in the construction industry.*

## INTRODUCTION

A distinct feature of the construction industry is the collaborative nature of construction projects. Typical construction projects involve a head contractor engaging various trade based sub-contractors to carry out specialized works, each with their own agendas that can often become a source of sub-optimization on a project (Abduh & Skibniewski, 2003). The wide range of stakeholders involved on a construction site include planning and design consultants, suppliers, financiers, insurers, statutory authorities and developers. (Gimsey, 1992). The foreman is the head contractor's representative on the construction site and it is their role to ensure the smooth operation of site works. Furthermore, the foreman's role involves the coordination of the various participants involved in the construction site and as such represents the focus of the collaborative system (Er & Kay, 2003). To date the use of mobile communication technologies to assist the foreman more efficiently undertake collaborative tasks at the construction interface has been limited, largely due to strong resistance to the adoption of new technologies.

In order to develop a new approach to the adoption of collaborative technologies in the construction industry, this paper will examine two non-construction case study contexts where the use of mobile collaborative technologies had been attempted. The paper will also report on interviews conducted with construction site collaborators to ascertain their attitudes toward new technology adoption. Based upon the results, it will be argued that unless the software, hardware and the existing work processes of the user are considered as a single system, the technology is likely to fail. The adoption of new technologies usually represents a significant change to the work process of the user, with the change being a source of resistance, not only should the software interface mimic the paper based documents it replaces, but the hardware should also provide for minimal changes in the physical work process.

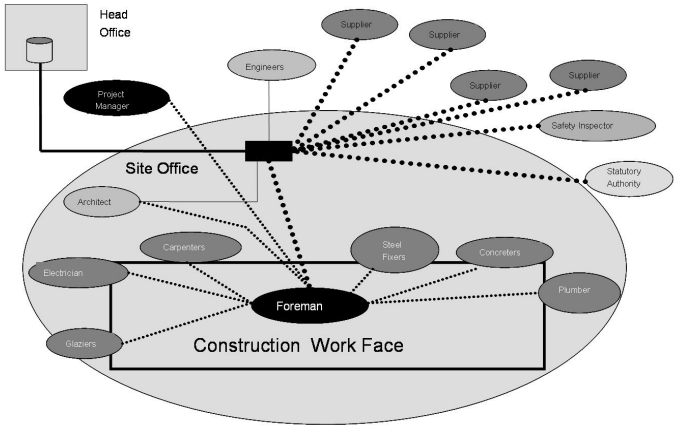
In order to present these ideas, the paper will briefly describe the existing issues associated with collaborative systems in the construction industry, the research methodology used and the results of the interviews. The results of the interviews will then be discussed in order to illustrate the need for a more holistic approach to the development of collaborative technologies for the construction industry.

## COLLABORATIVE SYSTEMS IN THE CONSTRUCTION INDUSTRY: INFORMATIN INTEGRITY, SCALEABILITY AND ACCESSABILITY

Bowden and Thorpe, (2002), found that 65% of rework by contractors in the construction industry arises from insufficient, inappropriate or conflicting information. There are a number of potential sources for this information mismanagement, however, the greatest source of problems is due to an over dependence upon the construction site foreman to assess, record, communicate and understand the data that is presented to him/her. Typically, data is recorded on site by the foreman through the use of paper forms. Copies are required for both head office where the majority of contract administration is processed, as well as copies on site. Copies of the documentation are also provided to all collaborators involved in the particular process, therefore there might be mass duplication across multiple organisations. For example, in the case of the structural specifications for a building, a copy of the specifications would possibly be held by the architect, project manager, structural engineer, other design engineers, head office of the contractor, site office of the contractor, sub-contractors involved (possibly concreter, structural steel manufacturer, reinforcing steel placers, suppliers etc) as well as a copy used by the foreman at the work face. As such, there is a strong need for both scalability and integrity in the data management process that is adopted.

The dynamic nature of construction work often requires ongoing modifications to these specifications as the project unfolds, and the creation of new versions which supersede the old document. In order for data integrity to be maintained the changes must be made to all issued copies of the document, however, this is often not the case due to the lack of a shared database between users. Furthermore, not all forms used for recording data can be carried by the foreman at the work face as there would be simply too many items to hold in a physically restrictive area. This means that, if for example, the foreman were to issue a written site instruction to a sub-contractor, they would have to leave the work face and go to the site office, fill out the form and then return. This is not only time consuming (particularly on civil and high rise construction) but impractical as site issues need to be resolved quickly and efficiently to avoid cost overruns and this often requires collaboration between on-site and off-site personnel (Bowden and Thorpe,2002). In the situation where a construction company has established an intranet with a server to hold documentation, the data is still not accessible from the work face as it is not mobile. The inaccessibility of data by the foreman at the workface represents a considerable threat to the maintenance of data integrity as often the foreman may take rough notes of specification changes at the workface, transferring these notes into a more formal document at a later stage when he/she returns to the site office. See figure 1 below for a description of the collaborative system on a building site.

*Figure 1: Conceptual model of construction related communications (Er & Kay, 2003)*




Further inefficiency and delays can occur when an issue requires a decision to be made by an off site collaborator, such as the architect. This may require the works to stop until the appropriate expert can be brought onto the site to inspect the problem. (This sometimes happens in order to allow the expert collaborator to make an assessment of the situation through first hand observations.) Often these delays could be avoided through more effective communication of the situation.

Many of these issues could be addressed through the use of newly developed wireless technologies, however, there is often considerable resistance to the introduction of new technology within the construction industry, particularly those related to computers or what many builders consider non-core functions. With this in mind, the research described in the next section will explore two case studies from other industries in order to identify common factors that would appear to support or inhibit the adoption of new collaborative technologies.

## METHODOLOGY

The research in this paper involved two case studies in organisations where wireless network communications had been utilized for the purposes of enabling collaboration between participants in the system. The first case study incorporating wireless enabled PDA's in a restaurant environment, the second involved the use of Tablets/laptop computers as the interface in a hospital ward. The case studies involved four semi-structured interviews with users and developers of the systems. A further four semi-structured interviews were conducted with construction staff to ascertain their attitudes towards the adoption of new technologies on building sites. Interviews lasted on average for 1 hour, with an interview guideline used to ensure that all interviews covered the same topic areas. Interviews were audio recorded on a digital recorder and transcribed for subsequent analysis. A thematic analysis of the issues and benefits was undertaken.

### Case Study 1: Restaurant Mobile Ordering System

The Restaurant Mobile Ordering System utilizes mobile PDA technology in order for table staff to take orders for meals in the restaurant and communicate these orders with bar and kitchen staff. Prior to the introduction of the system the traditional restaurant ordering process was employed. The waitress/waiter using paper note pads wrote down client's drink and meal orders. Initially, table staff would record drinks orders from clients and verbally passed these on to bar staff for preparation, before returning to the table with the order. On return, meal orders were taken by table staff and handed to the kitchen staff who would cook the meal. Table staff retained the original order with the kitchen receiving a carbon copy. When orders were ready a bell was rung and table staff would deliver the order to the client. On finishing the meal, the floor staff present the clients with the bill and the payment process takes place.

The restaurant owner, in an attempt to improve customer service, decided to replace the hand written order taking process with a wireless network framework, incorporating the use of wireless enabled PDAs for the table staff. "What I really wanted to achieve was improved customer service. The table staff were spending too much time running back and forth between the bar and the kitchen when ideally they should be waiting on the customers. The PDAs mean that they can stay on the floor for a greater percentage of the time" (Restaurant owner, 28/7/03).

The hardware underpinning the system includes: "…wireless enabled PDA's (personal digital assistants) which are used as a replacement to the order pads." (Restaurant owner, 28/7/03) The PDA's have an interface similar to the menus used by the customers with cascading screens allowing table staff to select the items for consumption, the quantity and any special requests to do with that order. The PDAs also allow orders to be changed at any stage. "The PDAs connect to the restaurant's wireless network through two wireless access points." (Restaurant developer, 28/7/03) The wireless protocol utilized by this system is IEEE 802.11. This protocol allows connectivity to a "printer located in the kitchen and the till system located at the bar". "It also connects to a database server which stores all processed orders." (Restaurant developer, 28/7/03)The software used on the PDAs was a proprietary package purchased by the restaurant and as such the basis of the system was created from an "off the shelf" product. That is the base system, prior to adaptation and adoption by the restaurant, had undergone a rigorous (but generic) development process. Prior to testing the system, the manager "organized a meeting with all staff, including the table, bar and kitchen staff." (Restaurant owner, 28/7/03) In this meeting the proposed system was explained to staff and they were given the opportunity to participate in the design process, providing feedback about any concerns with regards to the automating of their work and specific user issues which needed to be considered. It is important to note that the system is relatively uncomplicated, only requiring the development of an interface for the restaurants menu and order forms, and no further modification to the already existing systems of the restaurant.

The restaurant manager acknowledged that the system provided almost instant benefits to the business, with further unexpected benefits emerging over time. The benefits described by the restaurant owner and manager were as follows:

- **Greater accuracy in the orders produced**: "…we now have fewer misinterpretations compared with the written orders form."(Restaurant owner, 28/7/03). This was achieved through the use of check boxes on the PDA interface with the consequence that there was less chance of misinterpretation by kitchen and bar staff (and therefore less incorrect orders).
- **Improved record keeping**: "…all orders are recorded to a database server" (Restaurant developer, 28/7/03) via the wireless network. There is no need to double handle the information, in the form of subsequent data entry from the hand written notes. This resulted in a reduction of recording time, associated cost benefits and improved data integrity.
- **Improved customer service:** The waiter / waitress no longer needs to physically move between the table service area and the kitchen or bar, allowing more time for waiting on the customer. It also has the added benefit of providing table staff a greater opportunity to sell more items such as drinks and desserts.
- **A quicker response time to variations in customer orders**: The use of the PDAs has also allowed for faster interaction between table staff and bar / kitchen staff. For example, "if a customer wants to know how their order is progressing then the waiter can make the query from the PDA and tell them more or less straight away."(Restaurant developer,28/7/03),

Interestingly, the restaurant owner did not perceive any issues associated with the system's introduction.

**Case Study 2: Mobile Hospital Ward System**

The Mobile Hospital Ward System is being developed to access information in the patient records used by doctors on their ward rounds. The previous system required doctors to download information regarding a patient from the patient records of different departments (such as radiology or pathology) when appropriate. These documents were downloaded to create a paper-based hard copy, early in the morning prior to the doctors conducting their rounds. A number of collaborators could contribute to the patient record including several doctors (various specialists as well as the attending doctor), nurses, different medical departments as well as other medical consultants such as physiotherapists. It is important to note that there was no shared database between these collaborators and each was able to update information in the patient record at any point in time. This created a problem, in that if an update was made whilst a ward round is in progress, the doctor would not have access to that information until the end of the round, which could take up to 3 hours. The potential is therefore created for the doctor to make an incorrect / uneducated diagnosis in the absence of the most up to date information.

To address this issue, the case study hospital began trialing a wireless system that would allow doctors to access the up-to-date information whilst on their rounds. The system includes a wireless enabled Tablet PC, which allows the user to just write their reports using a sensor pen access data as well as providing the availability of a keyboard. IEEE 802.11b is used as the protocol for data transfer to allow access to the patient records. The same graphical user interface as the ward's desktop PC appears on the tablet. As such the interface is exactly the same as the one used to download patient information.

The development of the system included a long consultation process with the users. Training sessions were also organized however, no doctors attended. It is interesting to note that the system did not at the time of the interview, allow doctors to update the patient records and this process remained paper-based. The hospitals CIO suggested "…changes to the work process could only be achieved in small steps…" (Hospital CIO, 12/9/03) and as such functionality was purposefully limited

Unlike the restaurant example described above, this system has not met with a high level of success in terms of user adoption. The observed outcomes of this system include the following points:

- The system had been in use for approximately one month. At the time of implementation only one out of the three doctors on the ward had used the system. The doctor who had used the new system had only used it once and then returned to the traditional method. As such, document access is still undertaken using the old process.
- The system was perceived to be a useful tool by both the developers and users (even though they weren't using it).
- A key issue was security of the equipment. "Unless nailed down any piece of equipment will walk out of here (be stolen)."(Doctor 3, 12/9/03) This point has significantly contributed to the poor success / adoption of the system, as neither nurses or doctors felt prepared to take responsibility for it, if it was stolen during their round.
- The users / doctors were familiar with the technology, having to interface with a computer to download patient information.
- Access to the laptop is restricted to the doctors. The doctors believe that "if everyone else (administration, nurses etc) has access to the laptop then the system won't be available for our use (by the doctors)." (Doctor 2, 12/9/03/03)
- Having tried the new system (once), one doctor returned to the old system because he felt "more comfortable with it" (Doctor 3, 12/9/03)

Although the system had been created in consultation with its users, the doctors continued to use the paper based system. It should be stressed however that this application is in an ongoing trial period and as such the potential exists for many of these issues to be addressed so that a more thorough evaluation of the system's benefits may be undertaken in the future.

## TECHNOLOGY FOR THE CONSTRUCTION SITE

To further ascertain the necessary characteristics for a system to be adopted in the construction industry interviews were conducted with construction site staff, regarding attitudes towards the use of technology for collaborative purposes. The results of these interviews due to space limitations are summarized in the following points:

- Interviewees recognized the issue of sub-optimization of the collaborative system on construction sites and the communication inefficiencies of the foreman current role.
- Technology is familiar to site staff, however its use on construction sites is perceived as being unnecessary. One foreman remarked that he "owned a computer at home but would never use one on a building site." It is interesting to note that this foreman often used cameras as a visual recording device, and email for communication. Yet, the proposal to use a digital camera to capture an image and then email this image to off-site collaborators (such as an engineer) to help identify an issue on site, was considered "…too modern for me [the foreman]".
- The proposed use of technology to help improve the foreman's ability to collaborate was not considered to offer enough documented economic benefit at present. Management "would prefer to wait until someone else develops the gismo and just buy an off the shelf package from the local software shop."
- There was concern that current technologies were not flexible enough to suit the needs of the foreman. For example currently available hardware does not possess the ability to display full size working drawings, which is an indispensable tool for the foreman

## CONCLUSSION & INTERPRETATION OF RESULTS: DEVELOPING A SYSTEM FOR USE BY CONSTRUCTION STAFF

The two case studies present examples of a successfully implemented system and one that is having difficulty in being accepted. Even though both systems involved considerable consultation with users during development, the hospital system was failing to demonstrate a level of acceptance that would achieve critical mass. This failure would not appear to be due to inadequacies in the functionality either of the hardware or the software provided. The key distinguishing feature between the restaurant and the hospital related to the degree of change required in the work process itself. The use of PDAs in the restaurant environment did not represent a significant departure from the original information input process. The PDA had a very similar look and feel both in terms of function and size to the notepads the table staff had used before. Conversely, the hospital example required doctors to undertake an extra activity in the form of accessing information whilst "on the job" rather than before. This change in work practice had an instant impact on other processes, including the way the doctors interacted with patients for example.

This hypothesis requires further investigation in order to establish its applicability to the construction industry. Given the comments of construction site staff regarding the incompatibility of existing hardware with their existing work processes, the wireless access of paper forms in digital format is not necessarily going to convert to successful adoption. The process by which users both access and update information needs to closely mimic the existing work practice, in terms of physical activity and cognitive process.

Future research will aim to explore this observation in more detail, in order to gain a better understanding of the factors underpinning the successful adoption of technology particularly for collaboration in the construction industry.

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