SOCIO-TECHNICAL MANAGEMENT OF COLLABORATIVE MOBILE COMPUTING IN CONSTRUCTION

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The constant changes of plan and unanticipated events in the production process at construction sites result in communication patterns that are dynamic, spontaneous and informal. Most of the existing ICT tools do not sufficiently support informal communication for powerful collaborative problem-solving, management of site resources, handling of parallel process activities and do not correspond to the basic needs and work patterns at the construction sites. Mobile computing technologies have the potential to provide an inclusive wireless mobile ICT platform (voice and data) that can enable improved support for informal communication and on-demand data at construction sites, which can result in improved project collaboration leading to increased efficiency and productivity in the construction process. Still, an implementation strategy for collaborative mobile computing at construction sites is complex and must consider numerous issues regarding system capabilities, mobility, applications, services, integration of existing ICT systems, user interface and user devices to meet the requirements and behaviours of site workers in the mobile distributed heterogeneous construction environment. A mobile computing platform needs to be designed, implemented and managed with a socio-technical bottom-up approach realizing end user and group needs, understanding the separate issues of adoption on different organizational levels, and recognizing mobile computing as a process integrated enabling technology for improving collaboration and project communication throughout the whole construction process.

Keywords: construction site, informal communication, mobile computing, project collaboration, unanticipated events.

INTRODUCTION

In the construction industry much effort has been made to improve processes with the help of ICT, but the industry has not achieved increased productivity to the same extent as other industries. Samuelson (2003) shows that while the utilization of ICT is high in the design phase and in facility management, the use of ICT by contractors and site workers in the construction process is surprisingly low. Part of the poor productivity figures in the construction industry could be explained by the fact that the information needs and communication behaviours in the production at the construction sites are not adequately met. Most of the available project oriented ICT tools are meant for formalized "white-collar" office use. These tools give modest support to the craftsman-like construction activities and the unpredictable, dynamic, spontaneous and mobile environment that the "blue-collar" site workers work in. Improving ICT support for the core activities at construction sites and for site workers' information and communication needs is a strategic challenge for the construction industry to increase efficiency and productivity in the construction process (Samuelson, 2003).

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The construction site can be described as a reactive environment, where unplanned changes to work regularly occur (Ward et al., 2004). Unanticipated events and temporary critical problems are in this environment inevitable. The high frequency of unanticipated problem situations at construction sites is due to the inherent complexity and dynamics of construction projects (Magdič et al., 2004). Construction activities are dispersed and site locations frequently change, which is problematic when giving construction sites sufficient ICT support. The required ICT infrastructure is often deployed to the site office, but rarely reaches the construction site itself (Čuš Babič et al., 2003).

Quality, quantity, and timing of information are the three fundamental variables which can either hinder or facilitate successful results in a construction project (De la Garza and Howitt, 1998). As much of the administrative tasks at a construction site are still paper based, this delays the flow of data and the available information may become obsolete or insufficient. Much of the inefficiencies at construction sites arise from interruptions between activities and processes as well as delays within individual operations. These interruptions are often a result of poor planning, insufficient information and supply-chain problems (De la Garza and Howitt, 1998). In addition, low efficiency occurs because of the gap in time and space between the paper based administrative tasks at the site and the subsequent computer work back at the office (Kimoto et al., 2005).

Aouad et al. (1999) observe that during the last decade of the 20th century the construction industry has started a technological shift from ICT driven solutions to ICT enabling ones. However, the industry has become frustrated with the failing of ICT as many companies have invested in the wrong technologies without addressing business needs. Another aspect that complicates this picture is that the involved participants in a construction project typically are at disparate levels of organization and IT use. Therefore, they are forced to use mutual project oriented ICT tools at a very low level of integration (Čuš Babič et al., 2003). It is believed that mobile computing has the potential of providing solutions to the ICT issues at construction sites and enabling better use of knowledge and experience of site staff to handle and effectively resolve on-site problems caused by unanticipated events (Magdič et al., 2004). Innovative implementation and use of ICT can also enable businesses to structure and coordinate activities in ways that were not possible before, leading to new strategic advantages (Attaran, 2004).

However, designing, implementing and managing a mobile computing platform in a mobile geographically distributed and heterogeneous construction project is far from trivial. This paper reflects upon some of the socio-technical collaborative aspects of mobile computing in construction. A Socio-Technical Systems (STS) perspective on technology management is the starting point for the analysis. This STS perspective focuses on the design of work for both organizational and human good and how the complex interactions between people, organizations and technology should be arranged to enhance the quality of work (Griffith and Dougherty, 2002).

THE ROLE OF INFORMAL COMMUNICATION IN COLLABORATIVE WORK

Informal communication plays an important role in handling unanticipated events and solving critical problems. Informal communication is not a planned activity with a set agenda or fixed location. It occurs spontaneously, almost everywhere and has a large

impact on work processes and outcomes that can be even greater than formal communication (Johansson and Törlind, 2004). The spontaneous interactions in informal communication enable frequent and instant exchange of useful information resulting in issues being discussed and resolved as they occur, instead of waiting for a suitable and scheduled time to make a formal decision (Johansson and Törlind, 2004). The nature of formal communication, on the other hand, is that it tends to be used for coordinating relatively routine transactions within groups and organizations (Kraut et al., 1990).

Informal communication supports organizational and group coordination, especially under conditions of uncertainty. It helps members of a group in learning about each other and understanding their work. Informal communication supports both the actual production and the social relations that underlie the work, and is a critical activity to initiate collaboration, maintain it, and drive it to a common goal (Kraut et al., 1990). Informal interactions are also important in getting people to know and like each other to create a common context and perspective to achieve better planning and coordination in group work. Collaboration is less likely to start and becomes less productive if informal communication does not occur (Kraut et al., 1990).

Informal communication is distance sensitive and happens most often between people who are physically close to each other (Kraut et al., 1990). Designing ICT systems that enable better support to informal interactions in dispersed organizations is a great challenge. Systems that do not create the "virtual shortcut" that improve the flow of information or enable better support for interpersonal communication, make communication even more complicated.

Studies (Johansson and Törlind, 2004, Törlind and Larsson, 2002) have shown that many of the contemporary collaboration tools for distributed teamwork, e.g. video conferencing and shared applications, can support formal meetings to a certain extent. But to adequately support informal meetings, distributed social activities and informal communication processes that often arise spontaneously in between the formal meetings are important issues yet to be resolved. The vital informal component in teamwork communication has so far been difficult to support in collaboration applications (Johansson and Törlind, 2004). Larsson (2002) points out that the formal approach of holding meetings through telephone or videoconferences do not entirely fit the way in which geographically dispersed teams need to interact in order to "get the work done". These tools are often useful and critical to the project, but are missing the elements of day-to-day interaction between members. Finding a good time to interact, and being able to establish easy and rapid connections with co-workers need to be better supported in the technologies for distributed collaborative work. Otherwise there is a risk that the social collaboration process is reduced to a formal process where team members are "explaining to each other" instead of "thinking together" (Larsson, 2002). Extra formality and inflexibility should not be introduced into distributed collaborative teamwork without special consideration (Larsson, 2002).

COLLABORATIVE MOBILE COMPUTING

Often when mobile computing is adopted to improve collaborative work, the existing concept of the desktop-based computer is transformed to mobile platform. It has resulted in that the potential of mobile computing have not properly exploited (Rebolj et al., 2004). Kristoffersen and Ljungberg (1999) explain the fundamental differences between the mobile work context and the office setting. Tasks external to operating

the computing device are the most important in mobile work, as opposed to tasks often taking place "in the computer" in the office setting. The hands of the mobile worker is often used to manipulate physical objects, as opposed to users in the traditional office setting, where hands are safely and ergonomically placed on the keyboard. In a mobile work environment users may be involved in tasks "outside the computer" that demand a high level of visual attention to avoid danger as well as monitor progress, as opposed to the traditional office setting where a large degree of visual attention is usually directed at the computer. Mobile workers may also be highly mobile during the actual task, as opposed to in the office, where doing and typing are often separated (Kristoffersen and Ljungberg, 1999).

Johansson and Törlind (2004) underline that mobility support is essential for both formal ICT applications and informal communication tools in distributed work environments. Mobility is vital to create awareness - awareness of people (a sense of who is around) and awareness of process (what they are doing). Maintaining awareness across distance is crucial for successful collaboration (Johansson and Törlind, 2004). In the daily activities on a construction site interactive personal communication is the basis on which unanticipated events and critical problems are solved. If the informal communication is not effective in this complex process it may cause delays and disruptions with lower productivity and financial losses as a result. Mobile computing can provide powerful tools to support these activities and make the information more available and the communication faster and more reliable (Čuš Babič et al., 2003).

This paper argues that mobile computing can enable better support for informal communication which is essential in handling unanticipated events and solving critical problem situations that constantly occur at construction sites. Mobile computing can deliver good access to timely and accurate information, and quick and efficient communication with on- and off-site personnel. This can reduce or maintain project durations, make better use of resources, increase labour and equipment productivity, decrease cost, increase problem solving speed and make cooperation between personnel less distance sensitive (Bowden and Thorpe, 2002, Olofsson and Emborg 2004, Magdič et al., 2004).

The walkie-talkie has played an invaluable role in wirelessly supporting the spontaneous informal verbal communication for handling unanticipated events and solving critical problems that constantly arise at construction sites. But what is missing in a walkie-talkie is the spontaneous on-demand flow of information-rich data, documents and drawings which is a vital component of construction projects today. If this information combined with improved communication tools could be obtained wirelessly at the specific location where a construction task is being carried out, mobile computing has the potential of improving productivity more than has been achieved so far by the walkie-talkie (De la Garza and Howitt, 1998). To accomplish this, mobile computing platforms must be able to deliver powerful applications with an interface as simple and intuitive as the "push to talk" feature of the walkie-talkie. To create a future all-inclusive handheld mobile wireless ICT platform (voice and data) for project collaboration is a major challenge and incentive for improving productivity in the construction process.

SOCIO-TECHNICAL ASPECTS OF IMPLEMENTATION

The issues of implementing a mobile computing system are complex and numerous. Network architectures, wireless infrastructure equipment, handheld computer devices, information systems, communication services, distributed collaboration tools and other applications have to be chosen and planned carefully in detail to meet the requirements and behaviours of the mobile workforce. This section will briefly highlight some important socio-technical issues of an implementation strategy for collaborative mobile computing at construction sites. Different wireless infrastructure and networking alternatives as well as capital and operational costs will not be considered here.

The socio-technical gap

To strategically implement and integrate an ICT system into an organization there has to be an alignment between the work processes and the technology (Aouad et al., 1999). ICT systems and work processes have to be co-developed to be able to improve organization and increase productivity. When introducing collaborative ICT systems into existing work environments and business processes it is important to recognize the fundamental socio-technical gap between what is required socially and what can be done technically (Ackerman, 2000). This social-technical gap is difficult to overcome, but it can be better understood and approached. It is critical to understand the targeted environment, the needs and behaviours of the intended users and how people really work in groups and organizations to be able to prevent the introduction of unusable systems that are mechanizing and distorting collaboration and other social activities. In stead, a problem-driven demand-pull approach should be applied to identify and utilize the potential application areas for ICT tools in construction (Björk, 1999).

Organizational perspectives

Based on Samuelson (2003) the implementation and use of ICT in construction can be described consisting of three levels of organizational perspective; individual/personal, project/group and corporate/industry level. Many of the problems associated with ICT in the construction industry are related to its adoption, which has been relatively uncoordinated, and its strategic application appears to have been determined by its availability rather than its suitability (Aouad et al., 1999). When introducing new ICT solutions into organizations it is important to review all three of the organizational levels and realize that different viewpoints of adoption strategy are needed on different levels.

Level of mobility

The mobility issue itself gives rise to several aspects that need to be handled in the implementation strategy. Pierre (2001) accentuates that a true mobile computing infrastructure should be able to support different wireless and wireline communications devices optimized for their specific environment. In this way, a person would be able to communicate and receive information anywhere, any time. The needed level of mobility is decided by the specific requirements of the construction site. For example, is the system required to support continuous operation of applications while users move between network boundaries? What level of mobile awareness should be supported by the system? Does the system need to support multipoint distributed conference applications? How heterogeneous are the networks and the devices? The answers to these and other relating mobility issues assist in

narrowing down the possible choices of suitable technology solutions for a collaborative mobile computing platform.

Applications and services
An implementation strategy of a mobile computing network must also include an appropriate mix of applications and services. On a general level, there are two types of mobile applications and services; horizontal applications which are domain independent (e.g. web-based public information services), and vertical applications which are written for a specific application domain that respond to the specific needs of a mobile work force (Pierre, 2001). It is important to identify what information and communication needs are not sufficiently supported and how this could be resolved.

Integration of existing ICT systems
Integration of existing information systems into a mobile computing platform is of critical importance. It is essential that mobile computing does not add another incompatible stand-alone ICT structure that fragments the construction process even more (Bowden and Thorpe, 2002). A mobile computing platform must be integrated with existing information systems and project collaboration tools in order to achieve a seamless flow of information throughout the whole construction process and to make use of the benefits of the information generated in earlier phases of the project. Merging existing information structures to create better integration and organization between design, planning and construction phases are imperative to increase productivity and improve the quality of the construction process (Stewart et al., 2002).

User devices and interface
The mobile computing solution introduced at a construction site must meet the special demands on durability, user interface and be able to handle operation in harsh environments, otherwise the promised rationalization will be lost (Olofsson and Emborg, 2004). Overcoming the limitations of the user devices is a critical issue in this context. Although handheld computers are improving rapidly, they still suffer from small screen size, slow text input facilities, low bandwidth, small storage capacity, limited battery life, and slow CPU speed (Pilgrim et al., 2002). Of particular importance is the screen size and resolution. Small screens often have a negative effect on browsing related tasks because there is too much data and too little display area to present the information (Pilgrim et al., 2002). Data models in engineering applications tend to be complex and to designing the corresponding mobile device user interface is challenging. Also, compared to the design of desktop-oriented software there are relatively few guidelines available to aid the interface design of mobile computing devices (Pilgrim et al., 2002).

TOWARDS A RESEARCH FRAMEWORK

To accomplish effective mobile computing at construction sites, technology solutions need to be developed and implemented with a bottom-up approach recognizing end user and group needs and the separate issues of adoption strategy on different organizational levels. By mapping established research fields to the three organizational levels mentioned previously, an overview of a socio-technical bottom-up research framework for collaborative mobile computing in construction can be outlined.

Individual/personal level – Human-computer interaction (HCI)
The field of Human-Computer Interaction (HCI) is concerned with the design, evaluation and implementation of interactive computing systems for human use. An important issue in the HCI context is the user acceptability of a system. A system that satisfies the needs and requirements of the users is an acceptable system and has a high level of "usefulness"; the system is capable of achieving the desired goal (Berg von Linde, 2001). Usefulness can be divided into utility, the level of functionality of the system, and usability, how well a user can utilize the functionality of a system (Berg von Linde, 2001). The usefulness perspective is crucial to be able to design suitable mobile computing systems with appropriate user interfaces that meet the user needs in a demanding and heterogeneous construction environment.

Project/group level - CSCW and Groupware
Like HCI, the Computer Supported Cooperative Work (CSCW) research field is socially oriented rather than technology driven. CSCW studies how people work together, and how computer and ICT related technologies affect group behaviour. By looking at the way people interact and collaborate, technology can be developed that properly supports these collaborative activities (Larsson, 2002). The term CSCW is often associated with the term Groupware. Groupware are the computer-based systems that support group work to achieve a common task (Greenberg, 1991). Groupware systems assist both groups of people working together and also single individuals performing isolated tasks. The challenge for the CSCW and groupware perspective is to understand the socio-technical gap of what is required socially within a work group and what can be done technically. This is a critical issue to be successful in designing and implementing mobile computing at the group/project level. It is important to understand how people really work in groups and organizations so that the introduction of new ICT systems do not deteriorate and distort the collaboration process and social interaction.

Corporate/industry level – Management of technology and process innovation
The term "enabling technology" can be used to describe a technical solution that is introduced into an organization's production operations in order to enable productivity increase and to improve work procedures and organization. These improvements of an organization's production are often referred to as "process innovations" (Utterback, 1994). A collaborative mobile computing platform can be regarded as an enabling technology for the construction process. It is important point out that mobile computing is not that kind of enabling technology that creates process innovations that will change the physical construction process, i.e. the way buildings are built. Nevertheless, mobile computing can enable radical innovations in the information and communication processes that surround the entire construction process, which can lead to significant productivity increase.

A socio-technical approach where technological innovation and implementation aspects interact with work practices and human factors is essential for successful management of technology and process innovation at the corporate/industry level. Therefore, the management of collaborative mobile computing in construction needs to be approached from two directions, where both technological and organizational innovation aspects have to be handled and developed in conjunction.

It is important to stress the process perspective and the enabling role of mobile computing. The technology management of mobile computing needs to be addressed as an enabler that should be integrated with the production process, instead of a

process independent driver. This becomes evident when looking at the failing of ICT in many parts of the construction industry. While ICT solutions have been introduced through various professions, there has been a lack of focus on the integration and use of ICT to improve construction project collaboration process on a holistic level (Aouad et al., 1999).

CONCLUSIONS

Changes of plan, unanticipated events and temporary critical problems are inevitable at construction sites. The need for appropriate information-rich communication tools in this environment is not well addressed today. Informal communication plays an important role in handling unanticipated events and solving critical problems. Informal communication is also vital for improving project collaboration, social group relations and teambuilding processes. The problem today is that informal communication is poorly supported by information and communication technology. High level of mobility and awareness in ICT tools are important to be able to support efficient ICT-based group communication in distributed work environments. The rapid developments of wireless mobile computing technologies over the past decade have brought new opportunities to the information and communication issues at construction sites. These technologies have now the potential to provide a complete wireless mobile ICT platform (voice and data) that can enable improved support for informal communication and on-demand data at construction sites, which can result in improved project collaboration leading to increased efficiency and productivity in the construction process. Towards accomplishing this, valuable experience can be obtained from the example of the walkie-talkie and why this technology has become a powerful tool for verbal informal communication at construction sites. Likewise, the breakthrough and user acceptance of a mobile computing platform in the construction process depends much on whether such a system can be designed to deliver powerful applications with an interface as simple and intuitive as the “push to talk” feature that the walkie-talkie provides.

An implementation strategy for collaborative mobile computing at construction sites must consider numerous issues regarding system capabilities, mobility, applications, services, integration of existing ICT systems, user interface and user devices to meet the requirements and behaviours of site workers. A socio-technical bottom-up approach is needed to able to improve the design, implementation, usage and management of collaborative mobile computing in a mobile distributed heterogeneous construction environment. Different viewpoints of technology implementation and adoption strategy are needed on different organizational levels. Human-Computer Interaction (HCI) issues need a lot of consideration and further research at the individual/personal level. Usefulness concerning utility and usability of system applications and user interfaces are important aspects to meet the specific needs and behaviours of construction site workers and to achieve high user acceptance of the mobile computing system. Computer Supported Cooperative Work (CSCW) and Groupware have to be addressed at the project/group level. The challenge of this perspective is to understand the socio-technical gap of what is required socially within a work group and what can be done technically with mobile computing. Understanding how people really work together, the culture, social and organizational structures, communities of practice and the tacit knowledgebase of a construction site is essential to be able to design a collaborative mobile computing platform that truly supports the existing knowledge formation, develops and enhances organizational

capabilities and improves collaboration, social interaction and project communication in the construction process. Methods concerning management of technology and innovation processes have to be developed at the corporate/industry level. The management of collaborative mobile computing in construction needs to be approached from two directions, where both technological and organizational innovation processes have to be handled and developed as one integrated unit. It is critical to approach these management issues with a broad construction process perspective and accentuate the enabling technology role of mobile computing for improving collaboration and project communication throughout the whole construction process.

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