MOBILE COMPUTING AND PROJECT COMMUNICATION
– mixing oil and water?

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– mixing oil and water?

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ABSTRACT

The use of mobile and wireless Information and Communication Technology (ICT) tools in geographically distributed project organizations appears to be an appropriate application of new technical capabilities in an existing business environment. But to successfully introduce and adopt a suitable mobile ICT-based project communication platform in an existing operational setting involves a complex framework of socio-technical issues that have to be considered.

This Licentiate thesis presents the results of an ongoing doctoral research project. The study explores the implementation process of mobile computing tools at Sweden’s largest construction company, with the aim of improving information management and project communication of production site operations in construction projects. The research project highlights the interdependencies between the creation of usefulness and its resulting benefits. It emphasizes user-oriented implementation as the enabling process for realizing technology fit and user acceptance of the mobile computing tools, as well as achieving long-term benefit and business value of the ICT investment.

The studied case specifically addresses the neglected mobile and flexible information needs and communication demands of management staff at construction sites. The fundamental issue is to identify what the usefulness perspective of mobile computing for construction operations consists of relating to both technology and the different groups of people who are supposed to use it. Generic access, mobility of project data and individual adaptation of information and communication resources are technological aspects that are emphasized and discussed in the context of creating usefulness and benefit of mobile computing in construction projects. The often present political dimension of ICT implementation within an organization is also highlighted. The socio-technical introduction and adoption process of mobile computing involves balancing various perspectives and agendas inherent on different organizational levels in order to achieve an acceptable outcome for all the actors involved.

Topics for further research are discussed and refined relating to the ongoing case study and the conceptual framework presented.
IN HIS OWN WRIGHT

This Licentiate thesis presents concepts and empirical reflections from my ongoing doctoral research project at the Royal Institute of Technology (KTH) in Stockholm. My academic background is in industrial management and telecommunication systems. The ideas behind the research project presented in this thesis were initially awaken during the writing of my Master of Science thesis in my last undergraduate year at KTH in 2004. My fellow alumni and I were conducting a study at the Swedish telecommunication company Ericsson AB of the next generation mobile and wireless Information and Communication Technology (ICT) for addressing new rural market segments in Russia. That project had a clear equipment and service provider perspective, and we were looking at different business models for wirelessly bringing voice and data communications to these underserved rural areas. During this time I got increasingly interested in the customer and consumer side of the mobile value chain. I started to ask myself; who is really the potential customer group for new mobile and wireless ICT? What is the value that the technology is supposed to bring to these users?

Soon the corporate end user perspective of integrating mobile and wireless ICT into companies’ existing business enterprise ICT platform caught my attention. New questions started to emerge; what industries would benefit from making their existing business information systems and communication tools more flexible and mobile? What companies have recognized the business potential of mobile and wireless ICT and have the drive and determination to carry out such an in-house system integration project and technological expansion?

I approached professor Örjan Wikforss at the Department of Industrial Economics and Management (INDEK) at KTH with my initial thoughts of investigation. Örjan, whose main area of research is in the field of project communication, architectural design and construction, listened to my ideas and told me that the topic was highly applicable to the construction industry and its current state of ineffective communication in both design and production processes. I soon got aware of an industry that is struggling with various performance issues in their business activities, and especially the information management and project communication concerning production site operations. The geographically distributed construction site is an environment that involves a lot of complexity and diversity in the project collaboration by the different actors involved, as well as volatility and uncertainty in its physical production processes. These characteristics put special requirements on the end user ICT tools that are intended to improve information and collaboration processes surrounding construction site activities.
I immediately saw the potential of mobile and wireless ICT for the building site production environment, and that it could possibly enable new opportunities for offering the enhanced on-site communication tools requested. What caught my interest is the intricate combination of new methods of project communication through cutting-edge mobile and wireless technologies and the rough craftsman-like production environment concerning the construction site. Introducing mobile computing at construction sites appeared to be an ‘extreme sport’ of ICT implementation, or is it even mission impossible?

I was employed as a research engineer at INDEK in the spring of 2004 where I took part in an ongoing feasibility study concerning project communication and ICT tools in the design phase of construction projects. Through a case study of functions and usage of Internet based project management tools I got to learn more about information issues and collaborative communication patterns between different actors of the construction industry (see Löfgren chapter six in Wikforss, 2006). After the 6 months experience of that research project I was accepted as a doctoral student at INDEK under the supervision of Örjan Wikforss in the fall of 2004, and my research in construction site oriented mobile computing kicked off immediately. Now the completion of the project is half way through, and it is time to present a progress report in the form of this Licentiate thesis.

The writing that follows consists of a reflective cover essay and three theoretical framework papers. The purpose of the thesis is to discuss different perspectives of the research topic and the findings of the study so far. It is trying to broaden the horizon and show the complexity of introduction and adoption of wireless and mobile ICT in an existing production business environment. The thesis describes the ongoing research and case study without presenting any general conclusions. Its purpose is only to define and refine research objectives for further research.

Some readers may ask what the purpose is to go public with unfinished research and incomplete material. Well the way I see it, the first half of the research project is completed and it is now time for a quality control of its conceptual and methodological standpoints, as well as its results so far and directions for further research. This is a chance to reach out to academia and the business world with new results from a vast and partially unexplored research field, as well as an occasion to get feedback from the academic community and receiving opinions relating to industrial relevance. I see it as an opportunity to obtain a critical discussion of the content of the research. Are the theoretical concepts relevant, should they be revised and what is missing? What about the
choice and design of the empirical research approach? Obtaining and considering criticism of possible research flaws as well as defending one’s research accomplishments is the openness and attitude that I think should apply to all academic research. This feedback will then be used to develop theoretical concepts and modify the empirical approach. Hopefully that will further improve the final research results, which will be presented in my doctoral thesis with the expected publishing in the fall of 2008.

Before going further, I would like to acknowledge the people who in different ways have contributed and inspired me in my research. These people are:

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Peter Neuberg and his team at Gamla Filmstaden, Skanska Hus Stockholm Syd.
All the interviewed people at different business units and subsidies of the Skanska group.

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Pablo Valiente at the Department of Information Management, Stockholm School of Economics.
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THANK YOU!

For the good times at work, compliments to my doctoral student colleagues at INDEK.

Stockholm, April 2006

Alexander Löfgren
LIST OF CONTENTS

Cover essay

1 INTRODUCING THE PERSPECTIVES...........................................................1
   Construction in-site ...............................................................................................1
   Mobile project communication .............................................................................3
   Emerging themes ..................................................................................................7
   Research approach ...............................................................................................8

2 CONCEPTUAL REFLECTIONS ..................................................................... 13
   Paper work ........................................................................................................... 13
   The importance of usefulness ............................................................................. 14
   The scope of benefit ............................................................................................ 17
   The art of implementation................................................................................... 18

3 CASE OF THE ART...........................................................................................23
   Setting the scene ..................................................................................................23
   Birth of a mobile platform ...................................................................................26
   Case discussion ....................................................................................................29

4 THE ROAD AHEAD..........................................................................................33

SOURCES ................................................................................................................39

Paper I
SOCIO-TECHNICAL MANAGEMENT OF COLLABORATIVE MOBILE COMPUTING IN CONSTRUCTION
Reviewed, accepted and included in the 21st annual Association of Researchers in Construction Management (ARCOM) conference, 7-9 September 2005, London.

Paper II
USER-ORIENTED IMPLEMENTATION STRATEGY FOR MOBILE COMPUTING AT CONSTRUCTION SITES
Reviewed, accepted and included in the ICCCBE-XI/CIB-W78 Joint International Conference on Computing and Decision Making in Civil and Building Engineering, 14-16 June 2006, Montreal.

Paper III
ICT INVESTMENT EVALUATION AND MOBILE COMPUTING BUSINESS SUPPORT FOR CONSTRUCTION SITE OPERATIONS
Reviewed, accepted and included in the 5th annual Mobility Roundtable conference, 1-2 June 2006, Helsinki.
1 INTRODUCING THE PERSPECTIVES

The construction industry and specifically building site operations is a complex and fascinating application area for the business potential of mobile and wireless ICT. The following section will try to describe the information and communication struggle concerning a typical construction site in Sweden today. The narrative is based on the findings of the case study at the residential construction project ‘Gamla Filmstaden’ in Stockholm during the fall of 2005.

Construction in-site

The production environment of the construction site involves a very tight time schedule with the full attention to planning, coordination and completion of the building activities. The production management team and construction work supervisors have a tough time handling the constant flow of on-site construction issues, including prefabricated elements that are not dimensioned properly, components missing to complete assembly processes, building material that are not delivered on time and various sub contractors and participating actors that do not show up on time or perform inferior work. Also, there is the administrative work concerning the overall progress of the project.

Production managers, construction supervisors and superintendents are needed on site to coordinate work, do inspections, conduct environment and safety rounds, document and follow up ongoing and completed construction activities. The very same persons also need to be located at their computers inside the site office ordering equipment and building materials, exchanging digital CAD models and drawings between architects and design engineers, e-mail subcontractors about upcoming work, follow up budget figures and invoices as well as prepare deviation reports on construction work with unsatisfactory result. In addition to this, there are daily production meetings that afterwards need to be transcribed in computer documents and e-mailed to all involved parties.

Prefabricated building elements are nowadays a part of the regular construction process. Even though the general idea is that this construction method is supposed to increase the efficiency of the building process, it is common that production site staff are experiencing that it is causing a good deal of deficiencies and delays. The main problem seems to be that it sometimes can differentiate several centimeters or decimeters when assembling different prefabricated building elements. Construction site supervisors and work coordinators spend a lot of time compiling drawings from different designers and subcontractors to be able to figure out how it all should fit together. Sometimes the
dimensions can differ immensely from an original blueprint to the physical construction element. The large number of delivery delays and design deviations has resulted in an increase in extra effort in swift blueprint modifications and acute on-site construction adjustments. Not precisely the lean assembly line and efficient workflow that the prefabrication process is supposed to deliver.

There are problems associated with local planning and activity coordination that cause delays of production work. Production managers themselves admit that the breakdown of responsibilities for certain construction activities can be vague and that there is no time for advance planning of delegated tasks. Production managers and construction supervisors experience that they often have to be at two places at the same time; at the site office doing administrative work at their computer as well as being out on the site coordinating work. Construction site personnel feel that there is a need for improved routines and tools to achieve better control and planning of building activities.

There is a huge demand on documentation of construction projects due to both internal and external quality standards that regulate the auditing of construction quality as well as storage of historical project proceedings and data. Every meeting protocol, drawing, safety round record, deviation report and other continuous documentation of the project is commonly stored centrally in digital format. Even though these demands are good from a quality assurance point of view, they are causing double amount of administrative work for the production management. Documentation of building activities, production meetings and various inspections has to be carried out twice; once when they are actually occurring and then again in a computer document using different templates which are then uploaded centrally or e-mailed to all involved project participants.

Construction projects of today are dependent on reliable and updated information through a number of ICT-based business systems, communication tools and shared storage servers. To solve arisen on-site problems and critical construction issues there is a need for quick access to necessary information. To solve a site problem, production management personnel have to run back and forth between the construction site and their computers inside the site office. This leads to inefficient use of managerial resources. Another downside of this is that the production management team is occupied at their computers a large part of their working hours. Even though the intentions of the ICT-based business support systems is to improve project communication, they have lead to that production managers, construction supervisors and superintendents are experiencing that they are doing the wrong things. For example, whole days are sometimes spent in front of the computer writing protocols from previous meetings. This has resulted in
negative effects on the on-site presence and firm leadership of production management personnel. Unwillingly, production managers feel on occasion that they have become slightly detached from the action at the construction site. Construction coworkers and fellow craftsmen, by all means, are wondering what the supervising staff are doing indoors in front of the computer all that time?

**Mobile project communication**

Organization and government of projects are complicated matters. Project participants, often from different organizations with separate backgrounds and professions, are brought together under a limited period of time to jointly carry out a specific task. A project normally includes three main stages; planning, execution and evaluation, which are often partially concurrent processes. A project demands high level of integration and understanding between the involved parties and persistent coordination of people, information, tasks, options, technology, and material recourses to achieve a successful project outcome. A central enabling process to make this happen is communication. The role of effective communication in projects can not be stressed enough. It is a facilitator for achieving coordinated results, managing change, motivating employees and understanding different needs of the workforce (Dainty et al., 2006).

In construction projects these matters are particularly evident. In recent years it has been identified that the primary causes of the construction industry’s poor performance are its ineffective communication practices, its organizational fragmentation and lack of integration between design and production processes (Dainty et al., 2006). A construction project is carefully planned into the last detail. Architects, design engineers and production teams spend months or years on specifying and drawing blueprints, setting up time plans, calculating budget figures and coordinating collaborative project processes. No matter how much effort that is put into the design and planning process, as soon as the production work at the construction site starts all kinds of problems and issues arise that calls for immediate attention. In this constant reactive production environment, handling problem situations result in natural communication patterns that are dynamic, spontaneous and informal (Dainty et al., 2006).

The on-site production issues in construction projects can be described as a classical resource allocation problem with design attributes (Milgrom and Roberts, 1992). This is the coordination problem that arise when allocating a fixed set of resources among various possible uses, and in which there are specific information in advance about how different
parts of the task must fit together and in which small failures of fit are very costly. Design attribute problems require:

- **Synchronization** – It is critically important for the involved actors to be in pace with each other to make actions of the team synchronized.
- **Assignment** – There are a variety of tasks to accomplish and there is a need for just one person or unit to do each. The coordination problem is to ensure that each task is done and that there is no wasteful duplication of effort.

These production coordination issues have a strong relation to the communication and information exchange between the involved parties of a construction project. The foundation for improving the communication processes in a project is to realize the specificity of the production context at hand; its unique needs, demands and behaviors of collaboration and information exchange. This is mainly a matter of avoiding the theoretical formation of a universally ‘good’ project communication theory of how people ought to communicate in projects, and in stead focusing on how they actually do collaborate, exchange information and administrate data, as well as how these business activities could be better supported. For example, the seemingly erratic informal pattern of on-site communication is actually a vital component in the construction process. Informal communication is important to handle unanticipated events and solving critical problems. This involves the direct interaction with other project participants and the exchange of the needed project data ‘right here, right now’. Another vital part of the informal communication process is that it enhances project collaboration, social group relations and teambuilding processes. It strengthens social relations among project members and creates learning and understanding between different work practices and professions.

There is a lack of flexible and intuitive ICT tools that properly support the administration of construction site activities and collaborative problem-solving. It is sort of a semi-structured communication behavior that needs improved ICT support. This implies making information exchange and problem-solving communication more structured and consistent on a technological system level without adding unnecessary formality and inflexibility on social interactions and collaboration processes. This is about creating information and communication tools that unite and strengthen connections and understanding between people, professions and processes, as well as integration between the design and production phase of construction projects (Wikforss, 2006). ICT developers and corporate governments of construction enterprises have to listen more closely to what production site personnel is asking for and together translating this to appropriate and functional ICT tools.
During the last decade the Swedish construction industry has highlighted the need for an overall ICT platform that is robust and flexible to be able to better match different professional information needs and communications behaviors, as well as the often swift organizational changes and suddenly altered circumstances in construction projects. The national R&D program 'IT Bygg och Fastighet 1997-2002' was a joint force in the search to realize a shared ICT platform for all actors involved in the Swedish construction industry. The program resulted in improved standards and methods for construction modeling, data exchange, document management and collaborative project communication (see Wikforss, 2006). The strive towards a shared ICT platform for construction involves a complex underlying system architecture with many interdependent components and processes that have to be intimately synchronized to be able to deliver the full advantages of the technology in the intricate business context (see Löwnertz, chapter nine in Wikforss, 2003). Therefore, a shared and accepted project communication platform is not created in a twinkling. In the end it is about bringing together different concepts and perspectives of what ICT is supposed to deliver in different parts and phases of the project life cycle. Issues concerning the development and use of ICT tools have low priority in the construction site production environment because there is simply no time for considering these matters. Nevertheless, it is quite obvious from the discussion above that on-site information needs and communication behaviors are poorly supported by ICT. The main problem is that ICT tools are often designed for formal office use and lacks flexibility and mobility that the site environment demands. Also, information systems that actually could be useful are regularly only extended to site office and not into the hands of the site personnel. In the past, the ICT needs and demands of production operations in construction have been forgotten, and many of the implemented information systems and ICT tools has certainly not been in line with construction site requirements, or been asked for by production personnel for that matter. Therefore the full potential of these systems and technologies have not been utilized. It can also be argued that the appropriate end user ICT for construction sites has not technically been available previously. The rapid development of mobile and wireless ICT and handheld computer devices have now enabled new possibilities of portability and on-demand access of information systems and communication tools that the production organization is requesting.

Creating the appropriate mobility and flexibility of an ICT-based business platform for any production environment or project organization has very little to do with the physical mobile user devices. A much larger technological challenge lies in developing the underlying enterprise specific ICT infrastructure. This includes integration of existing information systems, developing a powerful document management structure and end
user presentation layer with personal adaptation of project data based on individual needs. With this holistic thinking the user terminal through which information and communication is managed becomes a secondary issue. Different project roles and professional groups have diverse needs and demands concerning their administrative ICT business support. Many of them require a high level of communication mobility and instant information accessibility, while others do not have these requirements at all. Therefore, taking the mobile step in ICT-based project communication is to enable generic access of data. This means that project data should be able to be accessed, presented and computed through a personalized interface using any type of user terminal regardless if it is a mobile handheld device, a portable laptop or a fixed desktop computer. From this overall picture of ICT-enabled mobile business support the mobile computing aspect is the focus of study of this research project. Through the remaining part of this thesis, mobile computing is used as a generic term for the ability to wirelessly connect to and use centrally located information and/or application software through small, portable and wireless computing and communication devices.

Figure 1. General system architecture of ICT-based mobile business support (based on Nilsson et al., 2003)

The findings of this research project have indicated so far that the often alleged conservative ICT culture at construction sites is somewhat false. Interviews and conversations with construction site personnel show that they are in fact aware of the
inefficiencies of information management and project communication at the site operations, and not seldom they have own ideas of how to solve these problems with assistance from technical solutions. In these discussions handheld computers have often been mentioned and the mobility and flexibility of information and communication systems are of high priority. The key issue of improvement in their point of view is to be able to carry around the needed ICT-enabled business support to access it at any time.

Nevertheless, the very same construction site staff interviewed indicates that mobile computing also could cause intricate problems. They describe scenarios out on the field when critical problems occur that cause temperamental and indignant gushes of emotions. In some of these cases instant mobile access of project communication tools could lead to rash conclusions resulting in incorrect decisions which may cause unnecessary conflicts with other project actors, or lead to further construction costs or delays. Production management personnel argue that it is sometimes better in these often occurring situations not to have direct access to project data or immediately get in touch with certain people. Instead they can cool down, get some time to think things over and establish a nuanced picture of what actually occurred. Then a well considered decision can be made that involves the accurate set of project participants and resources. Other issues of mobile computing which relate to the impacts of ICT in general are the risk of reducing of face-to-face contact, the danger of information overload and the stress of always being online and reachable. Many of these issues may contribute to undermining the informality and flexibility of normal patterns of effective human communication, as well as distortion of the natural interaction of problem-solving and collaborative processes.

Emerging themes

A well run company knows how its business processes are designed and conducted, as well as how the handling of information and communication processes surrounding these activities are carried out. Also, there is generally a constant drive within organizations to achieve improved business performance through introduction of new routines, organizational changes and new technology. The awareness of the potential of new technical solutions and how these can complement and extend existing in-house information systems and ICT infrastructure is normally high, at least in some parts of a firm. Methods for ICT implementation and ICT project management are typically also well known. Still, time and time again deficient organizational and financial outcomes as well as maladaptation of technology are recurring results of implementation of new ICT solutions into existing business organizations.
Technically, mobile computing is nothing revolutionary. For the specific business context of this research project, it is simply about using commodity mobile and wireless ICT to extend existing information and communication resources to the production environment of the construction site. The whole concept is driven by the anticipation of being able to improve quality of work and business performance, as well as deliver the full potential of existing information systems and communication tools by making them more mobile, flexible and adjusted to construction site operations. Nevertheless, a scratch on the surface of this seemingly insignificant technical matter, a vast field of organizational, social and cultural issues arises that is far from trivial. This results in a highly complex socio-technical introduction and adoption process that needs to be managed accordingly to be able to achieve a successful outcome.

The overall question for the ongoing research project is what are the difficulties of successfully introducing and adopting mobile computing business support in a project organization? Three general themes have been identified relating to the concept of usefulness, benefit and the management of the implementation process. The discussion throughout this essay and the included papers will highlight and reflect on these themes relating to the above question.

**Research approach**

The first six months of the research project, October 2004 – March 2005, consisted of a literature study. The purpose of this literature review was to learn more about the business dynamics of the construction industry, and specifically its issues concerning information management and project communication at production sites. The objective was also to establish a picture of the potential for mobile computing in construction, based on previous pilot projects and feasibility studies. The results of that research are presented in the included papers.

During this period the research questions were refined, and it became quite clear that some sort of a real life case study had to be carried out to avoid that the research project would become an academic dry run. In the beginning of May 2005 the Swedish construction company Skanska AB was approached in the anticipation of establishing a research collaboration with them relating to mobile project communication in production environments. Skanska were positively inclined to the rather vague early research proposal. An opportunity was given to conduct an initial case study at the construction site Gamla Filmstaden, a large residential housing project in northern Stockholm, during the fall of 2005.
Gamla Filmstaden represents in many ways a typical large long-term construction project at Skanska. Through daily observations of the production operations at the construction site a broad picture of issues concerning information management and project communication in such a characteristic environment could be established. The observations consisted of being out on the site following the developments of construction activities and on-site communication and collaboration, as well as taking part in production meetings listening to discussions of construction issues and project planning. Observations were written down as they occurred, and at the end of each day these observations were summarized and reflected upon in daily journal notes. The first person observations at Gamla Filmstaden was complemented with additional project documentation such as official production plans, procedural guideline documents, blueprints, protocols and contractual information. The initial purpose of the study was then to examine how observed deficiencies could possibly be improved with mobile computing technologies.

Some case study researchers argue that there is a formal way of conducting case study research (Yin, 2003). The standpoint of this research project is that a case study is not a methodological choice, but a choice of a study object that can be examined in many ways (see Stake, chapter four in Denzin and Lincoln, 1998). The empirical approach of this research project embraces an eclectic case study design that emphasizes understanding and learning from the specific case at hand, rather than generalizing beyond. The view is that the case study researcher along the way freely can choose and combine several kinds of different methods as long as it creates improved understanding of the case. A case study often contains a substantial narrative element that depicts the complexities and contradictions of the studied real-life environment. A broad and hard-to-summarize narrative is not a dilemma; it is often a sign that the study has uncovered a rich complex of problems. Summarization and generalization, which some of the critics of case study research see as an ideal, is not always desirable (Flyvbjerg, chapter 27 in Seale et al., 2004).

The overall research approach that filters through this research project is to learn from the real-life experiences. If generalization on a theoretical level cannot be realized, improved knowledge and higher understanding of the research topic will be achieved anyhow through the findings of the studied case. Theoretical concepts only play a supportive role to be able to give further explanations and add new perspectives to what is observed in the case study. It could therefore be considered as a rather pragmatic research approach where as long as the message of the research gets through and the observed processes are credibly depicted and explained, the theoretical concepts is of secondary importance. The empirical approach has a narrative perspective and is driven
by a broad problematic issue and the various questions and concepts surrounding it. The complex of problems and the research questions develops and becomes more determined as the case study evolves. This process of refining the complex of problems of a case is often called progressive focusing (Stake, 1995).

At Gamla Filmstaden, the main case study method was participant observation which has deep roots in social science research with the Chicago school in the 1920’s through the 1960’s as the main contributor to its development (Fangen, 2005). The method is often associated with the profound cultural and social studies of ethnography. This broad and rather pretentious research approach is not in the frame of reference for this research project. The main standpoint of the participant observation method is that there is not enough to have knowledge about a certain matter, the researcher also have to get to know it through experience. The method highlights the importance of first person observations of developments, processes and situations. Participant observation is a very suitable collective method for the described approach of this research project. The term participant observation says more about the researcher’s way of working rather than focusing on the conceptual positioning of what a case study or field work constitute. Participant observation as a method is simply about balancing the complex role of being among people and participating in their interaction, at the same time as the very same people and processes are being studied and observed (Fangen, 2005). The scope of participant observation imply that the researcher is moving on a scale ranging from pure observation to just participation. There are problems associated with both extreme points of this scale. As a pure observer there is a risk of that the researcher will become a passive bystander that does not fully grasp the processes occurring or understand the communication between people. A pure participating role, on the other hand, involves the risk of ‘going native’ with the study or that the researcher is actively influencing and changing the studied environment (Fangen, 2005). This intervening approach is normally not a part of the participant observation method; it belongs more in an action oriented research process.

The described research design at Gamla Filmstaden early on showed problems of getting too close to the environment that was studied, or ‘going native’. Also, there was an obvious risk of taking on an engineering role where the researcher is proposing new solutions for improvement. The research task could then become an evaluation of the own accomplishments in the studied environment, which is somewhat ethically problematic to say the least. Fortunately, that original research concept at Gamla Filmstaden was not realized because another innovative development process at Skanska was discovered that related strongly to the topics of this research project. In the fall of
2005 the corporate management of Skanska initiated a company-wide project concerning mobile ICT tools to improve the performance of projects and specifically production sites. Skanska’s mobile computing project and the ongoing case study of that endeavor is further described and discussed in chapter three.

With the newfound circumstances at Skanska, the case study changed direction. The now ongoing case study of the company’s mobile computing project is not as intense and the one conducted at Gamla Filmstaden. The current study mainly consists of participating in project group feedback meetings represented by both technical developers and users, listening and taking notes on various aspects and perspectives of the mobile computing venture. A technical solution is eventually going to be tested in full production at various construction sites in Sweden. At that point the degree of engagement of the case study will increase again. The researcher role will then become a daily observer of the introduction and use of the technology in the construction site work environment.

To strengthen the reliability and credibility of studies based on participant observation and to get a nuanced picture and additional perspectives of the study findings, the method is often combined with *unstructured detailed conversations* and *semi-structured interviews* with involved individuals and groups of people (Fangen, 2005). So has been done in this research project. This has included semi-structured interviews, meetings and longer conversations with involved persons about arisen themes found interesting for the study. The interviewed persons have been personnel employed in production and business support units on different organizational levels at Skanska.

One final methodological consideration. The overall framework for this research project could be regarded as a *process-oriented* approach. Process research is focusing on capturing data directly from an ongoing process through which development and change occurs (Poole et al., 2000). In other words, the research is carried out where the action is and it is ‘the event’ that are the basic unit of analysis. Even though process-oriented research often seeks generalization, the conceptual framework of the process approach is still useful because it seeks to explain how change emerges, develops and diminishes over time. This includes narrative exploration relating to multiple models of change to identify and understand developing events, interaction between individuals and groups of people, technological and organizational change and innovation processes. As will be described in the next chapter, the dynamics of mobile computing implementation is the process that is the primary object of study for this research project.
2 CONCEPTUAL REFLECTIONS

The papers included in this thesis deliver a rather theoretical view of the management process of introducing mobile project communication tools in the construction site production context. As described in the papers, the technical installation process itself is certainly not rocket science. Still, why is it so difficult to succeed in such a venture? This chapter starts with establishing the main themes of the included papers. A general framework is then presented that forms the conceptual basis for further investigation in this research project. The framework highlights and discusses the concepts of usefulness, benefit and implementation, and why these are some of the central issues for successful mobile computing adoption in the construction site production environment. The interested reader preferably looks through the papers before continuing reading this chapter.

Paper work

Paper I is written at an early stage of the research project and takes a broad view on the introduction process of mobile computing at construction sites. The paper describes the reactive nature of building site operations, the important role of informal communication in construction projects and the lack of appropriate ICT to support the collaborative production processes. It highlights the socio-technical bottom-up perspective of implementing mobile computing at construction sites, which 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 and performance of work. The paper recognizes three organizational levels that require different perspectives and approaches to successfully introduce and adopt mobile computing: the individual, the project and the corporate level. Meeting the specific needs, behaviors and realizing user acceptance of construction site workers at the individual level, understanding the gap of what is required socially within collaborative group work and what can be done technically with mobile computing at the project level, and bridging separate perspectives and directing the overall innovation processes at the corporate level is the basis of successful multilevel management of the mobile computing introduction process.

Paper II takes a closer look into the dynamics of the technology implementation process itself. This paper highlights the socio-technical user-oriented approach of creating technological-organizational fit through system usefulness to realize long-term benefits of the mobile computing technology. The implementation process is described as the continuous struggle to align the technology with its social and cultural business
environment. This demands extensive involvement by the supposed users in the development process and the full understanding of the operational business context that is intended to be improved. The important role of key users in the implementation process is emphasized. These so-called champions are construction site personnel that have the ability to function as ambassadors of the technological change. They are the link between the construction operations and the ICT development team for bridging the sometimes differing perspectives to be able to realize a fitting mobile computing solution. The paper also briefly addresses the evaluation practice for mobile computing implementation. The technology evaluation should be designed and conducted as an ongoing integrated monitoring process throughout all phases of the implementation lifecycle.

*Paper III* further develops the initial ideas of evaluating mobile computing presented in paper II. In this last paper of this thesis the difference between benefit and the broader concept of value of an ICT investment is described. The benefit of mobile computing is connected to the improvements of specific operational business activities that the technology contributes to. The collective set of business activity benefits can in turn generate various types of improved operational, tactical and strategic business value. The corporate management perspective often strives for immediate financial benefit and value of an ICT investment. But this narrow focus on hard benefits can give rise to harmful technological shortsightedness that leaves out the less tangible benefits of the technology that enables long-term innovation benefits for the business operations. The paper stresses the need for an integrated evaluation method for evaluating innovation benefits and business value of mobile computing in construction. Such an evaluation framework should include a limited number of performance measures with a mix of short-term and long-term goals, with both quantitative financial and qualitative intangible measures of organizational benefits.

**The importance of usefulness**

The usefulness perspective comprises the adjustment of a technology to an existing user context. The specific concern for this research project is how mobile computing tools should be designed to improve the performance and quality of work for construction site operations. In this sense usefulness can be described as the balance between the formal use, structure and functions that is embedded in ICT systems technology and the complex fluid and social nature of on-site work practices and collaborative activities. Whatever technology implemented in this organizational context, it should serve and enhance its business activities and not the other way around. Research has shown that the necessary
user perspective for accomplishing this is often marginalized or even abandoned in ICT system development (Boivie, 2005).

Usefulness should not be confused with ‘ease-of-use’. Usefulness is not just about where buttons and icons are localized on the screen; it includes both utility and usability aspects and is about making the technology fit the organization, its business activities and specific work routines. This is illustrated in figure 2.

Figure 2. The effects of system usefulness (inspired by Nielsen, 1993)

Many existing ICT-based business information systems may have an initial outline that is conceptually right, but the problem is often that they are not properly designed from the user’s point of view. If the systems do not make individual users’ job situation better and are practical tools in their everyday work, there is a risk that this will create obstructions for work activities and that the full potential of the systems are not utilized. Likewise, there is a risk that mobile project communication tools for construction sites may become an end in itself if the usefulness perspective receives low priority. Making existing information systems and communication tools portable and instantly accessible through mobile computing poses new questions on both the user interface between the technology and the individual operator as well as the practical application of the ICT tools in the work organization and its specific production activities.

It is of great importance to develop a robust knowledge of the business processes that the technology is aimed to support, and an understanding of the needs of the intended users
in order for the mobile computing system to be accepted and utilized effectively. From
the user perspective mobile computing should enable improved administration of
construction activities, as well as facilitating effective tools for communication with other
project participants and involved actors. So the utility aspects range from individual work
routines to the project communication context as a whole. In addition, the mobile
computing platform has to be delivered through a user interface with low personal cost of
communication. The use of the ICT should not be conducted at the expense of other
activities such as social collaborative processes, business practices and transactions or
project management and leadership. Mobile computing tools must be designed in such a
way that they fit the existing construction process and work practices, rather than to
disrupt them. If the technology does not serve and enhance these processes, it will be
considered as an obstructive element for effective construction operations and project
delivery. Therefore the technology has to be intuitive and effortless to use to be able to
create the necessary everyday usefulness and acceptance of the intended user.

When discussing usefulness of mobile computing in construction, inherent cultural
aspects of construction project communication that cause intricate collaborative issues
between different work practices and professional groups have to be considered. These
issues are often shown in the form of a constant struggle between involved project actors
of who is controlling and owning the information (for a more thorough discussion see
Söderholm, chapter two in Wikforss, 2006). This struggle will not be solved by new
mobile and wireless ICT, but fitting technology can assist in bridging the cultural
differences through creating improved transparency of project information and increased
understanding between contradicting professional viewpoints. This implies a cultural
dimension of usefulness which is about facilitating shared synergies for all project actors of
improving the clarity of project communication practices. So, the usefulness of mobile
computing at construction sites can also be regarded as an endeavor of creating a more
equal project communication process between all involved parties. Making project
communication more transparent inevitably means that some project participants that
have an advantage of power over the communication today will have to give up some of
their control over it in the future in favor of other actors. The improved information clarity
that mobile computing can bring consequently involves a disturbance of the present
power balance of the information and communication processes between project
participants and professional groups. Therefore, creating usefulness of mobile computing
also implies an appropriate handling of the disbandment of limiting political information
and communication boundaries within and between organizations and their business
activities. This is essentially about creating mutual understanding between work practices and
professional groups of how technology and project communication practices should be
designed and conducted to be beneficial for the performance of the project as a whole, instead of instruments of power and control for certain units, organizations or professional groups.

The construction industry in general has been accused for being a slow adopter of new ICT tools, and that the construction site environment has a conservative culture towards technical change. But it can be questioned how well ICT systems implemented is the past have been in line with usefulness requirements of construction operations. If properly designed mobile ICT tools are introduced, that enables explicit benefit to the individual users in improving their everyday construction operations, will the adoption and use of the technology really be an issue or will it be an intuitive process among the users of recognizing and appreciating the technology? The true quality, utility and value of the mobile computing technology can only be judged when it is actually put into use and tested; the proof of the pudding is in the eating.

**The scope of benefit**

The benefit perspective is of course central when organizations and firms invest in and implement new technology. But benefits do not materialize by themselves by simply introducing new technical solutions. Organizations have to consider how they should use ICT in their business processes and have an overall idea what the technology is supposed to improve. Simply having increased computing power and functionality will not automatically result in improved communication practices. It is through finding new ways of utilizing technology in the specific business operations that makes improved ways of working possible and creates long-term innovation benefits of business processes. Construction is the business activity, ICT is only a supportive tool. Wirelessly bringing e-mail or general internet connectivity to the site hardly adds any additional business support. The benefit of mobile computing should focus specifically on improving the actual construction activities and its surrounding business processes, developing the current way of communicating, administrating work and collaborating with other project actors.

It is important to keep in mind that the benefit of mobile project communication is different on separate organizational levels. The creation of benefit of mobile computing in construction has to be considered from the bottom-up perspective. This starts with the identification of specific construction site activities that calls for improved information and communication support. This may include procurement of equipment and material, on-site work audits and reporting, administration of meetings and collaborative problem-
solving of construction issues. The improvement of many of these activities belongs to
the more intangible benefit category. These benefits are often hard to measure, but there is
no doubt that they are actually contributing to the increase of business performance. If
these operational benefits are not identified and pursued, the foundation for creating
benefit, value and strategic business development on higher organizational levels is lost.
So, the generation of long-term benefit of mobile computing starts with addressing the
individual end user perspective and its specific work context. The benefit perspective is
therefore closely related to the usefulness of the technology. Fulfillment of the usefulness
criteria is the foundation for developing a culture of acceptance of ICT innovations in the
project organization, which is the basis for widespread adoption of mobile computing
with resulting benefits and business value creation for the construction process as a
whole.

The value-generating chain of usefulness-to-benefit is of course also strongly linked and
determined by the specific system design of the technology and the particular operational
production setting in which it is introduced. Case-by-case studies are required to carry out
a more detailed mapping of the explicit benefits to be identified, pursued and generated
on different levels within an organization. Such investigations are the only way to be able
to understand the unique dynamics of the introduction and adoption of the technology in
a specific business environment, and its complementary socio-technical improvement
potential. This is exemplified and further discussed in the presentation of the ongoing
case study in chapter three.

The art of implementation

Technology implementation is the highly complex process when technical, organizational
and financial resources are configured together in the attempt to provide a purposeful
operational system. The implementation process of mobile computing at construction site
operations is not just the installation of mobile wirelessly connected handheld computer
devices. It involves a complete bridge between technical development and its adoption
and use, where the continuous adaptation process for aligning technology and organization
is the central issue. Technology implementation is characterized by a trial-and-error struggle
to coordinate and enhance the system of technical, organizational and social factors
involved. It is about recognizing widely differing perspectives and intentions of
introducing the technology and finding new innovative ways of bringing them together,
creating mutual adaptation and reinforcement.
Like the construction process itself, mobile computing implementation comprises a struggle between an intentionally shaped ideal design concept and what can be accomplished in reality delimited by the social, technical and organizational production context. This process starts with an initial mobile computing design and conceptualization of what is sought to be accomplished in the end. The technical concept is then introduced in the specific work environment. The early technical solution is commonly not aligned with individual operational activities or with higher level business processes. This calls for adjustment and adaptation of the technology to make it more aligned with the organizational context that it is supposed to serve and improve. A sound technology implementation process therefore recognizes the cyclic pattern of:

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\text{design/ modification} \rightarrow \text{introduction/installation} \rightarrow \text{utilization} \rightarrow \text{evaluation}.
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As already been mentioned, managing the implementation process is a problematic issue. But in that case, what is the underlying cause of this alleged difficulty? The interview material of this research project shows that ICT developers often do not regard technical matters as challenging concerns in the implementation process. They consider getting the users to actually adopt and appreciate the ICT tools as the main problem. Interviews with construction site users on the other hand reveal that they often feel neglected in the ICT development process, with the result that they experience that misaligned ICT systems are pushed out to the production environment. So the root cause of the problems associated with implementation can be partially explained by the conflicting views of what the technology is supposed to contribute with, and deficient communication between developers and users.

The research so far has identified the implementation process itself as a key information source for obtaining improved understanding of the interdependent and reinforcing concepts of usefulness and benefit of mobile computing in an existing business context. Implementation can be considered as the enabling force for communicating and aligning different professional and organizational perspectives of usefulness and benefit. This is important to be able to identify and satisfy diverse needs, demands and objectives for the involved parties in the technological development process. By studying the multifaceted dynamics of implementation new knowledge about the management of its intricate socio-technical processes can be gained. Therefore, the handling and the evaluation of the wide-ranging implementation process of mobile computing in the operational project environment is the primary study object of this research project.

If managed correctly, the implementation process can enable the creation of direct usefulness at the operational level as well as make sure that benefits and business
enhancing processes are distributed through the project organization and more long-term performance improvements is generated that is measurable for corporate government. This is a continuous introduction and adoption management process aiming to find a synergetic compromise that is sufficient for all benefit criteria on different organizational levels. This process may be entitled learning, adaptation, innovation or, whatever. In this research project it is called the *art of implementation*. The term ‘art’ is implying that it includes both a creative *artistic* dimension of designing an appropriate technical system solution, as well as the *skill* of introducing and adapting it to the specific organizational context. This means that there are actually good and bad arts of technology implementation. This research project studies some of the components that constitute the art itself relating to the achievement of usefulness and resulting benefit of mobile computing at construction site operations.

By now it should be quite clear that this research project highlights the significance, characteristics and interdependencies of usefulness and benefit of mobile computing, and that implementation is the facilitating process for reaching multidimensional objectives relating to these two concepts. Looking specifically at the dynamics of the actual implementation process, it can be described in more generic terms as a process of change aiming at improving a certain set of activities, its traits and organization. Change processes are often explained through four basic models of change (Poole et al., 2000):

- The *life cycle* model is characterized by linear and irreversible sequence of prescribed stages in unfolding potentials present at the beginning of the change process. Normally this type of change processes has a prefigured program or rule regulated by nature, logic or institutions.
- The *evolutionary* model of change consists of a repetitive sequence of variation, selection and retention events among entities in a designated population. The key metaphor used in studies of this type of change processes is the natural selection based on competitive survival.
- The *teleological* model is based on the assumption that development proceeds towards a goal or end state. According to this theoretical perspective entities of change are purposeful and adaptive. These entities, by themselves or in interaction and cooperation with others, construct an envisioned end state, take action to reach it and monitor its progress, often in a recursive cyclic pattern.
- The *dialectical* model uses conflicts and confrontation between opposing forces or different interests as the generating force for change processes. It uses the theory of thesis and antithesis in order to achieve synthesis as the main explanation for change. Recurrent sequence of confrontation conflicts and synthesis between contradictory values or events lead to change.
These general change process categories can be considered as ideal types and they describe different motors of change driving a certain path of progress forward. However, real life change processes comprise a higher level of complexity and combinations of these ideal types will better depict ongoing technological and organizational change processes (Poole et al., 2000).

When considering the implementation process of mobile computing at construction site operations, all four models of change are useful to be able to uncover as a complete picture as possible of the implementation dynamics. The first three change models described above are fairly natural to fit in with the discussion so far. The life cycle approach is often used for describing technological innovation processes. The notion of following a technology through different stages of its development and how it affects the context were it is adopted and utilized is commonly used in innovation oriented research. So is the evolutionary approach, which stresses the incremental nature of technological development and its progress based on a natural selection of a satisfying technical solution by the social and organizational context. The teleological model is of course also applicable when studying the implementation of construction site mobile computing. The idea that the cyclic implementation process is striving towards a defined final objective is what triggered the search for the improved technical solution to begin with. Although, the question is if there really is an end state of such an initiated change process? Things can always be improved.

The dialectical model of change is highly interesting for the defined scope of this research project. The confronting view is necessary for describing the intricate and often conflicting social, organizational and cultural dimensions that drive the progress of the implementation process forward. The development and implementation process of ICT systems in an organization is a socio-technical task that inherently includes political dimensions (Mähring, 2002). It can be used for many other purposes than the effective and efficient introduction and adoption of an appropriate ICT solution. The result of the implementation process both reflects and reinforces the social and organizational context. As already been emphasized, implementation is the enabling process for creating usefulness, and identifying and evaluating its resulting benefits and business value. Managing implementation correctly will facilitate a complete bridge between usefulness and resulting benefit, linking the perspectives together and reinforcing their individual potential as well as mutual business value contribution. But there is another side of the implementation process that includes often contradicting organizational perspectives of usefulness and benefit. These perspectives have to be well-balanced to achieve successful execution. The contradicting standpoints can be described as a struggle between technical
development and usefulness versus usage and benefit value. The usefulness of a mobile computing system in the construction site production environment is a design issue for ICT developers and is accomplished through the insights from the site users’ needs and demands. The benefit of the technology is a multi-level result within the organization, but its fundamental creation is made through the individual users’ acceptance of the mobile computing system and how well it fits in their operational work context. This enables purposeful use of the technology that can result in increased business performance that is distributed throughout the company and between different organizations. The tangible financial business performance perspective is of primary interest for management teams within a firm. But the understanding of the full value-making chain from usefulness to benefit is generally not widespread among these leading individuals and groups of people. They often want results now. Metaphorically the implementation process can therefore be described as balancing and aligning the struggle between creating the appropriate long-term usefulness for the end user and the corporate drive for realizing benefits of the technology investment as soon as possible.

The socio-technical characteristics of implementation are also illustrated by the importance of having innovative and pragmatic key user champions in the operational production context. The champions play the vital role of being the link between technical development and the targeted user group. These persons are important to get other users acquainted with the technology and its possibilities. Through the champions a dialog between ICT developers and the proposed users can be established and maintained. This is the primary source of information to collectively be able to find appropriate work routines and discuss areas of utility for the technology, which can then be translated into fitting tools and applications. This hands-on user orientation of the mobile computing implementation process is essential for the usefulness perspective leading to technology fit and the acceptance of the system.

The conflicting socio-technical dialectical model of change and the importance of the key user champions in the implementation process are further illustrated in the case study presentation in the next chapter.
3 CASE OF THE ART

In the fall of 2005, during the case study at Gamla Filmstaden, another highly interesting technological change process at Skanska was discovered. It was a recently initiated globally oriented project concerning mobile information and communication tools that specifically addressed construction sites. This chapter presents the background of the mobile computing project at Skanska, and describes and discusses the ongoing case study of the implementation of the new technology at the company.

Setting the scene

In recent years, the Swedish construction company Skanska AB has recognized the issues of information handling and project communication of its on-site production operations. Regardless if these matters have been neglected by the company in the past or not, the appropriate mobile and flexible end user ICT for construction site purposes has not been available before. But this market supply condition has now changed. New mobile and wireless commodity ICT alternatives have enabled new opportunities for the addressing the issues involved.

Skanska’s recently initiated coordinated mobile project communication effort started at the company’s USA-based subsidiary, Skanska USA Building, with an individual creative initiative during a construction project at Duke University in North Carolina (Document management case study, Duke University CIEMAS project, Skanska 2005). The Duke University site staff evaluated their existing building processes in the search for new solutions of deficient handling of construction site work activities. Members of the project team began to investigate ways to improve field construction information by expanding the use of ICT onto the jobsite. In their evaluation, the team found that managing the physically overwhelming quantity of information that is passed to the construction site often generated poor quality of information in the field. As a result, construction personnel were forced to deal with slow issue resolution and rework due to construction errors. In the search to improve this situation, the project team combined several existing commodity wireless ICT with internally developed software to create tools to provide field based construction personnel with the same quality of plans and specifications found in the project management office to enable higher distribution speed of information. After the team implemented digital document management tools and practices, software tools were used to wirelessly synchronize the latest plans and specifications with tablet computers used by supervisors in the field. A tablet computer looks like a laptop computer without a keyboard, and is therefore thinner and lighter than a
regular portable computer. The main property of the tablet computer is that it consists of a screen with the size of an ordinary sheet of paper on which the user navigates with an electronic pen writing directly on the screen. The project focused on the management of plans and specifications used on the construction site. The targeted users were field supervisors and how their administration of construction site activities could be improved with the mobile tablet computer ICT platform.

As new systems and tools expanded, a champion was identified to help foster their development. The champion’s role at Duke University was loosely defined, but included training, support, and encouragement of the use of the technology by other members of the team. The champion started this process by replacing its own work routines with those possible using the new mobile computing tools. To help carry new ideas to realization, the champion together with the project manager expanded the relationship with a software consultant that initially deployed project web tools for the Duke University construction project group. This collaborative effort between the developer and the production management team resulted in improved understanding of the limitations of existing technology and the generation of new tools that were more useful to the construction site environment. As needs of the project evolved, so did the tools that were designed to meet them. The result was a growing ICT enabled toolset that could replace existing administrative on-site work processes.

In the production management team’s own evaluation of the test of the new ICT tools at Duke University, the users experienced improvements in their own personal productivity when equipped with updated project information on tablet computers. With the extra time generated, they were able to respond to a larger amount of issues in more detail to prevent construction rework. Once an issue was identified in the field using the mobile computing system, resolution of the problem by the project management staff avoided many of the traditional obstacles that delay responses including information and material distribution, issue clarity, and redesign and reprinting of drawings. With issues resolved quickly and returned to the field accurately, field staff was able to continue to work unhindered.

During the course of the tablet computer tests at Duke University it was noticed that the quality of the project could be further improved by also providing document management capabilities to subcontractors. Since subcontractors often represent the majority of plan and specification holders of a typical construction project, the ability to ensure they are using correct data is critical. This observation initiated a growing support and demand for digital document sharing and tablet computers by the subcontractors at Duke University.
The tablet computer document management project at Duke University showed tendencies of improved project performance by increasing issue resolution speed, reducing rework, allowing crews to maintain productivity and ensuring that construction quality standards were maintained. When issues were identified in the field, the use of tablet computers enabled supervisors to generate better documentation. Using document annotation software, they could clip a portion of a plan or other document, insert relevant photographs taken with digital or web cameras, draw sketches, and hand write explanations. With the presence of a wireless network on site, this information was transmitted directly back to the project management staff for review. The project also identified that with several existing software packages on the tested mobile computing platform, superintendents in the future could develop new administrative routines for digitally handwrite quality control forms, punch lists, daily reports and safety audit protocols directly on the tablet computer screen.

**Birth of a mobile platform**

In the late summer of 2005, the Duke University project team was awarded for the most innovative use of construction technology in the United States. The project showed that the combination of wireless networking solutions, mobile handheld user devices, new system applications and the array of existing office software tools in the field created new opportunities for improving on-site project management and supervision. The results and the media attention of the tablet computer project at Duke University received the awareness of the senior executive team of the Skanska group. In the fall of 2005, a global mobile computing effort was initiated and a coordinator was appointed to encourage that the technology is implemented, used and evaluated in various construction projects Skanska worldwide. The corporate management team requested that tablet computer tests were to be carried out in various kinds of production operations and building project types.

At Skanska Sweden, a tablet computer project has now been initiated by the northern Stockholm house building region and the Swedish ICT unit. As a joint venture between the production organization and developer support unit, the purpose of the pilot project is to find out if the tablet computer concept is useful for the Swedish construction site environment. The objectives are to identify how such a mobile computing platform should be designed and what its benefits are compared to the current way of working with construction data and project communication on site (Projektdefinition: Tablet PC, Skanska 2006). A mobile tablet computer concept is then going to be implemented and tested at three typical house building sites in Stockholm. Also, a parallel tablet computer
test with a similar approach has been kicked off at an industrialized building project in southern Sweden.

There are however, differences between construction work procedures in the United States compared to the Swedish construction site environment which separates the Swedish tablet computer approach from the American. The pilot project at Duke University focused a great deal on bringing drawings and blueprints out on the production site. In Sweden construction management personnel is more dependent on being online with various central information systems, such as procurement systems, activity based project management budget tools, and resource planning systems. Interviews with both ICT developers and the proposed on-site users involved in the Swedish tablet computer project reveal that the increase of mobility and flexibility of these existing information systems is considered as the foundation for creating future benefit of the site oriented mobile project communication platform. These anticipated production benefits will now be described.

The first category of benefits of the mobile tablet computer platform that the Swedish tablet computer project is hoping to achieve can be derived to the enabling of more effective on-site administration of construction activities through mobile on-demand wireless access to existing business information systems and construction project administration tools. The aim is to reduce inefficient paper work, make better use of human and material resources and create more flexible work planning, coordination and follow-up procedures. The idea is that with the wirelessly connected tablet computer the procurement system can be brought up on site and additional equipment and material purchase orders can be placed immediately as they are discovered. It can enable production management staff to be online with activity based project management budget tools on site when doing inspections and follow-ups of current and completed construction work. Environment and safety rounds, deviation reports and other inspections can be filled out on site directly on the tablet computer in digital forms and templates using the electronic pen and then upload them on shared project storage areas or e-mailed to the concerned project participants. One interesting usefulness aspect of the tablet computer concept seems to relate to the procedure of working with a pen directly on the tablet computer screen. This appears to be an intuitive user interface because construction management staff is accustomed to using pen and paper on site doing inspections, documentation of activities, and taking notes on purchase orders and other on-site administrative work. With the tablet computer, the idea is that these administrative duties are supposed to be carried out once only, at the time of occurrence. This way of working could also include many of the administrative tasks in the site office. Meeting
notes can be taken directly with the electronic pen on the tablet computer. Using the built-in tablet computer text recognition tool, the notes can be translated into an ordinary data text document when the meeting is over, which directly can be distributed via e-mail to project participants.

The second category of desired improvements relate to the enhancement of real-time risk management and collaborative problem-solving in construction projects through mobile multimedia information exchange between construction site personnel, expert teams and other project participants outside the production environment. The test users of the Swedish tablet computer project have for example themselves identified the potential of the combined use of the tablet computer and a digital camera on site. By photographing observed construction problems, the photographs can then immediately be transmitted between the camera and the tablet computer via short-range wireless connection and attached to site inspection reports. The construction issues can be further described using the tablet computer electronic pen to highlight pictures and other parts of the document, before sending it to the project participants concerned. In this way the distribution speed, information quality and understanding of production issues communicated to involved actors can be enhanced. Ideas of using web cameras and videoconferencing software to enable real-time collaborative problem-solving with technical expert teams and other actors outside the construction site setting have also started to emerge in the project.

The third category of benefits considered in the project is associated with facilitating improved on-site presence, involvement and leadership of production management through making information management and project communication mobile. The objective is to change the current situation of construction management staff being tied-up at their computers inside the site office, or running back and forth between their computer desk and the site. Creating improved on-site management of construction site operations was the starting point of the mobile computing effort at both Duke University in the United States as well as at Skanska Sweden. The basic idea is that on-site leadership and coordination of project resources can be improved if production management’s ICT-based business support is made portable.
Case discussion

The tablet computer project at Skanska Sweden is still in the conceptualization phase of finding and testing different requirements, features, applications and work routines of the technology. The overall concept that drives the progress of the development process forward is the intention of delivering a complete information management and project communication platform for the business activities surrounding construction site production. The pilot project tries to identify a general ICT platform concept that delivers the mobility, flexibility as well as robustness that the construction site requires. The platform is targeted towards production management personnel and the idea is that when they are on site they are wirelessly online to the company network, extended from the site office via wireless access points. In the site office they can use the tablet computer as an ordinary computer using a docking station with keyboard, mouse and bigger screen at their own desks, as well as connect wirelessly elsewhere in the office, for example during project meetings. Both the ICT staff and the targeted construction site users involved in the tablet computer project are striving towards getting closer to a single fitting and versatile computing solution for the production environment, instead of the fragmented and disrupting ICT environment that the construction site is experiencing today.

The current case is a highly interesting object of study for the issues raised in this research project. To begin with, the mobile computing effort initiated at Skanska does not seem to have the one-off character that many ICT projects in construction enterprises have had in the past, Skanska is no exception. Many of these projects have been private initiatives in individual construction project organizations. Technology keen project managers often initiate these new ICT ventures, more or less for the fun of it all. Typically these projects are fairly uncoordinated, poorly documented and have in the end lead to nothing. The problem of this recurring pattern of formless local ICT projects is that lots of financial, technological and organizational resources are spent on testing new systems and practices, and no knowledge of its success or failure is gained or distributed to the rest of the organization for learning and further development. The whole learning process of incrementally separating effective technical concepts from inadequate ones for the production environment is therefore lost.

The tablet computer test at Duke University started as a bottom-up project where people in the production management team had ideas of how to satisfy the ICT needs in their own job situations. These ideas have then reached all the way up to the senior execute team of the Skanska group, and now there is a risk that the continued development gets a top-down perspective where inappropriate technical solutions are pushed out to the site.
users. But this matter is also a question of balance. The approval and authorization from the top management of Skanska is a prerequisite for achieving long-term benefits and goals of the mobile computing venture (this is also stressed in corporate internal guidelines for development projects; Process for selecting and implementing ‘integrated information systems, Skanska 2003, and Programhandbok, Skanska 2005). On the other hand, a too narrow focus on achieving immediate results urged by the corporate management will most likely lead to negative consequences on existing work routines and job performance.

The agenda that the corporate government might have may not only include the pursuit of hard financial benefits of the mobile computing investment, it is likely to have image-making purposes too. During the last decade the construction industry has tried to develop and publicly communicate a new image for construction. This involves the ambition towards making construction business less craftsman-like and more contemporary and industrialized. Skanska, as one of the top ten largest building and engineering firms in the world (Engineering News-Record, 2005), is trying to distinguish themselves on the global arena as a leading and innovative construction company in order to attract new customers, more profitable projects and competent, motivated and hard working employees. If the tablet computer project is considered by upper management as a venture for receiving attention from media and industry partners and strengthening the brand of the company, rather than improving the operational production environment, then it can lead to unfortunate results for the long-term usefulness and benefit of the technology.

The same unfortunate result could occur if the balance of decision influence between the ICT unit and the production organization is unequal. In those cases there is a risk that ICT developers are making up their own idea of the practical problems at hand and creating technical solutions that are not adjusted to the construction site production environment. This kind of behavior often involves an intricate political dimension within the company; business support units may try to justify financial claims or even their own existence by initiating new ventures instead of serving the revenue making organization, which is the building projects in the case of construction companies.

The result of these differing political agendas of ICT development and implementation within an organization is often that new ICT systems repeatedly becomes severely misaligned on the individual user level. This failure of over and over again not recognizing the operational context in which the technology is going to be used often leads to a negative attitude towards implementation and use of new ICT among the users in the organization. If the level of user acceptance was low to begin with, this will eventually undermine the
culture of technology adoption in the organization totally. So the struggle facing Skanska is the balance of objectives and political agendas of corporate management, supporting staff functions and the operational user perspective to achieve a successful strategic outcome.

So far the mobile ICT project at Skanska Sweden has managed to balance these issues successfully. It was initiated as a global change process, coordinated from representatives of the top management of Skanska, but it tries not to be a project that pushes inefficient technical solutions into the hands of the construction site personnel. Instead, the approach so far has been to listen to the information needs and communication demands of the production environment and trying to translate that to appropriate mobile project communication tools. The tablet computer project has emphasized the important role of getting the users of the technology involved in the development and implementation process from the beginning. Getting the appointed key user champions and pilot test persons acquainted with the technology and let them explore, figure out and explain potential usage and application areas of the tablet computer for the development team is a central approach of the project. This integrated socio-technical teamwork process emphasizes the dialogue and collaboration between the proposed construction site users and the ICT staff at Skanska to be able to translate practical on-site communication issues into useful ICT tools that generate improvements. The essential source of information is obtained through the frequently occurring feedback meetings in which both users and technical developers are participating. During these meetings the key user champions and the other test users can describe how they are using the tablet computer, for what purposes and in what situations. This information can then be used to identify positive and negative effects of specific tablet computer applications and user interfaces as well as the effects of the use of the technology in general in the production setting. Skanska Sweden has an intranet-based construction project management procedural system that contains administrative tools, documents and routine descriptions. This supportive construction project management framework is called ‘Vårt Sätt Att Arbeta’, VSAA. The tablet computer project tries to find new ways to co-develop VSAA administrative work practices together with a more suitable technical approach to improve organizational routines as well as the usefulness and benefit of administrative ICT tools for construction operations. This reveals a long-term strategic perspective of partially changing the current ways of conducting business, and matching this with an appropriate and sustainable technological solution with mobile computing as a main facilitating concept.

The described way of collaborating and communicating within the tablet computer project group also enables the vital mutual understanding between production site
personnel and the ICT support unit within the company. ICT developers will enhance their knowledge of the complexity of introducing the mobile technology in the construction site setting, and may realize that their conceptions of the information and communication issues in the production environment as well as the needs and demands of the construction site personnel are somewhat simplified or incorrect. The construction staff user on the other hand may understand the possibilities of the new technology and develop a positive attitude towards adopting new ICT solutions that is actually improving their work. The users may also be able to better comprehend how the existing ICT based business support systems work, how they are designed, why they are constructed and integrated the way they are, and how and why this determines the possibilities and delimitations for further development of new ICT tools. This form of technological path-dependency or technological trajectory that is both enabled and restricted by existing capabilities, processes and circumstances is common in any development process within an organizational context (for further discussion of these mechanisms, see for example chapter five in Tidd et al., 2005).

From the ICT perspective Skanska Sweden is striving towards a service oriented business support platform that enables flexible system architecture for supporting different needs and demands of the organization (Nulägeskartläggning – ‘tillhandahåll IT’ processutveckling, Skanska 2005). Interviews with ICT unit staff at Skanska reveal that there are two main technical components missing for the realization of that concept; a centralized document management system and a personalized presentation layer through a user portal tool. These issues are critical to resolve to achieve full generic access, mobility of data and individual adaptation of information and communication resources (see figure 1, page 6). The existing limiting technical factors can prevent the realization of appropriate construction site mobile computing practices through the tablet computer platform.
4 THE ROAD AHEAD

A well functioning development of an industry involves both radical and incremental changes, both on the social organizational side as well as technological aspects. The challenge is handling these change processes to make it work in a coordinated fashion. New changes, large or small, introduced in construction will probably not turn into an immediate success. Tweaking both organization and technology will be necessary to achieve an appropriate configuration. The pieces of the puzzle do not fit together from the beginning and it is through the continuous trial and error process of implementation that eventually will lead to a configuration of technology, business communication processes, work practices and organization that is acceptable and good enough. This involves large and small parallel configurational changes on many organizational and technological levels.

There is a general drive in the construction industry towards the development of an industrialized building process in the anticipation of achieving faster completion of construction projects and radically decreased production costs. One of the ideas of the industrialized building concept is to turn the current construction sites into assembly sites that require less human and material resources. So far there is little evidence that these lean production methods are in fact creating the expected benefits and improved performance that many construction companies are hoping for. Also, the industrialized building projects comprise only a fraction of the turnover of the construction enterprises today, which make these projects more image-making cutting-edge products towards customers and competitors rather than important business cash-cows. In the short run, there is of course more benefit and performance potential to improve the existing processes of construction practice instead of focusing on new systems of building.

The Skanska group has a general corporate development strategy that is based on two parallel overall change processes (based on Skanska operational risk assessment model, Skanska 2004; Kommunikationsplan, Skanska 2005; Annual reports, Skanska 2004 and 2005). The first process involves improving performance in existing business activities. This has a focus on improving efficiency, productivity, risk assessment and construction quality of construction projects through development of better work routines, use of new materials and technology and improvement of business support functions and tools. The second overall business change process targets the development of a significantly more efficient construction process in the future. This primarily evolves around ideas about industrialized manufacturing processes and lean production methods applied to a construction context, with the car industry as the main role model. This includes for example centralized electronic
purchasing and prefabricated building systems. These two development processes within Skanska actually have somewhat contradicting purposes and goals. The company is trying to enhance performance and quality and reduce risks in its existing business processes by improving work routines and introduce new technological solutions into the production environment. At the same time, Skanska is trying to introduce an industrialized building process with flexible prefabricated building systems, slimmed organizations and production teams. Looking at it from a short-term perspective, this is the opposite direction of refining and rationalizing the current way of doing business. This development path introduces increased risks and start-up inefficiencies of new design and manufacturing processes, changed work practices and new ways of organizing and completing projects.

Nevertheless, this industrial development process is almost inevitable. The general industrialization concept involves all the continuous and discontinuous processes of achieving higher degree of maturation, rationalization and sophistication of an existing industry. In this ongoing development the construction sector has highlighted the importance of prefabricated building systems. These ideas of an industrialized production process are certainly not new. Already in the 1930’s Foster Gunnison introduced these concepts and was looked upon as the ‘Henry Ford of housing’ (Hounshell, 1984). But these production techniques have so far not shown considerable performance increase compared to the traditional way of construction and comprise only a peripheral business activity in larger construction companies. Ahead, it is likely that the focus on the development of the prefabricated building processes will be complemented and nuanced with other less disruptive technological and organizational improvements. In this way, the industrialized agenda of the construction industry will be linked together and co-developed with current construction project practices. Consequently, the concept of what really could be called an industrialization of the construction industry and the evolution of the construction process will always be regulated by the constraints of the site-based production (Dainty et al., 2006). Further development of project communication practices and improved on-site coordination of production activities will be fundamental prerequisites to be able to drive the industrialization process forward. The question can therefore be raised if the construction industry partially is focusing on the wrong things in this development process?

Mobile computing production tools could be looked upon as one of many small contributions to achieve rationalization of the existing production process. These changes initially affect the methods for administrating and communicating construction project data at the individual operator level. But in the bigger perspective it also contributes to the
industrialized development process leading to a more effective construction industry as a whole, whatever the concept industrialized may imply in building projects in the future. This aspect of mobile computing involves finding new concepts and solutions for enabling improved real-time problem-solving, collaboration and exchange of project data in the reactive construction environment, contributing to sort of an industrialization of project communication in the same way that the industry want to go from a handcraft to a manufacturing production paradigm. Performance improvements of construction projects are delivered through effective collaboration between the parties involved. Effective communication is the prerequisite of any attempt to change the ways in which the industry operates. The improvement of project communication processes may change the organization of future projects and how its business activities and work routines are designed, planned, performed and follow-upped. This can result in the just-in-time deliveries and the more industrialized and rational business processes that the construction industry in fact is striving for. Mobility of data, on-demand access of information and enhanced communication tools at construction sites could be important components of this development process. The full recognition and determination to improve collaborative communication and information exchange will probably have considerable effects on the industrialization process of construction projects. Getting the construction sites up to speed with the rest of the project phases is starting to become a focal point for the construction industry. That is a welcomed change of attitude in a project based industry that historically has seemed to have taken appropriate project communication practices for granted.

The continued focus of the research project will be on the incremental improvements of project communication processes at construction sites through mobile computing tools and applications. The management of the socio-technical implementation process to create the necessary usefulness for the individual operator at different levels of a production organization will be the primary focus for further research. Identifying and evaluating the benefits of the technology will be key issues in this implementation process. The research project will also continue to study how mobile computing project communication tools fit in as a component in the wider long-term development perspective of creating a more industrialized and rational construction process.

The current case study at Skanska will be the continued primary source of input for the study of these research themes. The situation facing the company of properly balancing their mobile computing endeavor is of great interest for the research project. The initial setup of the tablet computer project described in the previous chapter indicates that it could result in either total success or complete failure. Through the discussion presented
in this thesis, a complex web of interdependent perspectives has emerged relating to the main concepts of usefulness, benefit and implementation. To conclude this introductory cover essay, a framework of issues for further research is outlined relating specifically to the continued case study.

As been highlighted throughout this thesis the usefulness perspective is at the core of the issues studied in this research project. It will be interesting to continue to follow the dynamics of the targeted users in Skanska’s tablet computer project and see how the composition of the user group will be changed over time. The project started with addressing the needs of management personnel at construction sites. Will that perspective be extended to include construction site workers in the future? In that case, what are their specific needs and demands? These questions relate to the fundamental issue of what the usefulness of mobile computing really consists of regarding both technology and people. There are probably separate information needs and communication demands on different organizational levels. For example, the view on the appropriate design of a mobile computing user device may be diversified among different kinds of construction site personnel because of their separate ICT needs to conduct their construction activities effectively. Once again, this stresses generic access, mobility of project data and individual adaptation of information and communication resources that have been advocated and discussed throughout this thesis.

The benefit perspective poses many interesting issues for further exploration in the case study. One of the main themes raised in this thesis is the improvement on-site presence, coordination and leadership of construction site management staff through the introduction and use of mobile computing technology. The effects of mobile computing on construction project management practices will be further explored in the continued research. Looking more closely at the specific case, the question is what the drive is for Skanska when making a major investment and effort in mobile ICT for production operations. What is it the company really wants to achieve? This could range from a vague idea of that the tablet computer user device could improve the administration of specific on-site construction activities to an explicit conviction and determination of that the whole concept of mobile project communication can facilitate the enhancement of project business coordination altogether. Most likely, strong political agendas within the company will also affect the benefit focus of the project. Maybe the most typical situation is when the operational user organization is overrun by the corporate management in the pursuit of a fast ICT project delivery. Failing to recognize the socio-technical long-term development process of ICT implementation and only focusing on fast realization of the technical solution, however misaligned it might be, will have dire consequences for the
whole value-making chain of creating usefulness, user acceptance, organizational adoption and resulting benefits. Another interesting aspect relating to the pursuit of ICT benefit is the *vanity versus performance* objective of the technology investment. If leading persons and groups of people within Skanska direct the mobile computing project to serve their own personal goals or mainly for the purpose of communicating a hi-tech image of the firm to the public, then much of the foundation for generating organizational benefit and business value of the technology will probably be lost.

The discussion from the previous chapter and the issues raised above make it quite clear that the tablet computer project at Skanska inherently includes a socio-technical implementation process where involved people on various organizational levels have different agendas and goal orientation of the project. The dialectical change perspective of identifying and balancing opposing organizational viewpoints and agendas of the mobile computing implementation process is an interesting aspect for further investigation. How is the mobile computing implementation process conducted at Skanska and whose opinions and objectives of the project will in the end prevail? As the project develops, will there be an increased attention to delivery of results which may include stricter focus on hard financial benefits and leave out the usefulness perspective?

A concluding reflection can be established from the results of the research so far:
Appropriate mobile project communication practice is not a matter of technical choice, it is a socio-technical selection process ultimately determined by the behavioral collaborative business patterns of the organization.

*The technology enables mobility, but it is the user that is mobile.*
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Paper I
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 too's 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 is for site

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workers’ information and communication needs is a strategic challenge for the construction industry to increase efficiency and productivity in the construction process (Samuelson, 2003).

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 (Magdić 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 Babić 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 Babić 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 (Magdić 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 Törnlind, 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 Törnlind, 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 Törnlind, 2004, Törnlind 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 Törnlind, 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 (Cuš Babić 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, Otlofsson and Emborg 2004, Magdić 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 be 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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Paper II
USER-ORIENTED IMPLEMENTATION STRATEGY
FOR MOBILE COMPUTING AT CONSTRUCTION SITES

Alexander Löfgren

ABSTRACT
Enabling mobile and flexible information management and collaborative project communication during the production phase of building projects are important improvement areas in creating a more efficient and productive construction process. The wireless and mobile computing technologies available today offer new possibilities for bringing improved ICT tools that better support the administration of construction activities at production sites.

Implementing new technology and work routines at construction sites are very complicated issues. Work practices and cultural issues have traditionally contributed to low willingness to change. The problem is commonly not the development and introduction process itself, but getting the users to actually use the technology and getting them to realize the long-term benefits of the technological change. It is a matter of creating technological-organizational fit through system usefulness. This paper outlines a socio-technical implementation approach to be able to overcome these challenges. The framework evolves around concepts from industrial dynamics and innovation theory, such as ‘design hierarchies’ and ‘learning by using/trying’, to describe a user-oriented technology implementation process of mobile ICT at construction sites.

KEY WORDS
Mobile computing, Construction site, Technology implementation, User-oriented innovation.

INTRODUCTION
It is widely known that the construction industry worldwide has problems related to efficiency and productivity as well as quality and risk management in the production operations of construction projects. The profit margins of construction projects are generally a couple of percent of the total production costs and the cost of construction defects and building rework usually comprise a considerable part of these total costs (Josephson and Hammarlund, 1999).

In the continuous search for an improved and more cost-efficient construction process, construction enterprises have recently drawn attention to how the advances in new wireless and mobile Information and Communication Technology (ICT) can enable an improved

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information and communication platform for the production environment to create better coordination, collaboration and exchange of correct construction data.

Most research on mobile computing for construction cover the technological design and practical applications of such systems and their efficiency benefits in the construction process. But there is a lack of knowledge on how to actually introduce a mobile computing platform that is adapted to the information and communication needs of the individual construction site workers.

This paper takes a generic approach and reflects upon the fundamental dynamic processes between technology development and user adoption. The paper argues that more focus has to be put on the actual implementation of technology and the involvement of the intended construction site users to be able to succeed in delivering an appropriate mobile ICT platform for the needs and demands of the challenging construction site environment.

**SOCIO-TECHNICAL TECHNOLOGY DEVELOPMENT**

Introduction of new technology in organizations tend to focus too much too soon on financial benefits, knowledge creation and learning within firms while the user side receives less attention (Geels, 2004). What is often missing is a socio-technical viewpoint that is the essential component in order to achieve a successful outcome and in the end realize the concrete organizational and financial benefits of the technology. The socio-technical system approach can create better understanding of mutual adaptations and feedbacks between technology and user environment and help bridging the separate perspectives (Geels, 2004).

The most important aspect of all technological development is that the resulting solution has to be accepted by the ones who are supposed to use it. The criteria for selecting a certain technological configuration have to reflect both technological effectiveness and user needs (Nelson, 2000). A mobile computing platform have to be in line with the site workers’ user needs and enable the ability to solve problems and facilitate progress within the harsh construction site environment and its organizational context. Therefore, technological advance needs to be understood as an integrated process between technological, social, cultural and organizational aspects (Nelson, 2000). One of the characteristic features of all socio-technical technological development processes is that they produce a satisfying outcome for its organizational and cultural context, and not a globally optimal one (Ziman, 2000).

**GENERAL PURPOSE TECHNOLOGY AND INNOVATION**

Mobile computing technologies, like all ICT, is best described not as a traditional capital investment, but as a ‘general purpose technology’ (Bresnahan and Trajtenberg, 1995). Such technologies are economically beneficial mostly because they facilitate complimentary innovations (Brynjolfsson and Hitt, 2000). General purpose technologies open up new opportunities and new ways of reorganizing existing resources rather than offering complete final solutions.

Making a general technological concept work in any specific work context requires further complementary innovation, and often a great deal of creativity to be able to match the technological potential with the organizational capabilities. To be successful in implementing
new information technology within existing business processes, firms typically need to adopt the technology as part of a system of mutually reinforcing organizational changes. Failed ICT implementation is often the result of either too comprehensive “all or nothing” approaches, or incremental implementations that have not been backed up with the appropriate organizational changes (“too little, too late”, Bresnahan and Trajtenberg, 1995). This result in negative interactions with existing organizational practices and disrupted business processes leading to increased costs and inefficiency issues (Brynjolfsson and Hitt, 2000). ICT investments must be accompanied by careful redesign and/or restructuring of the organization to obtain many of the anticipated benefits of the investment. New ICT systems often affect the very core of firms and the way activities are coordinated with information. Therefore, it is natural that it takes some time to find and implement the appropriate applications for a specific work environment (Lillrank et al., 2002).

**SYSTEM DESIGN AND USEFULNESS**

Adopting mobile computing technology does not involve radical disruptive innovation that changes the whole information and communication platform of an organization. Mobile computing is a component that adds new functionality and flexibility to existing ICT infrastructure and information systems. It is about extending, recombining, reorganizing and integrating existing ICT resources to provide customized workplace information and communication tools that make better use of the potential of both technological and organizational capabilities. Mobile information management and communication is a critical component for designing an appropriate ICT platform for the administration construction site activities (Rebolj et al., 2004).

In the case of the construction site it is clear that there are inefficiencies in the administration, information management and project communication in the production operations. These imbalances create incentives for change. The innovation process and the search for improvement are driven by increased understanding of the potential and limitations of new technological solutions in its organizational context, which defines a specific set of socio-technical design components or “design hierarchies” (Clark, 1985). Part of the challenge of creating a useful mobile computing system design lay in the absence of knowledge about the technology itself, and part in limited understanding of the technology fit within the construction site environment. Solving these kinds of design problems is therefore to a great extent a social process. The experience with the technology, both direct and indirect, is the basis of the incremental development that will hopefully result in a system with high user acceptability and usefulness in the organizational environment in which the technology is implemented and used (Clark, 1985).

ICT systems with poor usefulness, both utility and usability, are a serious problem in many workplaces. Usability issues and user needs are often marginalized or even abandoned in systems development, while technical issues and deadlines are given priority (Boivie, 2005). In ICT systems development there is commonly a conflict between the systems theoretical view, which emphasizes the formal aspects of work and views users as components in an overall system, and the view of work as a social process (Boivie, 2005). This lead to various obstacles to usability and user involvement, including difficulties with understanding how to adapt the technology to fit a specific work environment, which result
in that the full potential of the technology is not utilized and that the ICT tools become barriers in stead of improving the work activities.

The key to generate both financial and organizational benefits of mobile computing for construction sites is to enable acceptance by the users through creating usefulness; satisfying both ease-of-use and users’ information and communication needs. Such a mobile computing system design will allow construction site personnel to conduct and administrate their building activities more efficient and with higher quality. Usefulness is about overcoming the conflict between the complexity and unpredictability of the construction site work environment and the formalized user functions in the ICT systems. An implementation process that involves the user side is a vital source of information that enables the bridge between these socio-technical issues to be able to achieve a beneficial outcome.

IMPLEMENTATION AS INNOVATION

The introduction process of new technology can be looked upon as the major part of the actual innovation process within organizations. Some innovation researchers even argue that ‘implementation is innovation’ (Leonard-Barton, 1988). Instead of the normal view of the invention-innovation process with a predictable realization of a pre-designed plan, implementation is a dynamic process of mutual adaptation between the technology and its environment. The adaptation process is necessary because a technology rarely fits perfectly into the user environment. Even though technological uncertainty is reduced by prototyping and refinements, as soon as the technology gets into the hands of the users the complexity will increase again. This complexity consists of technological, social and organizational misalignments (Leonard-Barton, 1988). These misalignments can be corrected by altering the technology or changing the environment, or both.

LEARNING BY TRYING

The nature of implementation is often painful and uncertain in its nature, and is characterized by trial and error rather than accumulation of incremental improvements (Fleck, 1994). An organization may for instance, after having learnt many lessons from a first painful development process and implementation adventure, go on to achieve success with a completely different configuration. The initial failure may often be the reason for the final success. The problem an organization sought to solve can actually be better understood and structured because of the experience and knowledge obtained from the failed first attempt. Implementation can be described as an organizational learning process where the configurational implementation/innovation process is a matter of learning through the struggle to get the technology to fit into its social and organizational context. Fleck (1994) calls this process ‘learning by trying’; improvements and modifications are made to different technical and organizational components to be able to resolve a configuration that will eventually work as an integrated entity within its user environment. A successfully customized technological configuration is the result of substantial user input and effort.
USER INVOLVEMENT IN THE IMPLEMENTATION PROCESS

Learning how to solve the puzzle for a particular technology and organization is what the implementation process is all about. Successful implementation requires knowledge and commitment in two fundamental areas with an intertwined feedback between them (Fleck, 1994):

- **Generic technology knowledge** – knowing the possibilities and limitations of the technology and how that translates to technological consequences for the social and organizational context at hand.
- **Local practical knowledge** – understanding the social and cultural components of the particular organization concerned. It includes the specific knowledge base built up over many years of experience and the day-to-day activities which result in tacitly embodied skills and practices.

The only source to a large part of the local knowledge is through the actual users, due to the often tacit nature of practical knowledge. Therefore, the involvement and feedback from users in the implementation process is critical for achieving a successful outcome. It is often through the use of technology that various problems arise and potential opportunities for improvements are noticed. In this innovation process it is regularly the users who observe the bottlenecks of the technology, identify their own needs and can come up with creative solutions to solve the problems (Von Hippel, 1988). This user-oriented innovation process is especially important when introducing and utilizing more complex technical systems such as aircrafts and computing systems. These kinds of systems have a high level of complexity which results in that it takes time to get acquainted with the technology. Therefore, system utilization by the physical users is crucial to achieve technological and organizational fit. This user-oriented innovation process is often referred to as ‘learning by using’ (Rosenberg, 1982).

It is important to recognize that there are different performance criteria and requirements at different levels within an organization, ranging from the individual to the corporate level. Technologies that are reasonably well aligned with the performance criteria at a business unit or corporate level can still be severely misaligned at the individual user level. A productivity tool might be introduced for the good of the overall production but results in total failure because individuals have little incentive to use it, as it is not making their job situation better. This often occurs when developers and management are ignorant of the operations they are attempting to improve (Leonard-Barton, 1988). Therefore, getting the users involved in the implementation process, creating collaboration and communication between users and developers, is critical to succeed in the acceptance of the technology (Voss, 1988). Mutual respect and cooperation between the ICT development unit and the production operations within a firm are key factors to make ICT resources useful and highly valued by the workforce users. This results in effective use of the information systems in its work environment. End-user involvement and cross-functional team building are very important aspects in realizing successful technology implementation and high user performance (Rondeau et al., 2006).
A USER-ORIENTED IMPLEMENTATION PROCESS

Implementation clearly distinguishes from the demonstration of technical feasibility which often comprises an early stage of an overall development process. Implementation is the process when technical, organizational and financial resources are configured together to provide an efficiently functioning system. Implementation is often confused with installation, the final stages of putting a system into productive operation, but implementation has a much wider scope that comprises a complete bridge and feedback loop between design and utilization (Fleck, 1994). This definition of the implementation process recognizes the crucial role of the people inside the user organization, its social structures and interactions between individuals and technology.

Implementation of a construction site oriented mobile computing platform can be divided into three phases with factors influencing the success or failure of the implementation in each phase, described here below.

PHASE 1: PLANNING AND FEASIBILITY ANALYSIS

The planning and feasibility analysis phase is of critical importance because it constitutes the design of the implementation process. If the design is not tailored out properly then the resulting implementation will not fulfill the predefined business benefit objectives and will certainly not be in line with the computing needs of the production organization (Rondeau et al., 2006).

There is no standard list of planning and feasibility analysis factors that apply to all construction organizations because of the specificity of each business operations (Stewart et al., 2002). However, involving the users from the very beginning of the planning process and linking the individual user and operational perspectives to strategic goals are key factors for achieving implementation success. The construction site workers can provide the invaluable information on how they currently conduct the administration of various construction activities, what the deficiencies of these routines are and how a possible improvement should be designed from their user perspective. Distinct administrative construction activities that suffer from deficiencies can then be identified from this information. Subsequently, the ICT development team will be able to better translate these administrative issues to refined information and communication tools that reduce or eliminate the problems. A critical success factor in this problem identification process is to appoint one or a few ‘champions’ (Voss, 1988) that represent the construction site users. The function of the champion is to be the link between the construction operations and the ICT development team. The champion is important for maintaining communication and creating understanding between technological and construction work issues throughout all phases of the implementation, as well as in testing and evaluating usefulness of new technical improvements.

Stewart et al. (2002) suggest a method based on SWOT-analysis (Strengths, Weaknesses, Opportunities, Threats) in the planning phase to map out necessary integration of existing information systems and handling of internal and external socio-technical and organizational issues. By using this method, both the anticipated direct operational and long-term strategic benefits of the mobile computing platform can be identified. Also, how the organization and its processes will be affected by the new technology can be outlined, and what changes in
activities and work routines are necessary to realize the full potential of the mobile technology. The final step of this initial phase is the outline of an operational implementation strategy. This strategy should contain a specification of an implementation action plan including structuring and prioritizing of implementation procedures relating to the integration of construction activities, information systems and supporting business functions, descriptions of organizational structure, commitment and responsibilities, as well as strategies for avoiding implementation risks (Stewart et al., 2002).

**Phase 2: Installation and Commissioning**

The second phase comprises the physical setup of the mobile computing platform and getting the construction site staff to use the technology in an effective way. The established cross-functional communication and high participation of production workforce are key factors in managing this practical technology implementation process effectively (Voss, 1988). The role of the champion plays a vital role also in the second phase, especially in training the construction site personnel in using the technology and creating understanding for the mobile computing platform as an administrative tool that is helping them in their everyday work. The champion is essential in bridging the cultural issues and resistance to change that may be present in the construction site work environment. This end-user training and informal social learning create effectiveness of use, leading to performance increase in work routines (Rondeau et al., 2006).

**Phase 3: Evaluation and Follow-up**

Careful planning leading to a fitting strategic implementation design does not guarantee successful implementation of a mobile computing platform for construction operations. It is also important to outline an evaluation framework and then continually monitor performance effects and benefits of the technology in use over its entire life-cycle (Voss, 1988). These evaluation and follow-up procedures should identify and understand the socio-technical and organizational factors as well as business aspects influencing the success or failure of implementation. The monitoring plan should also include a limited number of performance measures with a mix of short-term and long-term goals, with both quantitative and qualitative measures of financial and intangible benefits (Stewart et al., 2002). An important aspect to recognize in the evaluation and follow-up process is that there are different criteria for performance and usefulness of the mobile computing technology on different organizational user levels (work practices). There is often a tendency to lump these levels to one user perspective (Leonard-Barton, 1988), and thereby excluding valuable performance and usefulness aspects when evaluating the technology implementation.

This third phase is likely to result in issues for further technical improvements in order to achieve better fit of the mobile computing platform for the construction site context. Therefore, this phase should not be seen as the end of the implementation process. An effective company should continually be seeking ways of improving its production processes (Voss, 1988). Arisen misalignments of an implementation round should trigger efforts to improve the technology. These technology improvements can be described as recursive ‘adaptation cycles’ (Leonard-Barton, 1988) of different scale. A large adaptation cycle
implies a fundamental redesign of the technological solution, whereas a small cycle entails incremental adjustments in the design of the mobile computing platform. In other words, knowledge and experiences from one technological implementation should be collected and serve as the input to the refinement of the technology which then will be the object of a new implementation round.

SOCIO-TECHNICAL SUCCESS FACTORS FOR ICT IN THE CONSTRUCTION INDUSTRY

A recent Australian study of ICT use in construction confirms the approach presented above. In summary, that study points out a number of critical socio-technical success factors for adoption of ICT in the construction industry (Brewer et al., 2004, 2005):

- Commitment of employees is vital to the successful adoption and use of ICT.
- Investment in staff development and training is vital for achieving successful adoption and use of ICT.
- Successful ICT implementation requires commitment of the management team.
- Cross-functional transparency and trust among project team participants is vital for successful ICT implementation.
- A champion should support new technology to be implemented and used across the project team. Project teams require a powerful ICT champion to support the technologically weaker organizations in order to ensure that communication processes continue to function as planned.
- Implementing and using ICT-based project communication requires long-term collaborative relationships and partnering. Construction organizations must commit to new ICT as project-based long-term investment decisions.
- Fragmented project teams lead to ineffective performance of ICT-enabled operations.

CONCLUSIONS

This paper argues that it is the management of the implementation process that differentiates a successful adoption of mobile computing at a construction site from a failing one. This paper has highlighted some critical success factors in the socio-technical ‘learning by trying’ process of mobile computing implementation:

- User involvement and implementation success – Involving the end users in the implementation process is a key factor for a successful outcome. The role of the ‘champion’ and cross-functional project teams is critical in bridging the technical and the production operation perspectives to communicate what needs to be done. It is through workforce participation in the implementation process that leads to increased knowledge of how to create usefulness of the technology in everyday work, which will result in tangible production benefits.
- Specificity of each implementation case – It is important to know and understand the specific production operations that is attempted to be improved. This imply understanding the specific construction organization at hand, its business processes, construction activities and organizational and social work structure. Mobile computing implementation cannot be generalized; it requires careful
planning and design for the situation and context of each construction organization.

- Construction activity based implementation – The prerequisite for any successful mobile computing implementation is to clearly define distinct administrative construction activities that call for improvement. This also includes defining the goals and anticipated production benefits, what to achieve with the new technology in terms of efficiency and performance improvements in the future handling of these activities.

- Strategic integration of ICT and organization - It is critical to realize that there are different views on system usefulness (usability and utility) and performance criteria related to the use of ICT at different organizational levels. It is important to link the individual operator perspective to corporate management goals, and translate this to necessary development and integration of both technical ICT issues and social/cultural/organizational aspects. Fully committed project management and top management that understand and support these perspectives are vital for achieving implementation success and resulting improvements in ICT enabled production performance.

- Recursive cyclic pattern of implementation – There is no final end state of a mobile computing implementation process. The evaluation and follow-up of one implementation round result in information on how to refine and improve the technology further. This continuous cyclic pattern of achieving technological-organizational fit is the very core of the ‘learning-by-trying’ implementation process. The technology evaluation should be an on-going integrated monitoring process throughout all phases of the implementation life-cycle.

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ICT Investment Evaluation and Mobile Computing Business Support for Construction Site Operations

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Abstract

The intangible qualitative innovation benefits of Information and Communication Technology (ICT) are essential for improving quality of production, enhancing business activities and creating new competitive opportunities. Still, these benefits are not accounted for in traditional financial investment evaluation methods like Return On Investment (ROI) and Net Present Value (NPV). The strict quantitative financial methods for evaluating ICT investments leave out most of the strategic long-term performance benefits that ICT provide. There is a need for a multidimensional evaluation method that includes the long-term performance perspective, generation of system usefulness and future business value of ICT investments.

This paper starts from a general perspective of ICT investment evaluation. It describes the complexity of ICT benefits, some of the common pitfalls when estimating the business value of ICT and two general approaches for evaluating ICT investments. The paper then reflects upon the benefits of mobile computing for the construction site production environment and the evaluation of such a technology investment in that business context.

Keywords: ICT evaluation; Intangible benefits; Mobile computing; Construction sites

1. Introduction

"You can see the computer age everywhere but in the productivity statistics" (Solow, 1987).

The so-called productivity paradox of Information and Communication Technology (ICT) has been debated and analyzed for over twenty years. The particular issue in focus has been whether the often huge investments in ICT have resulted in significant productivity gains or not. Brynjolfsson (1993) presents four explanations why ICT have not shown measurably improved productivity and therefore caused speculation of a seeming ICT productivity paradox:

1. Measurement errors – Outputs, inputs and benefits are not being properly measured by conventional evaluation approaches. The core of the ICT productivity paradox.
2. Lags – Time lags due to learning and adjustments of the new technology make analysis of current costs versus current benefits misleading. Benefits from ICT can take several years to show in significant financial terms.
3. Redistribution – ICT may be privately beneficial to individual firms but do not contribute to the total output of an industry or the economy as a whole.
4. Mismanagement – Decision makers may not be acting in the interests of the firm. Political interests and/or poor evaluation practice may contribute to failure to realize observable gains from ICT investments.

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Mismanagement in combination with mismeasurement is a viable explanation for the productivity paradox, resulting in failure to recognize new technological potential, needed changes and organizational effects in the implementation process, and lack of knowledge and methods to estimate and evaluate innovation benefits of ICT. These weaknesses have resulted in a static status of “what gets measured gets managed” (Willcocks and Lester, 1996).

The purpose of this paper is to draw attention to the complexity facing organizations when they are about to evaluate in-house ICT investments. A mobile computing case in the Swedish construction industry is used to further illustrate the unique requirements of evaluating a mobile ICT investment in an existing business environment.

2. Technological shortsightedness

ICT implementation and evaluation is an interdependent long-term process. An ICT investment plan and its following implementation should be supported by an ongoing evaluation of the benefits for the individual users as well as the organization. But it is unrealistic to expect immediate organizational benefits from the technology implementation. The effects of ICT have to be optimized and accomplished over a period of several years, rather than at a single point in time close to the implementation stage (Byrd et al., 2006). An evaluation method that takes into account a longer time period of the ICT investment provides more insight and better information for evaluating the impact of the technology in the organization.

The long-term performance perspective is often neglected in technological investment decisions. Some investments that are considered unprofitable may actually be beneficial because they enhance a firm’s competencies and enable it to introduce and produce more profitable products in the future. The ‘technological shortsightedness’ (Milgrom and Roberts, 1992) in investment decisions focus too much on the costs and benefits of developing the current production, instead of how to create future business potential. New ICT solutions are often designed and used to improve efficiency of what is currently done, rather than thinking about these applications as opportunities to redesign and redefine the organization and its business activities (Dos Santos and Sussman, 2000).

Corporate government that is trained in financial analysis but lack integrated technological-organizational knowledge will encounter problems. These managing teams often defend their investment estimates based on a narrow set of “hard” benefits, and ignore long-term innovation benefits that are difficult to quantify. They may also fail to distinguish technologies that offer these important benefits from ones that do not. Realizing and understanding the complementary nature of organizational and technological innovation benefits are of great importance to enable long-term strategic positioning and improve future business performance (Milgrom and Roberts, 1992).

For strategic technology investment decisions, a financial investment calculation based solely on direct cash flows often lead to the wrong answer because a large part of the value of the project may come from its indirect effects on other business units or projects in the organization (Milgrom and Roberts, 1992).

3. Intangible benefit

In the corporate world today, a company’s official book value accounts for less than half of its market value (Kristensen and Westlund, 2003). This gap between book value and market value comprise the intangible assets and benefits of a company, and has made the relevance of a firm’s balance sheet questionable. There is a need for improved methods for
evaluating intangible assets and benefits and include these in the financial reporting to better correspond to the actual business value creation of a company (Eskildsen et al., 2003).

The benefit effects of ICT in organizations and its business activities are problematic to categorize and measure. A major reason for this is that traditional evaluation techniques focus on the observable aspects of output, like price and quantity, while neglecting the intangible benefits of improved quality, new products, customer service and speed (Brynjolfsson and Hitt, 2000). Also, the accumulation of intangible capital assets, such as new business processes, new production systems and new skills are treated as expenses rather than as investments. This leads to a lower level of measured output (Brynjolfsson and Hitt, 2000). The complementary changes and the quantity of intangible factors associated with ICT are very large. Even though they are difficult to estimate, they cannot be ignored when evaluating the economic contribution of ICT. Hinton and Kaye (1996) use the analogy of the investment ‘iceberg’ when organizations fail to comprehend the hidden intangible costs and benefits ‘below the waterline’ of ICT investments and its socio-technical and long-term strategic characteristics.

There is also a difference between ‘benefit’ and the broader concept of ‘value’. The benefit of an ICT-based application is connected to the improvements of specific operational business activities. The collective set of business activity benefits can in turn generate various types of improved operational, tactical and strategic business value (Martinsons et al., 1999). Byrd et al. (2006) argue that the intangible benefits to the end-users are critical to the success of an ICT system investment that will lead to improved performance of the organization over time. Therefore, improvement efforts and evaluation methods that address the intangible user oriented needs in addition to financial impact are likely to result in long-term benefit to the organization (Byrd et al., 2006).

4. Financial evaluation

The traditional investment evaluation approaches are structured financial calculation methods that traditionally are used for accounting purposes. These techniques are based on the assignment of cash values to tangible costs and benefits, and do not include intangible factors. Investment risks can be included in some of these methods through discount rates. Short descriptions of four of the most common traditional financial investment calculation methods are presented here below.

4.1 Payback period

The payback period is the period between the moment when an investment is made and the moment when the total sum of the investment is recovered through the incoming cash flows. A time period is decided within which the investment capital must be recovered. If that time period is less than the calculated payback period then the investment calculation generate a positive return.

The payback period method should be considered the least suitable evaluation technique for ICT investments. Short-lived projects with fast payback are favored with this method and many long-term projects are rejected. This is especially harmful for ICT investments because of their strategic future oriented perspective (Milis and Mercken, 2004). Also, the payback period technique does not include risk assessment and ignores the time value of money in the evaluation. The time value of money means that if the moment of an incoming cash flow is located further into the future, the value of this cash flow will be less.
4.2 Return on investment

The Return On Investment (ROI) technique is based on the same principles as the payback period, but is a more appropriate evaluation method than payback period because it takes into account the total lifecycle of the investment. ROI still has a problem with including risk and does not consider the time value of money (Milis and Mercken, 2004).

4.3 Internal rate of return

Internal Rate of Return (IRR) takes the time value of money into consideration by introducing a discount factor. The IRR is the resulting net value threshold after discounting the incoming and outgoing cash flows. If this threshold exceeds the cost of investment capital, the calculation yields a positive return.

Nevertheless, IRR can be criticized for the following reasons (Milis and Mercken, 2004):

- The result of IRR is a percentage which makes it difficult to compare and rank different potential ICT investment alternatives of various shapes and sizes.
- IRRs differ greatly from the cost of capital make projects with different time plans difficult to compare.
- There may exist more than one IRR for an investment.
- When the IRR method is used for deciding between different investment alternatives, risks are not accounted for. Risk levels can not be included into the selection process.

4.4 Net present value

The Net Present Value (NPV) method calculates the present value of an investment’s money flows, using a discount rate. Unlike IRR, different rates can be used to reflect the risk levels when evaluating different investment alternatives. NPV is the most complete of the traditional strictly financial methods for investment calculation because it includes the total lifecycle of the investment, considers the time value of money and incorporates multi-choice risk levels.

4.5 Financial methods and ICT investments

When the purpose of an ICT investment is to improve operational efficiency, many of the strictly financial techniques may be considered appropriate because they consider the generation of tangible financial benefits related to the direct financial costs. ICT systems aimed to improve and enhance more complex organizational information and communication processes require a richer and more descriptive evaluation framework that considers the generation of benefit and value over the complete life-cycle of the technology. Such a framework have to identify and measure tangible/financial and intangible/non-financial costs and benefits, as well as recognize the differences of benefit value of the ICT investment on operational, tactical and strategic business levels within the organization (Irani, 2002). The strict financial evaluation methods tend to favor and approve ICT investments that lead to cost savings, but miss out on future oriented strategic ICT projects (Fitzgerald, 1998). They also do not include the important intangible costs and benefits of ICT investments.

More importantly, the traditional financial methods merely consider the ‘appraisal’ of an ICT investment concerning the feasibility on an investment before it is carried out. ‘Evaluation’ is a much wider consideration of an ICT investment and is carried out during the whole life-cycle of the technology; throughout the feasibility stage, the implementation and
follow-up stages (Ballantine and Stray, 1998). Stewart and Mohamed (2002) divide this ICT investment management and evaluation process into three main components:
- Project appraisal and selection – estimating benefits, risks and costs.
- Implementation and monitoring – applications, deficiencies and reviews.
- Performance evaluation – measurements, corrective actions and lessons learned.

These phases should not be viewed as separate steps, but as a continual interdependent management effort (Stewart and Mohamed, 2002). The technology that is appraised, selected and implemented needs to be evaluated with the same methods throughout all stages of the investment project. Otherwise there is a risk of mismatch of objectives over time and important benefits of the investment will be overlooked or lost. A well composed management approach for planning, implementing and evaluating ICT investments allows for high accuracy in the appraisal process, improved data on financial benefits, reduces strategic project risks and monitors both tangible and intangible benefits of the technology investment over the entire life-cycle. Such an ICT investment management process tries to find a suitable balance between combined business value and project risks (Stewart and Mohamed, 2002).

5. Integrated evaluation

The purpose of the integrated evaluation approaches is to combine and complement the quantitative financial dimension of investment evaluation with qualitative and descriptive measures relating to strategic issues such as innovation, business development and customer orientation. Two often advocated integrated evaluation methods for ICT investments, Information Economics and Balanced Scorecard, are briefly described here below.

5.1 Information economics

The starring point of the Information Economics (IE) evaluation method is a financial measure called Enhanced Return On Investment (EROI). The EROI includes cash flows arising from cost reduction and cost avoidance as well as estimation of incoming cash flows. The EROI is then supplemented with a strategic qualitative evaluation of the ‘business domain’ and the ‘technology domain’ to generate a total combined value of an ICT investment (Renkema and Berghout, 1997). IE uses a process of assigning point-rating scores to estimate the benefits and strategic relevance of ICT investments, and is generally done through an appointed group of leading persons affected by the investment decision within the organization. The point-rating process includes obtaining consensuses on intangibles, quantifying the importance weight of benefits and risks on a relative scale, estimating the probabilities of benefits and risks and multiplying each estimate by the weight and probabilities (Milis and Mercken, 2004). These figures are then summed up, and the best investment alternative has the largest total sum.

IE seeks to account for a wider scope of information system benefits by including less tangible factors such as improved customer service or a higher degree of competitiveness. The benefits and risks of an ICT investment is separated into the respective domains, the business domain and the technological domain, with each domain evaluated separately. The IE approach can be criticized for relying heavily on agreement of subjective opinions (Milis and Mercken, 2004). The result of an IE evaluation is also hard to interpret because the result of the analysis is expressed in an abstract number instead of monetary terms.
5.2 Balanced scorecard

The balanced scorecard is designed to complement financial measures of past performance with measures of the drivers of future performance. The purpose is to balance short- and long-term objectives, financial and non-financial measures, lagging and leading indicators and internal and external performance perspectives (Kaplan and Norton, 1992). The balanced scorecard approach can be modified specifically for different kinds of performance evaluation purposes. A balanced scorecard for ICT investments could for example include four measurement perspectives, or scorecards (based on Greembergen, 2000):

- Operational excellence – improving existing internal processes, reducing time and cost (efficiency perspective).
- User orientation – delivering utility, usability and value to end users (effectiveness perspective).
- Business contribution – increasing the financial value of business activities and management (effectiveness perspective).
- Future orientation – technological innovation and learning, enabling development of business and organization (performance perspective).

The design of the balanced scorecard approach is aimed towards enabling a complete strategic investment management tool, ranging from initial feasibility estimation, monitoring support of implementation and follow-up evaluation (Milis and Mercken, 2004). Also, different evaluation techniques can be integrated into the framework. The financial scorecard can contain for example ROI or NPV or any other traditional quantitative measure. The NPV technique can be used to calculate cash flows of the tangible benefits and costs, as an initial quantitative feasibility evaluation. The balanced scorecard method can then be used to obtain a multidimensional qualitative evaluation, identifying and assessing intangible benefits and linking these to the financial perspective with probabilities of achieving these values. This combined method can enable a technology life-cycle evaluation that considers both quantitative/tangible and qualitative/intangible factors and their performance effects (Milis and Mercken, 2000).

5.3 Integrated methods and ICT investments

Integrated evaluation methods as the ones presented above are very useful to map out and describe the benefit range of ICT investments. Still, the problem with these approaches is that it is difficult to carry out a complete analysis and translate these innovation benefits to financial measures. Also, there are no generic ICT measures that fit all organizations. Metrics must be specifically adjusted the goals, activities and user base of a firm. The performance measures within an organization should be designed so that they involve the personal development of employees. These measures have to be relevant to the work force in performing their everyday job activities and coinciding performance measures should be identified and linked together (Folan and Browne, 2005).

ICT projects whose purpose is to introduce new systems and applications always involve a strategic dimension and include intangible innovation benefits and indirect costs (Love et al., 2005). For these kinds of ICT investments a carefully designed integrated evaluation method is a more suitable approach compared to traditional financial evaluation techniques.

Still, the most crucial part is to adjust the ICT evaluation framework to fit the specific business operations at hand, the chosen technology solution and the implementation strategy. Investment decision and evaluation is a complex management process, largely due to the wide variety of interacting socio-technical factors within and surrounding an organization. This makes a design of a generic integrated ICT investment evaluation method impossible
(Irani, 2002). Measures must be adjusted to the specific organization and continually evolve to accurately evaluate the technology in the context of its particular business environment.

6. Mobile computing value in construction

This section puts the discussion so far into an existing real life production context. The complexity of ICT investment evaluation is exemplified by the insights from an ongoing case study of a pilot project concerning mobile ICT business support for construction site operations at the Swedish construction company Skanska AB.

6.1 Management and communication issues in construction projects

The construction industry today is struggling with issues concerning efficiency, productivity and quality in its building projects, especially during the production phase. These production issues have a strong relation to the communication and information exchange between the involved parties of a construction project.

Like all business processes of any industry of today, construction projects is dependent on reliable and updated information through a number of ICT based business systems, communication tools and shared storage servers. But this has also caused an increased work load and an almost untenable job situation for production management teams at construction site operations today. Production managers, construction supervisors and superintendents are needed on site to coordinate work, do inspections, conduct environment and safety rounds, document and follow up ongoing and completed construction activities, At the same time, they also need to be located inside the site office at their computers ordering equipment and building materials, exchanging digital CAD models and drawings between architects and design engineers, e-mail subcontractors about upcoming work, follow up budget figures and invoices as well as prepare deviation reports on finished construction work with unsatisfactory result. On top of this, there are daily production meetings that afterwards need to be transcribed in computer documents and e-mailed to all involved parties.

Unanticipated events occur all the time in construction projects. To solve arisen problems and critical situations, quick access to necessary information is needed. Production management personnel therefore have to run back and forth between the construction site and their computers inside the site office. With a large part of the management team stuck at their computers several hours per day, a lot of on-site production leadership, coordination and organization are lost, resulting in deficiencies of the construction process altogether. Also, there is a waste of productive work hours when construction management staff has to carry out administrative work of construction site activities and meeting notes twice; once with paper and pen during the actual event and then again writing it down in computer document templates for reports and protocols.
6.2 Mobile production management at construction sites

The narrative above implies that the ICT tools are not adjusted to the needs and demands of site production management personnel. Existing business information systems and project communication tools are not used properly and not to the level expected. This causes performance issues for construction projects altogether. Many of the major construction enterprises have begun to recognize these issues and started to realize the potential of new mobile ICT solutions to improve the information management and project communication at construction site operations.

A mobile computing pilot project at Skanska has highlighted the potential of tablet computers with wireless network connections for construction purposes. The project has indicated that the tablet computer concept could enable an appropriate ICT platform for the production site environment.

A tablet computer looks like a laptop computer without a keyboard, and is therefore thinner and lighter than a regular portable computer. The main property of the tablet computer is that it consists of a screen with the size of an ordinary sheet of paper on which the user navigates with an electronic pen writing directly on the screen.

The pilot project at Skanska tries to identify a general ICT platform concept that delivers the mobility, flexibility as well as robustness that the construction site requires. The idea is that when production management personnel are on site they are wirelessly connected to the company network, extended from the site office via wireless access points. In the site office they can use the tablet computer as an ordinary computer using a docking station with keyboard, mouse and bigger screen at their own desks, as well as connect wirelessly elsewhere in the office, in meeting rooms etc.

The fundamental approach of this project is very simple. It is about extending existing information systems out on the site, making them mobile and flexible to access. The purpose is to adapt the access and utilization of existing ICT resources to the needs and demands of the targeted user group at the construction site. The tablet computer concept could facilitate new ways of administrating construction activities, exchanging project data and handling collaboration processes to enable construction site personnel to improve their jobs. Generating usefulness and user acceptance is of critical importance in this context, because that is what ultimately will influence much of the benefit and value creation of the technology. If the mobile ICT platform creates usefulness for the individual in his/her everyday construction activities, then it will be appreciated by construction site personnel as a helpful ICT tool and will therefore be utilized. Apart from the mobility features, another
usefulness aspect of the tablet computer concept seems to relate to the procedure of working with a pen directly on the tablet computer screen. This is an intuitive user interface because production management staff is accustomed to using pen and paper on site doing inspections, documentation of activities, and taking notes on purchase orders and other on-site administrative work. With the tablet computer, the idea is that these administrative duties are supposed to be carried out once only, at the time of occurrence.

So, the starting point of the pilot project at Skanska is to achieve mobile on-demand access of project data and drawings on site through wirelessly connected tablet computers. With this technical setup the procurement system can be brought up on site and orders on additional equipment and material can be placed immediately as it is discovered. It can enable production management staff to be online with activity based project management budget tools on site when doing inspections and follow-ups of current and completed construction work.

Environment and safety rounds, deviation reports and other inspections can be filled out on site directly on the tablet computer in digital forms and templates using the electronic pen and then upload them on shared project storage areas or e-mailed to the concerned project participants. Using a digital camera, observed construction problems can be photographed, immediately transmitted to the tablet computer via wireless Bluetooth connection and attached to site inspection reports. In this way the information quality of production issues communicated to involved actors can be enhanced. In the site office, meeting notes can be taken directly with the electronic pen on the tablet computer. When the meeting is over a text recognition tool can translate the writing into an ordinary data text document which then directly can be distributed via e-mail to project participants.

The technical approach of this pilot project is rather mundane. It involves only simple and small changes in how construction data is accessed, information is administrated and how project communication is conducted. But these seemingly insignificant changes could enable a better match between information needs, communication behaviours and an appropriate on-site ICT. The key is to make production management staff at construction sites feel that the ICT tools is actually helping them performing their work, instead of being something that is obstructing them from doing an effective job in managing events and resources on site. So, much of the resulting benefit and value of the investment depends on whether the mobile ICT solution can deliver the appropriate usefulness and user acceptance or not.
6.3 Evaluating mobile computing in construction

The mobile computing concept at Skanska is going to be implemented and tested at several construction sites in Sweden. The company is hoping that the wireless tablet computer platform is going to deliver explicit benefits relating to three main areas of construction process improvements:

- **Enable more effective on-site administration of construction activities** through mobile on-demand wireless access to existing business information systems and construction project administration tools. The aim is to reduce inefficient paper work, make better use of human and material resources and create more flexible work planning, coordination and follow-up procedures of production activities.

- **Enhance real-time risk management and collaborative problem-solving in construction projects** through mobile multimedia conferencing and data exchange between construction site personnel, expert teams and project participants outside the production environment.

- **Facilitate improved on-site presence, involvement and leadership of production management** through making information management and project communication mobile. The construction management team does not have to be tied-up in front of their computers inside the site office if their ICT-based business support is made portable.

When considering the distributed benefits over a long-term perspective, the overall benefit framework of mobile computing for construction site operations becomes rather complex. Below is a simplified mind map of the scope of such a framework without showing interdependencies between different benefit measures.

![Mind Map of Construction Process Innovation Benefits of Mobile Computing at Production Site Operations]

*Fig. 1. Construction process innovation benefits of mobile computing at production site operations*
Putting the brief case presentation into a more general discussion, mobile and wireless ICT may be an enabling technology to facilitate an improved and more flexible information and communication platform for construction site operations, which in turn can increase project business performance altogether. Considering fig. 1 above, evaluating mobile computing in a specific business context involves measuring benefits relating to three general improvement categories (based on Andersen et al., 2000):

- **Efficiency** – ‘doing things right’, is the rate in which inputs are converted to outputs. This could mean reduced production time, less paper work, increased labour productivity, reduced waste of material resources. Efficiency is financially measurable and is represented by money.

- **Effectiveness** – ‘doing the right things’, is the rate of actual outputs compared to the planned. Effectiveness is measurable but not in direct monetary terms. It is represented by improved precision of production operations such as improved building quality and accuracy in available business information.

- **Performance** – ‘doing better things better’, is the level of new outputs enabled, e.g. production flexibility, product and business development. Performance is not directly measurable in quantifiable terms but is evaluated qualitatively in terms of long-term business innovation capabilities, improved partner collaboration and market share.

Love et al. (2005) argue that the evaluation methods for ICT investments used in organizations in the construction industry neglect to address the complexity associated with the ICT introduction and adoption process. No single technique can cope with the wide range of perspectives and aspects of ICT investment issues. A traditional strictly financial evaluation method like NPV would only cover the efficiency perspective, and misses out on the even more valuable benefits of the mobile computing technology. The complexity shown in fig. 1 suggest that an integrated approach have to be considered to enable an improved investment analysis and evaluation that ranges from current cost savings to the creation of future business value. But this integrated evaluation method can not cover everything. Therefore it is important to have an initial idea about the scope of the current problem and what is sought to be improved. This includes identifying what the critical problem areas are, how the technology is supposed to improve these issues and an approach for assessing the improvements. The chosen integrated evaluation method should therefore include a clearly defined delimited set of goals and measures relating to efficiency, effectiveness and performance categories. The method for conducting the actual evaluation has to be carefully constructed, including how different metrics relate to each other as well as to financial and more intangible business values. The intangible benefits have to be described and their impacts on human resources, material assets, organization and business processes have to be clearly mapped out.

Four fundamental steps need to be recognized, understood and managed in the process of outlining an appropriate technology evaluation approach (based on Love et al., 2005):

1. **Determine business benefits** – Tangible and intangible benefit: dimensions ranging from strategic, tactical and operational perspectives linking to specific business activities on different organizational and functional levels.

2. **Determine cost of technologies** – Tangible costs relating to hardware, software, networking and telecommunications, education and training, maintenance, consultancy and services etc. Intangible costs relating to re-design issues, delays, resistance, productivity losses, organizational changes, distraction, interference etc.

3. **Conduct financial evaluation** – Using one or a few of the more complete traditional financial evaluation methods, for example NPV.

4. **Risk analysis and risk assessment** – Identify the risks associated with the technology investment, their business impacts and probability of occurring.
A properly designed mobile computing evaluation framework for construction operations could for example contain five performance measurement perspectives; operational, user orientation, strategic competitiveness, benefits, and technology system (Stewart and Mohamed, 2001, 2003). A certain set of project-, tool- and process-specific ICT indicators could then reflect the particular aspects of how the technology affects information management and collaborative communication processes in the project organization. Such an integrated framework could enable a multidimensional evaluation of enhancements of specific construction process activities, improved efficiency, cultural change, improved user/staff training and support, tangible and intangible benefits, process coordination/integration, system usefulness and increased competitiveness (Stewart and Mohamed, 2001, 2003).

7. Conclusions

As the discussion in this paper has shown, there are a lot of complementarities between a wide range of different factors affecting the resulting benefits of implementing new ICT into an organization. There is a need for a shift of focus away from the strict financial efficiency factors to a strategic performance perspective when deciding and evaluating ICT investments. This includes a more comprehensive approach on how to manage and evaluate innovation benefits of the technology over its whole life-cycle considering both financial and intangible factors.

8. Implications

ICT evaluation has to be closely linked to the implementation and use of the specific technology within its organizational business context through an on-going integrated monitoring process. This continuous process and strategic long-term view on ICT investment evaluation include:

- Creating an implementation strategy that tries to establish cause and effect relationships, mapping desired benefits and value to achieve.
- Including sufficient generic outcome measures as well as firm specific performance drivers.
- Identifying the intangible costs, benefits and business value of the investment.
- Seeking to link the evaluation model to financial measures, striving to translate improved operational ICT benefit and value to increased financial performance.
- Understanding the specificity of each case. There are no generalized evaluation methods that suit all business organizations and all kinds of ICT investments.
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