

TOWARDS MOBILE LEAN COMMUNICATION FOR PRODUCTION MANAGEMENT

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ABSTRACT: This paper reports on an ongoing case study of a mobile computing pilot project at Sweden's largest construction company, Skanska AB. The company has recognized the potential of a mobile computing platform based on the tablet computer user device for construction site management teams. A global initiative within the company has started with the aim of improving information management and project communication at production site operations with the use of tablet computers. The paper portrays Skanska's ambition towards the creation of usefulness and benefit of the tablet platform for the site based mobile workforce in the initial development and implementation process. The evolving mobile computing project has so far been directly influenced by the needs of intended end users and progressed in a trial and error fashion. The paper also discusses the role of mobile computing and project communication in a wider industrialization perspective; integration of project organization and technology that enables an effective platform for collaboration to facilitate leaner communication in the construction process.

KEYWORDS: mobile computing, construction site, production management, tablet computer, usefulness, implementation, project communication.

1 INTRODUCTION

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. 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 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.

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 commonly have to run back and forth between the construction site and their computers inside the site office. 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 (Löfgren, 2006). Docu-

mentation of building activities, production meetings and various inspections often have to be carried out twice; once when they are actually occurring and then again in a computer document using different templates.

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 management presence and leadership in the production site environment (Löfgren, 2006). Most of the available project oriented ICT tools are meant for formalized office use. These tools only give modest support to the craftsman-like construction activities and the unpredictable and mobile environment that site personnel work in. Improving information and communication support for the core activities at construction sites is a strategic challenge for the construction industry to increase efficiency and productivity in the construction process (Samuelson, 2003).

The recognized problems with information management and project communication at production sites in the construction industry could possibly be explained by a partially misleading conception of what *mobility* is and what production site based *mobile work* involves. For more than a decade ICT systems designed for stationary office use have been pushed out to the production environment, which have resulted in that construction management teams are tied up inside the site offices at their desktop

computers a large part of their working hours. ICT implementation at construction sites have gradually forced production teams into partially unnatural and ineffective administrative work routines, due to the inflexibility and fixed nature of the ICT systems. But wirelessly extending these business systems to the construction site using certain mobile computing devices will probably not be a sufficient solution of these problems in the long run. A legacy office based system design will then be forced into a mobile ICT platform that might need an alternative design to better fit the mobile work context. There are differences in how ICT is related to different work types. In office work the computer is often the main tool for performing work, and functions virtually as the workplace itself. In mobile work the main job activities are regularly taking place external of the computer, and often demand high level of visual attention and hands-on execution (Kristoffersen and Ljungberg, 1999a). Therefore, in mobile work environments like construction sites ICT based systems only play a supportive but important role, if they are designed according to the needs and demands of the mobile workforce.

A part of the design problem of mobile ICT systems is that mobile workforces like construction site personnel are often considered to have a base for their work, e.g. their desk or office. Mobility is often seen as transportation between places of work, e.g. wandering, visiting, traveling (Kristoffersen and Ljungberg, 1999b). The mobility of the workforce is seen in relation to a place, from which workers move away. Designing mobile ICT then becomes to give people the same possibilities in the field as they would have at their bases. But mobility can also be a more fluid form of activity, where there is no such thing as a base. In work types like construction site work the mobility is an important component of the work itself. In these work environments people are mobile as the work activities occur, they are not mobile in order to transport themselves to some place to perform the work. This constant *inbetween-ness* (Weilenmann, 2003) is an important part of genuine mobile work. This view on mobility poses new challenges of understanding what mobile ICT is supposed to deliver in terms of usefulness and benefit in its specific job environment, as well as appropriate system design and use of the technology for mobile work contexts.

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 ICT can enable an improved information and communication platform for the production environment to create better coordination, collaboration and exchange of correct construction data. The following paper reports on an ongoing case study of a mobile computing pilot project for construction site operations at the Swedish construction company Skanska AB. The paper describes how the project was initiated within the company and how they have moved forward in their mobile ICT innovation process. As will be shown, this process has been characterized by a strong focus on everyday usefulness of the technology for the mobile workforce, where the development is directly influenced by the intended end users and to a large extent in a trial and error fashion. A large part of the following text is based on case study

material presented in a recently published licentiate thesis (see Löfgren, 2006). The case study at Skanska was initiated in the late summer of 2005 and will be finished in the end of 2007.

2 THE TABLET PROJECT

Skanska AB is Sweden's largest construction company and one of the top five largest revenue making building and engineering firms in the world (Engineering News-Record, 2006). In recent years, the company has recognized the issues of information handling and project communication of its on-site production operations. Skanska's interest for mobile computing solutions truly took off 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 in 2005.

The Duke University site management 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 problem solution and construction rework. 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, shown in Figure 1. The project focused on the management of drawings 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 platform.

As new systems and tools expanded, a user champion was identified to support 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.



Figure 1. Tablet computer with electronic pen.

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.

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 (Löfgren, 2006). 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.



Figure 2 - Tablet computer use at Duke University

The tablet computer pilot project at Duke University received attention both within and outside of Skanska. In the fall of 2005, a global mobile computing effort within the company was initiated. A coordinator was appointed to encourage that the tablet computer technology is implemented, used and evaluated in various construction projects at 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 pilot project was initiated in the fall of 2005 at the construction of a shopping mall in the Stockholm house building region. The Swedish pilot project was set up in a similar fashion as the tests at Duke University, focusing on site management usage and potential usefulness of the tablet computer device in the production environment. The Swedish pilot project was a collaborative effort between the project based production organization and the Swedish ICT unit at Skanska's head office, with an appointed user champion in the construction site environment and the pilot coordinator at the ICT unit. The objectives were to identify how the tablet computing platform should be designed and what its benefits could be compared to the current way of working with construction data and project communication on site.

Small scale tablet computer tests were also initiated in the UK and Norway operations at Skanska. These pilot projects have not been studied further. The rest of this paper will further discuss the mobile computing initiatives at Skanska Sweden and Skanska USA Building.

3 CASE DISCUSSION

The mobile computing pilot project at Skanska has so far shown three development aspects and process factors that appear to be more distinguishing than others. First of all

the concept of usefulness and what benefit the mobile technology is believed to bring have been a persistent focal point of the project. Secondly, a large part of the development and implementation process itself could be characterized as a learning process through trial and error. Thirdly, the input and commitment from key users in this socio-technical learning process is to a large extent the driving force of the pilot project developments. These three main characteristics and their interconnected and reinforcing dynamics will now be further discussed.

3.1 Usage and usefulness

The tablet computing tests in Sweden have so far had a more cautious approach compared to the pilot project at Skanska USA Building in North Carolina. The Swedish approach has been more in the form of a feasibility study where the tablet devices are put into the hands of construction site management personnel and together with ICT development staff try to figure out how the technology possibly could improve their everyday administrative work in different ways. They did not want to “go live” with the tablet computer platform on site before they had evaluated its usefulness and possible obstacles for adoption and use.

Early on in the Swedish tablet tests it was acknowledged that there were differences within Skanska in the handling of documents surrounding problem resolution and drawing update processes in Sweden compared to USA. These diverse prerequisites result in different potential and application areas for on site use of tablet computers. While supervising teams in the U.S. appreciate the tablet computer as a tool for handling and updating digital drawings, in Sweden that has a very limited application area due to a completely different way of administrating the blueprint update process. For Skanska Sweden it is more interesting to be able to use the tablet computer for field work report forms and online mobile use of various central information systems, such as procurement systems, activity based project management budget tools, and resource planning systems out on site. Interviews with both ICT developers and the pilot 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 any mobile computing platform at Skanska’s construction sites in Sweden (Löfgren, 2006).

Creating improved on-site management of construction site operations was the starting point of the mobile computing effort at both Duke University as well as the pilot project 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. This concerns changing 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. But while the tablet computer use at Skanska USA Building were concentrating on the handling of drawings and specifications on site, the focus of the tablet computer project in Sweden has been leaning more towards enabling more effective on-site administration of construction activities through mobile on-demand access to exist-

ing business information systems and construction project administration tools. For example, with 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 a procurement need 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. 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 taking place inside 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, these notes can then 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 test users of the Swedish tablet computer project also 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 and attached to site inspection reports. An arisen construction issue can then be further illustrated 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.

At Skanska Sweden computers and ICT systems have been used in the production environment for a long time. Swedish users already have desktop computers with good performance. Therefore many users feel that they were taking one step back when using the tablet computer. The tablet computer has an overall lower performance compared to the regular desktop PCs, especially when working with several applications at the same time. In contrast, for some of the tablet computer users at Skanska USA Building it was their first professional use of a computer. These users do not have previous experiences of computer use which they can relate to. The use of the tablet computer is therefore an overall positive experience. Another technical obstacle in Sweden regarding the development and extended use of the tablet platform is the lack of handwriting recognition for Swedish language. This function translates text written with the electronic pen on the tablet computer screen into ordinary data text, which is useful for form based documentation out in the field.

The handwriting recognition feature for Swedish language has not yet been released on the tablet operating system platform. The climate condition in Sweden is another barrier for efficient use of the tablet computer, e.g. bad battery time in cold weather and thick clothing during the winter period raise issues how to protect and carry around the computer device without creating extra burden for users. The desire from site management personnel in Sweden to constantly being able to be online with various information systems out on site also pose great challenges of covering the whole construction site with sufficient wireless connectivity.

In the end, user acceptance and benefit of the technology is a matter of creating everyday *usefulness*. The use of the ICT should not be conducted at the expense of other activities such as social collaborative processes, work practices 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. The usefulness perspective comprises the alignment of technology to an existing user context. In the Skanska case this entails 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.

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 3. User involvement in the technical development and implementation process is critical for achieving long term usefulness of mobile computing tools for the mobile workforce out in the field.

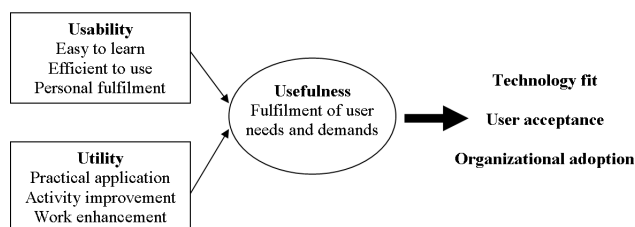


Figure 3. Cause and effects of system usefulness (based on Davis, 1989 and Nielsen, 1993).

3.2 Implementation dynamics

The tablet computer project at Skanska has so far shown that the implementation process itself is a key information source for obtaining improved understanding of the interdependent and reinforcing concepts of usefulness and benefit of mobile computing in the construction site environment. Implementation can be considered as the ena-

bling 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. 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. It 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 from the beginning. 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.

The tablet computer test at Duke University started as a *bottom-up* project where people in the construction site management team had ideas of how to satisfy the ICT needs in their own job situations. These ideas then eventually reached all the way up to the senior executive team of the Skanska group who encouraged production units across Skanska globally to test and adopt the tablet computer technology.

Even though the tablet computer project has become a global development initiative coordinated from corporate management within Skanska, 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 (Löfgren, 2006). The tablet computer project has emphasized the important role of getting the technology users 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 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 user champions and 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.

The findings of the Skanska case study 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 in the production site environment, and not seldom they have own ideas of how to solve these problems with assistance from technical solutions (Löfgren, 2006). 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.

The described way of collaborating and communicating in the tablet computer pilot project at Skanska also enables vital mechanisms of shared understanding between production site personnel and the technical development teams. ICT developers may enhance their knowledge of the complexity of introducing the mobile technology in the construction site setting, and may realize that their conceptions of information and communication issues in the production environment as well as the needs and demands of construction site personnel are somewhat simplified, or even incorrect. The construction staff users on the other hand may understand the possibilities of the new technology and develop a positive attitude towards adopting new ICT solutions that are 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 mobile computing extensions.

3.3 User driven development

Skanska's tablet computer project 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, which can be referred to as a matter of *learning by trying* (Fleck, 1994). This means that improvements and modifications are made to different technical and organizational components more or less in a trial and error fashion to be able to resolve a configuration that will eventually work as an integrated entity within its user environment. This configuration is the result of substantial user input and effort. From the very beginning of the tablet computer tests Skanska has emphasized the involvement of the users in the implementation process. Collaboration, communication and feedback between users and developers are critical to succeed in the acceptance of the technology (Voss, 1988). 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. High

complexity systems results in that it takes time to get acquainted with the technology. Therefore, system utilization by the users is crucial for further development towards technological and organizational fit. This user driven development process, also depicted in the Skanska tablet computer pilot project, is often referred to as *learning by using* (Rosenberg, 1982).

The Skanska tablet computer project has also illustrated the importance of having innovative and pragmatic key *user champions* in the operational production context where the mobile technology is implemented and used. The champions play the vital role of being the link between technical development and the targeted user group (Voss, 1988). 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 jointly being able to find appropriate work routines and discuss areas of utility for the technology, which can then be translated into fitting tools and applications. The construction site workers can provide the vital 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. This hands-on user orientation of the mobile computing implementation process can improve technology fit, and enable greater chance of achieving user acceptance and benefit of the system. The user champion role is also important for training the construction site personnel in using the technology and creating understanding for the mobile tablet computing platform as an administrative tool that is helping them in their everyday work. The champion helps bridging the cultural issues and resistance to change that may be present in the construction site work environment.

4 CONCLUDING REFLECTIONS

At Skanska, as well as in the construction industry in general, there is an ambitious drive 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. 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). So far there is little evidence that these lean production methods are in fact creating the expected benefits and improved performance compared to

the traditional way of construction 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 currently make these projects more image-making cutting-edge products towards customers and competitors rather than important business cash-cows.

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), no matter of what size and setup it has. 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 operational level. But in the bigger perspective it also contributes to an overall development process leading to a more effective construction industry as a whole, whatever the concept 'industrialized' may imply in building projects the future. This can be regarded as an alternative way of considering both industrialization and mobile computing. It 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 *lean communication* practices in the same way that the industry wants to go from a handcraft to a *lean production* manufacturing 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* practices and technologies on different functional levels may change the organization of future projects and how its business activities and work routines are designed, planned and performed. This can help enabling 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 almost has seemed to have taken appropriate project communication practices for granted.

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 of both organization and technology. The mobile computing adoption at Skanska does not involve radical disruptive innovation that contributes to fundamental changes to the corporate ICT platform or to the industrialization of the construction process per se. Wirelessly connected tablet devices on site only enable new functionality and flexibility of existing fixed communication infrastructure and information systems. This concerns extending, recombining, reorganizing and integrating existing technology to provide customized project ICT tools for the mobile construction site workforce, with the anticipation of making better use of both technological and organizational resources within the company.

The ongoing case study of the tablet computer pilot project at Skanska has so far shown that active workforce participation in both development and implementation seems to be a central knowledge contributor of how to create usefulness of the mobile technology in everyday construction work. *The role of user champions* and cross functional project teams appear to be key functions in bridging the perspectives of technical development and production operation issues to communicate what needs to be accomplished in moving forward in the process.

The mobile computing initiative at Skanska has so far shown four overall patterns of the development process that are interesting for further research and analysis:

- A *bottom-up technology pull process* where the end users are strongly influencing the technological configuration and its areas of use.
- Authorization and encouragement from top corporate management, including global coordination connecting the pilot projects together for experience sharing.
- A strong *focus on usefulness* and its resulting benefit of the technology for the mobile workforce in the field.
- An overall development process that is more characterized by trial and error rather than a linear accumulation of incremental improvements. This *learning by trying* development is a social collaborative process in the search of improved understanding of how to get the technology to fit the dynamic and mobile construction work environment.

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