USER-ORIENTED IMPLEMENTATION STRATEGY FOR MOBILE COMPUTING AT CONSTRUCTION SITES

Alexander Löfgren[1]

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 hierachies' 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

[1] M.Sc. Doctoral Researcher, Department of Industrial Economics and Management, School of Industrial Engineering and Management, Royal Institute of Technology (KTH), Lindstedtsvägen 30, 100 44 Stockholm, Sweden, alexander.lofgren@indek.kth.se

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 has 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 is 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.

ACKNOWLEDGMENTS

The following persons have contributed with a critical discussion of the content of this paper and provided useful improvements:

Professor Örjan Wikforss, Department of Industrial Economics and Management (INDEK), Royal Institute of Technology (KTH), Stockholm.

Professor Staffan Laestadius, Department of Industrial Economics and Management (INDEK), Royal Institute of Technology (KTH), Stockholm.

REFERENCES

Boivie, I. (2005). A fine balance: Addressing usability and user's needs in the development of IT systems for the workplace, *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology* 95, Uppsala University, Uppsala, 1-85.

Bresnahan, T.F. and Trajtenberg, M. (1995). General purpose technologies: Engines of growth?, *Journal of Econometrics* 65(1), 83-108.

Brewer, G., Gajendran, T., Chen, S.E., Drogemuller, R., Marchant, D., Chamala, R. and McCabe, K. (2004). Best practice guide: Generic guide, *CRC Construction Innovation Project 2001-016-A*, University of Newcastle, Callaghan, 1-17

Brewer, G.J., Gajendran, T. and Chen, S.E. (2005). The use of ICT in the construction industry: Critical success factors and strategic relationships in contemporary project organizations, *CIB W78 22nd Conference on Information Technology in Construction*, July 19-21 2005, Dresden, 543-550.

Brynjolfsson, E. and Hitt, L.M. (2000). Beyond computation: Information technology, organizational transformation and business performance, *Journal of Economic Perspectives* 14(4), 23-48.

Clark, K.B. (1985). The interaction of design hierarchies and market concepts in technological evolution, *Research Policy* 14, 235-251.

Fleck, J. (1994). Learning by trying: The implementation of configurational technology, *Research Policy* 23, 637-652.

Geels, F.W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory, *Research Policy* 33, 897-920.

Josephson, P-E. and Hammarlund, Y. (1999). The causes and costs of defects in construction - A study of seven building projects, *Automation in Construction* 8(6), 681-687.

Leonard-Barton, D. (1988). Implementation as mutual adaptation of technology and organization, *Research Policy* 17, 251-267.

Lillrank, P., Holopainen, S. and Paavola, T. (2002). Analyzing productivity with the enabler-effect map, *International Journal of Production Economics* 78(1), 69-78.

Nelson, R. (2000). Selection criteria and selection processes in cultural evolution theories, In: Ziman, J (editor), *Technological Innovation as an Evolutionary Process*, Cambridge University Press, Cambridge, 66-74.

Rebolj, D., Magdič, A. and Čuš Babič, N. (2004). Mobile computing – The missing link to effective construction IT. *International Conference on Construction Information Technology*, February 18-21 2004, Langkawi, 327-334.

Rondeau, P.J., Ragu-Nathan, T.S. and Vonderembse M.A. (2006). How involvement, IS management effectiveness, and end-user computing impact IS performance in manufacturing firms, *Information & Management* 43(1), 93-107.

Rosenberg, N. (1982). Learning by using, In: Rosenberg, N, *Inside the Black Box: Technology and Economics*, Cambridge University Press, Cambridge, 120-140.

Stewart, R.A., Mohamed, S. and Daet, R. (2002). Strategic implementation of IT/IS projects in construction: a case study, *Automation in Construction* 11(6), 681-694.

Von Hippel, E. (1988), Users as innovators, In: von Hippel, E, *The Sources of Innovation*, Oxford University Press, Oxford, 11-27.

Voss, C.A. (1988). Implementation: A key issue in manufacturing technology: The need for a field of study, *Research Policy* 17, 55-63.

Ziman, J. (2000). Selection and complexity, In: Ziman, J (editor), *Technological Innovation as an Evolutionary Process*, Cambridge University Press, Cambridge, 41-51.