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USER DRIVEN INNOVATION IN MOBILE TECHNOLOGIES?

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Developing dedicated mobile technology systems for AEC demands the introduction of user driven innovation. A Danish research project collected international examples and user-experiences of mobile and handheld ICT in the building industry i.a. by reading off the functionality of the mobile technology systems relying on the concept of affordance. This paper examines how innovation processes mediate between user orientations and technology offers. There is a great potential for mobile handheld ICT-systems to support numerous work processes in the AEC-industry and this can be substantiated by systems already in function. Stories of prior business successes can be an important tool to ensure further innovative investments since lack of enterprise strategies is often an obstacle for innovation, especially user driven. Both small and large software houses develops dedicated software for coupling site practises, and headquarters - inspired by specific user needs for optimizing work processes. The most important mechanisms evoked for creating the mediating found in the paper are 'hybrids' where professionals from AEC establishes a software house, developing ICT-products for specific on-site processes. On the other hand generic technologies are also widely implemented in routine and day-today activities, making mobile technologies in construction a mix of user and technology driven innovations.

Keywords: users, innovation, mobile technologies, affordance.

INTRODUCTION

It is the aim of the paper to analyse how innovation processes in mobile technologies in AEC mediate user and/or technology driven elements. The material stems from two stages of a Danish research project (Buser *et al.* 2006; Vogelius 2005) and the starting point is the development of dedicated systems for construction processes.

AEC should be suitable for mobile technologies, since the industry encompasses several types of mobility and mobile work. Spanning between headquarters, site work and vehicles during transport thus seem to be very feasible for mobile technologies (Olofsson and Emborg 2004). Moreover both generic and dedicated (tailor-made) technologies are available at least as a global status (Buser *et al.* 2006). Construction though, is often considered an unusually hostile environment for IT implementations perhaps especially innovations that target on-site processes. Hostile conditions on-site can be seen as physical barriers but maybe the temporary nature of projects with ever changing locations, processes and involved actors as well as organizational and management barriers is even harder to overcome. Research wise and in term of innovation project the technology has been on the verge for some time. Where Haas *et al.* (2002) early in this century describes tasks that can be supported by handheld ICT,

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compiled from different contributions, still Bowden *et al.* (2003) characterize the construction sector as an immature market for mobile technology solutions.

Berard and Hansen (2005) do find that 85 % of building workers and managers in small and medium sized construction enterprises in Denmark use a mobile phone; on-site and elsewhere for basic coordination and communication purposes. It seems however that such generic mobile technology has limited potential for improving building processes. The contention here at least is, that it is the dedicated (tailored) systems that hold the largest potential for restructuring building processes and to enhance efficiency, quality and skills development (Buser *et al.* 2006). Moreover to realize such systems there is a need to involve end-users in design to assure a close coupling to building processes. There is a need for user driven innovation (Von Hippel 2005). Buser *et al.* (2006)-s international examples and user-experiences of mobile and handheld ICT in the building industry correspondingly points at activity in dedicated software development in many regions. There is thus apparently a tension between technology driven innovations such as generic mobile technologies and user driven innovations such as dedicated mobile technology systems. The aim of this paper is thus to analyse whether innovation processes are user or technology driven. This is also done by identifying the innovative elements of the attempted change.

A final point is the issue of IT-architecture and interoperability. It is by now widely recognized that future IT-supported building processes should encompass a wide range of ICT-systems and systems element coupled together in a seamless interoperable ICT architecture. A large program initiated by the Danish state in 2003, called "Digital Construction" (see also Koch and Haugen 2006) to "unify, digitalize and coordinate information and construction process" thus form an important background for our discussion. The program is focusing mainly on adoption of existing and developed generic software and configuring of those to support a set of developed guidelines. This is orchestrated by initiatives such as a new classification of building data, a 3D-working method and tools for logistic process as well as a new classification of building data and providing "best practices" of ICT in construction. Although all of these initiatives practically ignore the use of ICT on the building site, they can be crucial to the success of future handheld ICT-systems as they deliver a foundation with a standardized interface covering most construction processes.

The paper is structured in the following way. It commence with methodological remarks regarding the empirical work done. Then the theoretical frame is presented focusing on system design and user driven innovation followed by a brief overview of the case-findings. Two illustrative examples of ICT innovation processes in construction are then presented leading to the discussion and conclusion.

METHOD

The point of departure is a Danish research project initiated in 2004 with the purpose of investigating the potential of strengthening the use of ICT in the construction phase – both on-site in site practises, and spanning between headquarters and remote sites.

The research project consists of two stages where the first stage was an evaluation of a web and PDA-based quality assurance information system on a building site (Vogelius 2005) following design and implementation processes. The second collected international state of the art examples and user-experiences of ICT-systems with a mobile element in the building industry (Buser *et al.* 2006). The focus of the cases is on the design of the software for the systems.

A multidisciplinary approach was taken, mixing management of technology and organizational sociology and information systems perspectives. The *first stage* evaluated a web and PDA-based quality assurance information system (Vogelius 2005) called ETJEK over a four month period, primo 2005. The researcher was invited to participate in testing the system and moreover followed the design process from telephone talks, meetings with the designer responsible as well as informal dialogues. Afterwards the system was tested on a building project by a small contractor (bricklayer) who was not a partner in the research project. The researcher was able to follow a pilot project of the implementation of the system on-site. In the pilot we followed bricklayers using the PDA' while they where working at a line of bathrooms. The observations covered both the planning and set-up of the system as well as the site introduction to the users (the masons) and the system in use on-site. The observations were followed up by evaluating interviews with the masons and the managing director of ETJEK. The *second stage*, the international state of the art examples and user-experiences of ICT-systems with a mobile element in the building industry (Buser *et al.* 2006), mainly included the United States of America and Europe. The study was primarily carried out as desk research with comprehensive internet searches followed by review of written materials, since the limited resources and the geographical extent prohibited a large array of case studies of the internationally present systems. The study used a work sociological approach, a taxonomy of tasks, and combined it with reading off the functionality of the systems relying on the affordance argument (Hutchby 2001). Hutchby argues that although users reinterpret technology in their use of work, they will do that within the affordance of the technology, in other words its limited bandwidths of interpretation. The research also included semi-structured key-person interview and on-site visitations in the UK, The study focused mainly on working processes related to construction of traditional housing and business structures. Moreover mobility in a broader perspective has not been systematically addressed, but the focus is on the micro-mobility on-site and the interaction between the site and the contractors headquarter (see Weilenmann (2003) for a discussion of types of mobility). Based on Swedish experiences Olofsson and Emborg (2004) emphasize that an important property in the use of mobile technologies in construction is mobility between headquarters and building sites i.a. allocation of working instructions. Studies of mobile technologies have to address methodologically multiple space and time issues. In the present case the technology studied support communication between actors in two different firms located at, at least, three different spaces; headquarters of the main contractor, the site management hut and on the construction site where the craftsmen carried out their work and made the quality check. Parts of the paper, especially descriptions of the ETJEK case are based on Koch and Vogelius (2006).

We recognize that the research behind have various limitations. In the first part the dynamics of interaction between the head-quarters and the building site were not followed in dynamic detail. In the second part the international study, resources restricted us from gather primary material of systems implementations and use. Intensive work process observations was not included but in one UK-case.

DRIVERS FOR INNOVATION?

The study includes both generic and dedicated systems used in the building processes. Development of dedicated systems demands some sort of interaction with the future use domain, and it has recently become popular to claim that this best could be done through the introduction of user driven innovation (Von Hippel 2005). Von Hippel

when looking at free/open source software suggested that the involvement of the end-user should lead to better products. This suggestion has later on been interpreted by many as a guideline for all innovations. However we would argue that the celebration of user driven innovation needs to be scrutinized. Woolgar (1991) in his study of designer- user relations suggests that rather than users influencing the design process, it is the designers that are "configuring the users". The design and production of a new entity amounts to a process of configuring the users (in Woolgars (1991) case-study the object of investigation is microcomputers) where 'configuring' includes defining the identity of putative users. Woolgar (1991: 75) moreover emphasize the rationale for not placing too much emphasis on the users' views since 'configuring the user' often involves future requirements and actions of users, which the company management tends to think they have better knowledge about than the users. This way of developing tools and products suggests major considerations on processes and user-needs. Woolgar has been criticized for describing configuration as a one-way process in which the power to shape technological development is attributed only to experts in design organizations (Oudshoorn and Pinch 2003). Also Woolgar are only considering the configuration inside the company that produces the product. The debate has been extended further and Hutchby (2001) outline Latour's description of how large-scale technologies spawn second-order societies, so that the continuously monitored behaviour of the users of the technology feeds back in a never ending loop into the managers' conception of how the technology and its users should be functioning. Hutchby (2001) hereby offers a compromise between the two viewpoints above that implies an internal mutual shaping of designers and users. According to Oudshoorn and Pinch (2003) Akrich suggests that "like a film script, technical objects define a framework of action together with the actors and the space in which they are supposed to act". In the script approach the users are more visible as active participants in technological development than when Woolgar is configuring the user and the script analysis thus conceptualize both designers and users as active agents in the development of technology (Oudshoorn and Pinch 2003).

Hutchby (2001) considers the affordance, as term for the relationship between technology and social processes, to "propose an alternative which takes account of the constraining as well as enabling materiality of artefacts" (Hutchby 2001: 13-14). According to Norman (1999) "the word affordance was coined by Gibson using at cognitive psychological definition. as "the actionable properties between the world and an actor". Norman in addition distinguishes perceived affordance and "real" affordance when considering the man-machine-interaction, and since "designers care more about what actions the user perceives to be possible than what is true". This lead to a more general interpretation of affordance as the potential for action afforded to a perceiver by an object (Norman 1988). Hutchby (2001: 17) also points to the fact, that many successful technological inventions became a success because they were not only concerned with the technological features but also with the context in which it should be used: social, economical and political factors. The capacity of designers to configure the users can be constrained by powerful groups within organizations that direct design projects (Oudshoorn and Pinch 2003). Norman focuses on design of everyday-things based on the needs of the user. User-centered design involves simplifying the structure of tasks, making things visible, getting the mapping right, exploiting the powers of constraint, and designing for error. Findings from cultural and media studies show that people have a fair amount of freedom and creativity in whether and how they consume, adopt, domesticate or appropriate technologies – or choose not to (Oudshoorn and Pinch 2003).

It derives from the above discussion that technology design and user interact in potentially complex ways. An increased interest has therefore emerged in getting a hold of potential design process and mechanisms that bridge or mediate between technology and user. Fleischmann (2005) points at role hybridization, which denote the ability of individuals to shift from one knowledge domain to another, thus allowing for simultaneous membership within otherwise distinct social worlds. One can talk about devices, which link between and transform the software developers, the technology and the users. Devices or mechanism not only merely bridge given object and subject. They also contribute in shaping them in a mutual process.

MOBILE TECHNOLOGIES AVAILABLE GLOBALLY

The international study served as a large framework to situate the findings of the Danish case-study in a broader context as well as it works as a comparison for the Danish initiative. The investigation showed that mobile, handheld ICT-systems has great potential to support numerous work processes in the AEC-industry substantiated by the systems already in function during the investigation. The greatest obstacle for user driven innovation is often the lack of enterprise strategies. Therefore success stories of prior business cases can be an important tool to ensure further innovation.

The research showed that a number of small and large software houses is engaged or have been engaged in developing dedicated software for site practises, and spanning between headquarters and remote sites. These software designs are inspired by specific user needs for optimizing work processes. Often user driven innovation occurs as collaboration or a hybrid of a small software house and a stakeholder from the construction industry. An example of such a hybrid is illustrated in the following section where professionals from the construction sector established a small software house developing ICT-products specifically for quality control on-site. The other example shows how generic technologies are widely implemented in routine and day-to-day activities e.g. communication, documentation, calculation etc. and in co-operation with dedicated technologies. The international tools mainly address site-management and/or supervisors, whereas the Danish example addresses the craftsmen.

TWO ILLUSTRATIVE CASES:

E TJEK – Mobile handheld quality control
The first case presented is a system designed by the Danish company ETJEK, which was the web and Personalized Digital Assistant (PDA) based quality assurance information system that was evaluated in the first stage of the research (Vogelius 2005). The system can be adapted to different users – including skilled construction workers. As mentioned, the study followed the pilot project of implementation, where two bricklayers executed on-site quality assurance. The case is an example of the above mentioned hybrid where professionals from the construction sector established a small software house developing ICT-products specifically for on-site processes. The system innovator has formerly been employed as a contractor and this way he partly represents the users as well as the designers. This way the system innovator himself had a hybrid role; linking between the designers and the users, which is rather untraditional.

The innovation is user-driven in the sense, that it is driven by specific user-needs, but since the point of departure is quality regulations, norms and legal framework the concept of user-driven must be seen primarily on the macro-/community level rather

than as one on one contact between users and software-developers. But it can merely be seen as a "user-pull" rather than a "technology-push". Since the system is based on the same basis as the traditional quality manual the output resembles the traditional dossiers. As the PDA-system is a product innovation though, the ETJEK-system can be seen as both an innovation of product and process.

In the pilot project we followed bricklayers using the PDA's while they where working at a line of bathrooms in a major renovation project in Copenhagen, Denmark. The system was loaded with the "real data" for the part of the construction that the bricklayers were working at, at exactly that time. The PDA's were fully installed, setup, and they were ready for instant use right on the spot. When deviances were discovered by the bricklayers they were entered in the system which immediately reported online via internet to the relevant actors/parties. Normally deviances would be handled through the manager of the bricklayers, perhaps via mobile phones, who decided if they should fix the problem themselves, or they should involve the site manager from the main constructor. With the ICT system – referring to their present position - they just rejected the wall according to a quality norm in the system. The rejection was emailed – often with a low resolution photo – to the site manager, and other relevant actors. Another chance initiated by the new process was the adjustment of the craftsmen wage system to reflect new tasks and responsibility.

On a more practical level the ETJEK system was developed with point of departure in the experiences of the managing director and key entrepreneur of ETJEK. He worked for a number of years as QA-officer at building sites. Before the implementation on site, the ETJEK company tested several beta versions of the system and ETJEK shared its design considerations with the researcher. A broad spectrum of matters had to be systematized regarding both the user interface and other decisions about how to define different control categories. A major input in this process was the already existing standards for building materials in Denmark (which to some extent is covered by EU standards). ETJEK also made interviews with different craftsmen on quality for different kind of work processes not covered by written standards. In the planning phase of the research project, a medium sized contractor had been involved, and an ongoing construction case was identified for the pilot project. The bricklayers accepted the system quickly, and after a couple of days a feed back meeting was held where the bricklayers raised their points of critique to ETJEK - which unfortunately implied major corrections which could only be implemented after the test period.

The central conclusions are that the integration and data transfer between building workers, foremen, managers and the construction company is an advance as well as the enabling of in-process quality assurance. A smoother and more efficient handling of errors and competence development amongst building worker is enabled. However the apparent positive results was relatively quickly contradicted by the participating contractor deciding to abandon the system due to a high level of current contracts.

SKANSKA USA Building Inc.
The second case is reported in Buser *et al.* (2006) and Löfgren (2006) discusses an innovation that integrated a number of current ICT systems at a building site run by Skanska USA. Skanska USA is the third largest contractor in the United States, has 4.100 employees and is a section of Skanska AB. The innovation was initiated in connection with a large building project – the construction of Duke University, Durham, North Carolina – which consisted of four projects at an expense of over 250

million US$. One of the projects, the CIEMAS-project, was 30.000 m^2 of facilities for education, conferences etc and is the primary project investigated in the study.

The total innovation is a combination of generic technologies, and previously tailored systems for Skanska, most of which was already implemented in routine and day-today activities, e.g. communication, documentation, calculation etc. The managers at the Duke project initially evaluated work traditional processes with respect to a strengthening of communication and increased use of ICT in the processes. The characteristics of the project were described as entailing complex communication amongst a wide range of actors' i.a. representatives of the client and the internal organization on the project. Moreover the large quantity of physical information material is overwhelming (Löfgren 2006) and project managers have experienced that problem solving and redressing of failures is sluggish and troublesome. Site management decided to integrate and merge the current ICT-systems in a website to assure the communication of project plans, photos, drawings and other critical data. The new website is linked to Skanska's "digital plan room" – an internally developed platform that assures that data are of the newest available version. Different types of information is submitted to and emanated from the coordinating websites e.g. current conditions on the site that needed to be addressed, drawings, schedules, logistics, construction site layout etc. Wireless tablet computers can connect to the website so the system is always synchronized and up-to-date with corrections in the project material in real-time. Microsoft InfoPath is used to manage and approve forms and webcams and digital cameras are used to attach photos to the forms via Bluetooth.

The primary users of the tablet computers are supervisors whereas site management and design engineers mainly are users of the web-interface. The link between software-design and the users is established through the role of a "Champion" – resembling role hybridization (Fleischmann 2005). The Champion is a member of site management and work as an "anchor-man" together with software-designers and the project manager to assure continual improvements to the system (Löfgren 2006). Moreover the Champion is responsible for the ICT-system training of colleagues in site management. The Champion acts as a mediator between the software-designers and the users. 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 (Löfgren 2006). Users and the software-designer frequently hold feedback meetings to assure the success of the system which may lead to, that software-designers comprehend users better and vice versa (Löfgren 2006).

When you try to integrate multiple systems this way, very often there are complications with the technical data transmission, which can haunt the initiative, but this is a barrier that the Duke project seems to have overcome. The strong integration of the system was awarded a price by Infoweek in the autumn of 2005. In the evaluation of the overall system site management reported that the individual productivity has been raised e.g. since site management has been able to handle more matters of concern than earlier. Communication and synchronization of information was improved as well as the process of redressing discrepancies and failures; answering the question, distribution of modified drawings. Löfgren reports that Skanska subsequently decided to implement tablet computers world wide.

DISCUSSION

In the following we identify the innovation and the various mechanisms in the two cases to mediate user, designers and technology.

The ETJEK case-study encompassed a process of realizing a tailor-made artefact as well as a set of changed business process. Below is first analysed the process innovation and the mechanisms for translating user need technologies and designers. The system addresses the craftsmen as opposed to the international study that mainly addressed site-management and/or supervisors. The innovation does not imply a total reorganization of the building process, but there at least four implications are a result of the initiatives: 1) quality checks are moved from a specific component focus to total locations (as a room) This holds the potential to assure a more fluently work-process in quality management as well as access to data tied to the location e.g. for future use in Facility Management i.a. 2) Quality checks can now be performed by the craftsmen instead of the designers. Responsibility and competencies regarding the required quality in the building process is thus tied closer together. The online element also reduces the number of interactions, since communication lines are rearranged and the system clearly improves coordination between building workers, foremen, manager and the construction company. 3) Quality checks are directly implemented in the work process although slightly differing from the visions of in-process quality assurance as advocated by Deming (1986), since in this case the craftsmen primarily checks output quality of prior processes and craftsmen. But the handheld system holds the potential of assuring quality checks in the process responding to critics of the quality measures as often carried out post festum and / or as a symbolic act (Koch and Vogelius 2006) It should be strived to optimize quality in each part of the supply network to optimize the total quality of the end product (Deming 1986; Dale 2003). Moreover the formal quality assurance and management might not always be in accordance with the actual perceived experience of the process on-site and the system therefore also hold the potential to shrink the gap between what is reported and what is actually materialized in the physical structure. 4) Craftsmen salary/piece rate structures can be reconfigured. Building workers rarely acts as quality surveyors and a change is requires in work organization and contracts – probably more than it requires a development of competences of the building workers (Vogelius 2005).

The ETJEK case encompasses a number of mechanisms for translating domain characteristics into a mobile technology system. First the founder of ETJEK is a hybrid spanning the IT-design and the site domains (Fleischmann 2005). Second the formal routines of quality audits are well describes in manuals etc. Third the contractors company professionals are asked to comment on the system. Fourth the end-user the bricklayers are testing the systems. Finally the researcher was giving comments on the systems functionality, which was given on his understanding of the use-domain (Vogelius 2005). By involving the end-user some modifications and improvements was obtained. It is however relatively modest changes which is realized

The case also demonstrate the problems of embedding innovation in everyday routines The main contractor chose to discontinue using the system, and this lack of strategic management support is a often seen as a problem with project tested innovations. IT governance in construction is of a laissez faire type and often relies on single project implementation (Lindhart 2006, Berard and Hansen 2005). It is moreover sometimes argued about business use in general of mobile technology implementation fail because they are not aligned with business strategy (Adesso 2005).

The Skanska case-study equally encompassed a process of realizing a tailormade artefact as well as a set of changed business process. Below is again analysed the process innovation and the mechanisms for translating user need technologies and designers. The Skanska case encompassed innovations in the following way: the managers decided to carry out a post- project evaluation on communication and ICT-use. Such post project evaluation have in the software been shown to be very important sources of improvement and success (Brown and Eisenhardt 1997). Subsequently site management organization was changed to encompass a software developer and mediator of needs and knowledge on ICT. This socalled "champion" is a process innovation, which then lead to further innovations in the shape of integration of ICT-systems with access enabled by various tools, including a tablet computer. The provision of these new tools implied an improved communication on-site. The mechanisms mediating between designer, technology and user in the Skanska case also encompass a hybrid. The software designer is asked first to realize a improved ICT- support for communication on site based on the managers post project evaluation. The software designer also acted as tutor on the site giving him a first hand impression on how the system worked. Moreover feedback meetings were used. Also in the Skanska case formal written material was used. The Skanska system is primarily consisting of existing applications built together and the involvement of the end-user is also initiated through the Champion. In this way you can argue, that the systems are actually only modified to users at the surface. The underlying parts are based on a foundation of standards and regulations as well as existing technology systems and platforms.

The international study showed that the most of the tools developed was configuring the users (Buser *et al.* 2006). ETJEK and The Skanska US case therefore can be said to be non-traditional examples.

CONCLUSION AND IMPLICATIONS

The investigation showed that mobile, handheld ICT-systems have great potential to support numerous work processes in the AEC-industry, not only on site but across spaces of work. The greatest obstacle for user driven innovation is, as also seen here, often the lack of enterprise strategies. The investigation showed examples of both generic and dedicated systems used in the construction industry. Regarding the innovation process the cases showed different types of set-ups to link the designers, the technology and the users. One we referred to as role hybridization. In one case the software-designer with a former background in construction ensured this link while in the other a formal position – "a Champion" – was introduced to mediate expectations of the concerned interests. In both cases this role hybridization was evaluated as an important factor for the success of the innovation and implications are that this type of considerations on the link between users and designers are important. However, in both systems innovations the user aspect is present only as surface modifications, since the innovations are based mainly on either a combination of existing technologies or existing platforms respectively. Whereas Skanska has decided to unfold the ICT-solution world wide, the contractor in the ETJEK-case decided not to implement the system, due to insufficient resources. Our contribution has showed that while the construction sector has engaged little in developing technologies, generic tools is also increasingly used making mobile technologies in construction a mix of user and technology driven innovations. The dedicated systems does not imply a total

reorganization of the building process, but there are certainly implications both to the process as well as to the product

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