SMOOTH OPERATOR: MOBILE INFORMATION TECHNOLOGY FOR IMPROVED FLOW AT THE CONSTRUCTION SITE

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Mobile information technology (IT) seems an ideal innovation to promote effectiveness of the construction process, particularly at the construction site; research has over the last 15 years focused on solutions, potentials and barriers with this field. This paper aim at the duality between research and industry for an updated and forward looking comprehension, and view of tendencies, of the roles and potentials of mobile IT at the construction site including potential for further research. Qualitative and interpretive methodology inspired by information systems and sociology of research and construction is used; mobility is classified as remote, local or micro. Literature study is employed along with market screening for mobile systems and case studies of companies adopting these as well as rejecting the technology. Within research communities, software manufacturers and construction companies a mixed attitude is seen; stretching from quick movers to full rejection; developing a taxonomy indicate mobile IT mainly as Extended ERP and for Rich Documentation. The ambiguousness of mobile IT on the construction site supports further research within this field using expanded arrays of multi-disciplinary approaches and including regulators, new technologies and innovation barriers/drivers within construction.

Keywords: mobile information technologies, mobility, enterprise resource planning, rich documentation.

INTRODUCTION

Research in the application of mobile information technology in the construction industry and particularly at the construction site has now been going on for the last 10-15 years. The research question has obviously been that when manufacturing and service industries have used IT as major transformation mechanism, why couldn't the same thing work within construction, even now given a host of wireless communication technologies, and suitably mobile, handheld equipment (Schmidt and Simone 1996, Haas *et al.* 2002). Surveys show that most of the employees do use cellphones, also the camera part of it; also communication supervisor-to-worker is highly based of cellphones (Berard and Hansen 2005). The shift from popular voice and imaging applications and to actual business use of IT seems to establish the centerpoint of the research. This is expressed in terms of barrier studies, studies of design of technology and a breadth of studies of business effects on (lack of) technological development (Leskinen 2008, Tsai 2009).

The research paradigm can be summarized as the duality of technology makers and technology users: The benefits, the barrier consideration and to conclude with future

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directions of both research and the two implied industries: Software developers and construction contractors (Koch 2007).

The construction industry profile should make it an avid ICT consumer: On-site coordination of operations requires complex interactions (Luff and Heath 1998). Tasks are complicated with time pressure and productivity requirements, data loss, misunderstandings, iterative negotiations and critical modifications yielding high risk for possible discordance of activities. (Andersen and Koch 2001) Construction projects often face extensive delays or rework decreasing effectiveness due to information that is unavailable, inaccurate or outdated. All these issues could at least partially be solved by using IT mobile solutions (Buser *et al.* 2006).

Construction sites are hostile to IT implementations and IT is "delimited" to the hut of the site management, where indoor conditions are stable. Outdoor conditions are nevertheless not the only hindrance to ICT. Organizational issues such as: the fragmented (Haas *et al.* 2002) and temporary "constellation" of enterprises, managers, employees and their ICT-systems, the working cultures, or the contractual relations, maintain strong barriers (Löfgren 2007). Besides, IT-innovation in construction is continuously lagging behind other sectors (Dansk IT- 2009).

New generic mobile ICT continuously lowers cost and performance barriers (Kazi *et al.* 2009). In the Danish context, adoption of technology is among the highest in the world (World Economic 2009) offering a positive background for the acceptance of and adoption of new systems in construction as well (Dong *et al.* 2009).

Buser *et al.* (2006) show how initiatives within mobile IT has turned in to modest collaborations between ICT and construction companies (Table 1). Initiatives as COMIT has studied the adoption of mobile IT within the UK Construction Industry. Several Danish reviews have compiled lists of initiatives (Heldgård 2005, Koch and Vogelius 2006, Buser *et al.* 2006). The current research and discussions has mainly looked at SME construction companies; and conclusions will mostly apply to these.

Barriers of implementation of ICT in building projects, and especially on the site (Leskinen 2008), might be lowered as ICT develops, and as building workers gets knowledge on ICT from everyday use. Research must address the management of barriers at the work place as suggested by international studies (Bowden *et al.* 2006, Haas *et al.* 2002). Many "IT in construction"-scholars points at using various technologies in construction, rather than the technologies in practice (Dong 2009, Song *et al.* 2008). Important exceptions are: Löfgren (2007), Ward *et al.* (2004) and Bowden *et al.* (2006). A broader understanding of innovation within technology also adding the social institution around the building site is needed (Hislop 2008).

THEORY

Here taxonomy is introduced based on a literature study of specific functions of the building work which can be supported by IT: then it discusses different concepts of mobility which relate and can account for the practices in the building industries.

Taxonomy of functions suitable for IT use

Mobile technologies in construction has been discussed in the literature since the beginning of the 90ies, (McCullouch and Gunn 1993) relates a project of handheld computers on the construction jobsite. Several studies identify the feasible and less feasible tasks, and/or processes of work related to construction site that would be fit within mobile technology. Many authors have focused for instance primarily on project management, schedule management, facility inspection, and field reporting

applications (Buser *et al.*, 2006). Where Haas (2002) or Bowden and al. (2006) have tried to give an exhaustive list of the various functions. The taxonomy is developed as a synthesis of these previous studies (Buser *et al.*, 2006). 30 dedicated mobile information systems for the construction industry were covered by the survey.

This taxonomy uses the differences between sites and sort out seven tasks at the main office and ten tasks at the building site. The main office tasks encompass: Resource management, Material management, Quality assurance, Knowledge management, Safety, Calculation, Purchasing. The main tasks are further detailed into sub tasks comprising 26 sub tasks. Resource management includes registration of work hours, issuing of work orders, material, travel registration or IT tools registration. For the building sites three more functions have been added: communication, measurement and processes. The tasks where derived out of international studies such as Haas (2002), Bowden and al. (2006.) The tasks focus on the information flow processes reflected in IT systems. Work processes are more or less decoupled from the construction execution as an independent "layer" of information processes; and even if supporting mobility down to micro mobility, detaching the actual worker. The taxonomy is used to map the functionality of the system. Reading the artifact and accompanying presentations as a text on how the designers have wanted their information systems to work. We thus label the affordance of the artifact (Tambo *et al.* 2010), and using activity theory identify the ideal (Wiredu 2006).

"Mobility" in Construction

Mobility is the distance between the core and the place of mobility in the business construction including separation between sociality, actors, processes and information.

Pica and Sørensen (2004) lists a matrix of tasks; active-passive, structured-unstructured tasks and processes in analyses of police work. Construction need the constellation of many companies located on multiple stationary addresses in combination with a building site, which is per definition a temporary and remote location. Using Luff and Heath (1998) distinctions between micro, local and remote mobility (see also Wiredu 2006), the following types of mobility in construction can be identified.

Remote mobility. The construction industry encompasses many locations to support the actual site of construction. Commuting of manpower, materials and equipment between these places is remote mobility. Reduced remote mobility is a cost cutting potential, if done with mobile devices (Oloffsen and Emborg 2004).

Local mobility. Local mobility is within a site; smaller or larger. Typical spatiality encompasses mobility between the building, storage for material, storage for tools and equipment, possible workshops onsite, management hut and staff facilities.

Micro mobility. Mobility related to the smallest space of work, like a room, a wall or a staircase. Most mobility is performed as pick and place operations. The spatial dimension shifts gradually along with the progression of the construction.

Mobile activities. Luff and Heath (1998) suggests wandering, visiting and travelling as generic mobile activities. Wandering is extensive local movement. Visiting means location-bound, time finite activities. Travelling is location shifting using vehicles.

Shifting view – from technology to business

Technology and business process design have for long been critical within research (Elaluf-Calderwood *et al.* 2005). Information Systems suggests a further view on the organizational context. Suman *et al.* (2009) suggests, that traditional conservatism on

IT in construction must be supplemented with a wider reorganization of the business proposed as 'reengineering of the construction process'. Within the remainder of this paper the inclusion of organizational and business issues is regarded to be critical in the combined understanding of promotion of mobile IT at the construction site.

METHOD

This study is multidisciplinary and interpretive including IT in construction research, sociology of mobility and information system approaches using classical approaches of information systems in single place approach (Walsham 1993). Studies of mobile technology argue that there is need for changing this when studying mobile technologies (Hislop 2008, Pica and Sørensen 2004, Weilenmann 2003).

The paper adopts a mixed methods research strategy combining quantitative and qualitative data gathering (Bryman and Bell, 2007). The material consists of: (1) a statistical account of use of mobile technologies related to construction sites mainly Berard and Hansen (2005); (2) an international cases-based state of the art analysis of working mobile information systems (Buser *et al.*, 2006); (3) a industry survey on willingness to adopt mobile systems; (4) an account of systems sold in a market.

A literature study has been conducted (Tambo *et al.*, 2010). Approximately 130 scientific articles and textbooks were found and the list is not exhaustive. Research was found mainly in Europe, the Korea-Taiwan-Australia axis. The Journal of Information Technology in Construction (ITCON) and Automation in Construction (AUCON) have been the dominating contributors. Company, systems and IT-supplier information was gathered through desk research, telephone interviews, onsite interviews and use of previous reports. Interviews made ultimo 2009. 4 cases are derived from the continued work of (Heldgård 2005), but continued until late 2009. CEG is defunct since February 2008. Trustworthiness is achieved through triangulation of different channels (Bryman and Bell, 2007).

EMPIRICAL STUDIES

The ICT in Danish Construction

Danish construction sector statistics shows it is lagging behind other sectors. Danmarks Statistik (2009) makes at status for each sector of the industry. This shows, for all sizes of companies: 37% of the employees in construction companies use webpages compared to 66% for the industry in general. 26% operates intranet – industry average is 42%. 9 % operates extranet – industry average is 24 %. Construction companies lag behind in terms of facilities on their webpage, such as access to product catalogues, recruitment, customer service and on-line trading.

The statistics show SME having lower use of ICT than larger companies. (Dansk IT 2009) show underutilization of IT across companies in construction, focusing a range of software applications that arguably should be intended for construction processes (this include CAD, project management packages and project web). Ruddock (2006) have similarly for UK found e.g. ICT spending in constructing of 0,4% of the turnover compared with all others sectors spending in the range of 1,5 to 6,6%. Chien and Barthorpe (2010) found that only 0,1 % of the turnover is spend on IT in the Taiwanese construction industry, and mostly on ERP and CAD/CAM.

Case systems

During the current research a number of systems actively being sold have been identified. The systems are according to the taxonomy above being used in a wide range of applications and business processes.

Table 1: Mobile IT systems for the construction industry

Name of system	Year of release	Taxonomical process and description	Use
Easytime	2003	Task assignment; Resource reporting	Construction, facility management, cleaning, outdoor services, municipality
Reeft	2002	Task assignment; Resource reporting	Technical service, carpentry, kitchen installation, electrical service, recreational
EV Byg	2005	Portal with a wide range of standard ERP functionalities	General construction
Etjek	2005	QA through documentation with questionnaires and photo	Bricklayer, concrete, drywall, tiling but intended for general construction
FotoDok	2009	QA and as-build documentation through photos and semi-structured description	Construction small and large, engineering, architects, insurance companies
Digitjek	2009	Shortage lists; outstanding tasks management. IFC compliant.	Construction – larger
WPA	2003	Task planning and resource reporting mainly on standardized items (GS1)	Plumbing and HVAC.

Easytime, Reeft and WPA are to be seen as extensions of regular ERP functionalities like order management, resource management, HR/work force management, warehousing and logistics operations. EV Byg is a portal build on the top op Microsoft Dynamics NAV. Fotodok, Digitjek and Etjek do not reflect ERP functionality as such. Etjek was developed to support IFC like taxonomies for construction, but due to the prolonged development of IFC, Etjek requires a substantial set-up for each assignment. The vendor of Digitjek states, that the lukewarm support for IFC makes this product difficult to sell. IFC requirements have in Denmark been claimed as statutory but not enforced.

All systems can be used on a range of regular – to more advanced cell phones. Easytime and Reeft state to operate on lowest-end cell phones. The other systems have a range of preferred platforms: From touchscreen, to Windows Mobile, to a PDA. All systems can also be used from a regular PC in a regular Web-browser. EV Byg is preferable used from a netbook or notebook computer. Particular notable is Fotodok and Digitjek both launched by the same company in 2009 in financially difficult times for construction industry but despite this do obtain a quick breakthrough in the market.

The system clearly differentiates themselves into two categories: (2) ERP extension (2) Rich documentation. Easytime, Reeft, EV Byg and WPA are marketed as easily integratable with host ERP-systems. FotoDok, Etjek and partially Digitjek are supporting mandatory, statutory or convenient documentation processes. Rich documentation is in the presented systems mostly images with attributes and text; further information elements could be physical measurements, GPS data, drawings, assembly instructions etc. ERP extension or ‘The Extended ERP’ has for long been a vision from both scholars and industry: The make the ERP support the surroundings, partnerships and collaborations necessary for most firms as a constant effort in position ERP as the enterprises single platform of information mobile systems naturally follow.

Industry screening
Below is a screening of typical construction companies including: use of software; motivation; self-observed benefits. The last four companies participated in a government programme to increase IT awareness in construction, but are mostly still reluctant. All companies have IT within the administrative processes.

Table 2: Selected cases

Company (employees)	Software	Segment	Potential users	Motivation or barrier	Benefit – Disadvantage
Hustømrerne (70)	EV Byg since 2009	Carpenters	Supervisors	Full ERP frontend	Improved flow of data
Hustømrerne (30)	Reeft since 2007	Facility management	All	Swift allocation and reporting	Improved utilization, cash flow
CEG (50)	Etjek during 2006	Main contractor	Bricklayers	Improve QA	Management reluctant
Kaj Bech (140)	Easytime since 2007	Earthworks, park/road	All	Smooth resource management	Embedded in work processes
RS Montage (15)	Photodoc since 2009	Roofing	All	Improve customer service	Cost savings
E. Pihl and Søn (large)	Photodok since 2010	Main contracting	All	Improve business processes	Cost savings
Hansen and Andersen (50)	None	Bricklayers	N/A	Not interested	Maintain status quo
Bygmestrene (30)	None	Historical renovations	All	Strong photo documentation	Cost, savings, compliance
HS Hansens (150)	Considering Etjek	Window mounting	Site engineers	Business process identification	Improve documentation
OM Entre penør (70)	Considering Etjek	Earthworks	Supervisors	Lack of IT readiness	Maybe long term benefits
Aagaard Gruppen (35)	Considering Etjek	Earth, concrete	Supervisors	Very low on IT skills	Need education
Bo Michelsen (65)	Considering Etjek	Bricklayers	Supervisors	Helps documentation	Too expensive

The material implies constellations of SME contractors, mobile information systems and IT-suppliers. Systems are mainly being developed by small entrepreneurial companies in the early 2000s, and still managed by these smaller companies as their main product, except EV Byg which has a large portfolio. All systems use standard hardware in the range from regular and smart cell phones to "high level" standard PC's. The suppliers and systems are "semi-competitive" partially overlapping in functionality and envisioned markets. For Reeft, Fotodok and Easytime, the vision is to expand horizontally.

DISCUSSIONS AND CONCLUSIONS

Below is presented the central discussions and conclusions with this paper; especially the combined research and industry effort of understand and promote a more effective construction process with the use of mobile information technology.

In most mobile jobs, mostly recognized by remote mobility, information technology is nowadays prevalent. In homecare, distribution, police work, snow sweeping, transportation of persons, travelling salesmen, mail, even garbage collection workers and vehicles are equipped with information technology. The same is much less the case within construction; forming a challenge to the research community.

Research on about mobile information technology within construction
Designing information systems – also with mobile elements – for tacit, fuzzy and poorly formalized areas are often a problem (Schmidt and Simone, 1996). QA is on

the one hand a relatively well structured domain. (Krabbe, 2009) has demonstrated Etjek specifically targeted for a structured QA-process embedded in the standard service of a concrete and carpenter company.

To promote mobile technology implementation also business strategy alignment of the contractors must be observed. (Koch, 2007). Indications of very low investment levels and a laissez faire type of (IT) governance also contribute to this (Lindhardt *et al.* 2006, Berard and Hansen 2005). In Love *et al.* (2005) management concerns more than employees' reluctance in shown as main inhibitor; in Ruddock (2006) failing adoption of ICT is analyzed as having negative impact on construction companies financial performance. The stronger propensity to use mobile information technology within work processes of remote mobility is discussed in Olofsson and Emborg (2004). The performance of technological platform needs to be well established (Kimoto *et al.*, 2005). Lack of considerations to technological performance is a parallel general critique of some mobile information systems for mimic of non-mobile systems (Wiredu, 2006).

Two kinds of work – two kinds of IT adoption

The current study has shown, that construction sites and industry to a large part is characterized by work bound to the site, and by work bound to a professionalism. Site bound workers rarely leaves the site; they exhibit mostly local and micro mobility. The workers bound to other professionalisms are only coming for shorter periods, are interchangeable with others sites, might engage in general services non-site related, and are at the site to augment the basic construction frame with certain properties of this professionalism, e.g. mounting of windows, plumbing, flooring, roofing. These workers exhibit all types of mobility; particularly remote mobility is playing a strong role. The two types of work differ in duration and activity profile during the total project period. The first group rarely use IT, but are asked to forward all types of information processing to the site officers and managers. The second group is about to be well equipped with mobile IT acting more as general service technicians: At Kaj Bech 140 men are interchangeable between construction sites and park/road service, all using Easytime. At Hansen and Andersen, all men are related to site during the most of the construction period and do not use IT. While adoption of the mobile systems for the originally intended users is slow, there is a faster horizontal spread of other adopters like architects, construction engineers, insurers, QA auditors, facility managers and technical services.Given the cases within the literature studies, the discussion of extended ERP, the types of work, the systems above and the cases above, an argument is raised, that the true interest from research and industry should not so much be on mobile information technology at the construction site, but more generally how to transform the construction site and the craftsmen into the same conceptualization of IT that most other trades do exploit.

The industry conclusion

Work rhythm and placement of the mobile technology with the craftsmen's work procedures seems to be a proper fit referring to (Pica and Sørensens, 2004) a.o. categories. In this sense our cases shifts the limit for ICT in construction as most systems seems to be designed to fit the need of typical white collar functions on the site, such as quality inspectors and other supervisor staff (Hislop 2008; Kimoto 2005, Dong, 2009). Designing a system to the craftsmen expands the system potential from local mobility to micro mobility.

Manufacturing and service industries extensively use ERP systems; construction industry does not use ICT-based information flow between the operational sites. Major breakthrough innovations might come from till now unconsidered sides: Regulatory or customer pressure; insurance industry; safety issues; new generations of craftsmen expecting a forward looking industry; new mobile technologies integrating long-term evolution mobile communication (LTE), GPS (geo tracking / tracing), RFID, 2-D barcodes, accelerometers, automated voice system, internet-of-things, etc. (Strachan and Stephenson, 2009) Larger contractors are likely to benefit over SME. Regulators must reflect on their role within digital construction. The width of processes support by mobile systems, but also the organizational comprehension and redefinition, can be enabler for important improvements in innovation, productivity, quality (Bowden *et al.*, 2006).

Major potentials are attached to mobile information systems if the industry is able to change its way of practising IT-governance and appropriate adaption of management processes e.g. distribution of responsibilities, control requirements for fragmented subcontractor networks, wages structures, and communication channels.

The research conclusion

Further research is required to support the ICT technology transfer processes of the construction industry. To put a quote from one of the interviews: “I can’t tell why, but I simply don’t find the (mobile) systems sufficiently good.” The Danish system of innovation within construction is a symbiosis of companies and institutional actors (Bang *et al.*, 2001). The programme, Digital Construction, has been setup, (Digital Construction, 2007) encompassing development of standards for buildings and components using Industry Foundations Classes, IFC (Koch and Vogelius, 2005). This is important in creating a service oriented architecture in the industry and will remove lack of interoperability as a barrier. Development of IFC has been ongoing more than 10 years and still unfinished. This prolongation along with low level of government and customer pressure is adverse to the dissemination of mobile IT in the industry.

Research must observe experiments with organization and mobile information systems to target the barriers (Leskinen, 2008). Workers do not seem to be a part of the barrier either in the cases or in the contemporary literature, e.g. (Love *et al.*, 2005). The conclusive main barrier is henceforth within the combined understanding of time, space and mobility seen from both the technology and organizational views.

Continuous reviewing of research efforts is required: Institutional coalitions, new actors (insurers, sustainability advisers, risk assessors, etc.), and the general technological development of ICT, are all giving research plenty of opportunities to grab. In the cooperation between research and industry the common goal must be to organize and develop the construction process to align physical processes, business processes and flow of information with the workers onsite in the centre to enable them to be the lead information providers, and work as the smooth operators.

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