EVALUATION OF WEB AND PDA-BASED QUALITY ASSURANCE SYSTEM ON A BUILDING SITE

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Quality assurance tends to dangerously balance between redundant externalized paperwork and real life problems in everyday processes of design and construction. This leads to too many failures and complaints from customers. This paper describes an evaluative study of the implementation and use of a new ICT system based on the use of Personalized Digital Assistants (PDA's) on the construction site supporting in-process quality assurance. In the pilot project we followed bricklayers using the PDA' while they where working at a line of bathrooms. The central idea of the PDA based system (developed by the small Danish company ETJEK) is to lift the standard quality procedures from the paper based platform to a real-time database with direct access. The evaluation shows that system in facts works, and the introduction on the workplace was smoother than could be expected. The perspective of the evaluation is that the PDA system not only enables in-process quality assurance, but also integration and data transfer between building workers , foremen, manager and the construction company. Hereby a smoother process a more efficient handling of errors and competence development amongst building worker is enabled

Keywords: craftsmen, quality assurance, PDA, software design

INTRODUCTION

Construction and especially the construction site are normally considered as unusually hostile to IT implementations. The outdoor weather conditions, the extensive use of machinery and the potential operators dirty fingers and direct involvement with dusty and noisy processes, apparently means that IT have "retreated" to the hut of the site management, where indoor condition have enabled the stabilization of the use of PCs, internet access etc. It is however not only a question of outdoor weather conditions, but more the fragmented and temporary "constellation" of enterprises, managers, employees and their ICT-systems, working cultures, contracts that possibly constitute the most important barriers.

In the recent years mobile computing has developed rapidly (Gartner, Adesso Systems 2005). That goes for telecommunication such as Cellular phones and WiFi as well as new computer variants. Portable laptop computers now comprise nearly a quarter of the stationary PCs according to Gartner. Prices of powerful laptops, smart phones and PDA's continue to drop. The latest generation of PocketPC devices, rapidly approaches the computing power of laptops.

The assumption behind the present study was that barriers of implementation of ICT in building projects, and especially on the site, might be removed or lowered as ICT

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develops, and as building workers along with other groups or the population to a higher and higher degree actively are using ICT tools in their everyday life outside the building site. This might relax the total set of barriers. This has moreover been supported by international studies (Bowden et al 2005, Haas et al 2002).

Actually by the end of 2005 there were more mobile phones in use in Denmark, than population (National Telecom Agency 2006). Also the statistics on internet broadband access show that Denmark in general is one of the most informatisized societies in Europe (VTU 2005). This could provide a positive background for new systems in construction as well.

This paper describes an evaluative study of the implementation and use of a new ICT system based on the use of Personalized Digital Assistants (PDA's) on the construction site supporting in-process quality assurance. The system can be adapted to different users – including skilled construction workers. In the pilot project we followed bricklayers using the PDA' while they where working at a line of bathrooms.

Studies of mobile technologies have to tackle the multiple space and time issues connected with the use of mobile information and communication technologies. In the present case the technology studied support communication between actors in two different firms located at, at least, three different spaces; the headquarter of the main contractor, the site management hut and on location in the building under construction where the craftsmen carried out their work upon which they made the quality check.

The paper is structured in the following way. It commence with a brief overview of the present state of ICT use in construction in Denmark. It then moves on to discuss the method of the evaluation of an implementation on a building. This case is described and analysed including pre-test design consideration

ICT IN DANISH CONSTRUCTION

Recent statistics covering the Danish construction sector shows it is lagging behind other sectors when it comes to broadband access, wireless network use, PC-use (VTU 2005) and the use of a range of software applications that arguably should be intended for construction processes (this include CAD, project management packages and project web, Berard 2006).

The sector and the institutional players, in particular the state, are currently under way with a major program "Digital Building" (see also Koch & Haugen 2004). The program was launched in 2003, with "a vision of a unified, digitalized and coordinated information and construction process". The main idea is to improve the adoption of existing and developed generic software and configure this to support a set of developed guidelines. The Program areas are structured according to public clients' demands within digitalised tendering, 3D models, project web and delivering of data for operation/facilities management. Moreover this is supported by the development of a new classification of building data, a 3D-working method and tools for logistic process. Finally Best practices of ICT in construction are developed.

If the programme is successful it will provide It-architecture with standardised interface, a service oriented architecture, covering most of the construction processes. This is of vital importance for development of services as the one discussed here, a quality assurance system web-based and with a PDA as mobile element.

Also on the building site use of ICT in Denmark is gradually becoming more and more widespread. Clearly the site management and subcontractors offices are the core,

but also the general ICT-systems become more widely used. Berard & Hansen (2005) thus finds that 85% of the building workers and managers use a mobile phone at work, whereas the use of PDA-s and PCs are much lower, around 10 %, and restricted to site management (PC) or the management of the company (PDA). Berard & Hansens study covers 457 small Danish contractors, like carpenters, macons, and general contractors with their questionnaire (small means less than 100 employees).

This can be interpreted as a differentiation along systems use between construction dedicated system and generic communication tools, where the first, the more professional use, lacks behind. As mentioned previous studies shows that ICT onsite have encountered a number of barriers Andersen & Koch (2001).

METHOD

The research project behind this contribution consists of two main elements. First an evaluation of a web and PDA-based quality assurance information system on a building site reported in Vogelius 2005. Second an international literature study making a qualitative state of the art, reported Buser et al (2006). The Research was supported by BoligfondenKuben and carried out in a collaboration with a contractor, an architect and ETJEK, the information systems developer.

The evaluation study (Vogelius 2005) follows to main lines. The one concerns the "man – machine" interface. Is it possible (as expected by the developer) to introduce the PDA's to the daily routines of the bricklayers without a major education effort? - an effort which most likely would be resisted by the bricklayers as well as their manager. And second, is the system itself functioning as planned? – or do it has a development potential to achieve the necessary functionality.

Studying an information system with a mobile element should imply a change in method (Pica & Sørensen 2005, Weilenmann 2003), since most methods studying IT and organization would assume that these are stationary (Walsham 1993). Although a number of research method issues would overlap with classical methods, such as access, interpreting case material, interaction researcher and observed, there are special difficulties related to the study of multiple space and mobile information and communication technologies (Urry 2000, Elaluf Calderwood 2005). The limited access in time of the present study is the main barrier for the production on knowledge. We did cover the two spaces; the main company and the building site in our study. But we did it in a relatively static way, simply interviewing on the activity carried out developing the quality database at the main company and following various activities on the site. The dynamics of interaction between the two places was poorly covered, and is not further discussed here.

Empirical field work occurred in the following way: The design of the system was followed over a period of roughly four months. Main method was telephone talks, meetings with the designer responsible and informal dialogues. The ETJEK Company shared its design considerations with the one of the researchers. ETJEK tested several beta versions of the system and the researcher was invited to test these versions. From the beginning of the planning phase of the research project, a small contractor became partner in the research project. When the software was ready for test implementation, an ongoing building project was identified for the pilot project.

One of the authors carried out the fieldwork during the test. The planning and setting up of the database in the central office was covered with a structured roundtable with a logistics planner, an IT-developer and a representative of ETJEK. At the site the

introduction of the system was observed. The following two weeks the use of the system was observed 3-4 times, whereas the entire process of tiling, which was selected as test, took 4 weeks. The post test evaluation with the masons, covering experienced problems of the system was observed. Finally an interview with the two masons was carried out. A follow up interview was carried out in the spring 2006.

CASE

The case commence with at brief outline of the broader context and domain of quality measures in Denmark. Then follows a section on software design. Finally the focus turns to the implementation on-site.

THE BROADER DOMAIN OF THE SYSTEM: QUALITY MEASURES IN DANISH CONSTRUCTION

The quality of construction is under continual debate in Denmark. The present set of norms and legal framework was established in 1986 and 2001 and 2005. In 1986 an order on quality was issued covering public financed and subsidized building activities (Bang et al. 2001). This installed formal procedures and documentation in design and production. A second element was uniform liability periods in the state supported building activities. A third element was the establishment of the building defects fund, which is an insurance pool covering defects (Bang et al 2001) and which commenced registering the amount and type of defects, becoming an important indicator of overall quality in Danish construction. These initiatives were followed by installation of industrial norms and guidelines (such as project review guidelines from the association of consulting engineers 1988). Many construction companies moreover took quality management initiatives following the ISO 9000 series (Bang et al 2001).

In 2001 Quality regulations was renewed and improved (By- og boligministeriet 2001). The most important newer initiative is the Benchmark Centre for the Danish Construction Sector. By July 2005 the state only accept enterprises, for the pre qualification for a call for tender, which have been evaluated three times at the benchmark centre. By April 2005, 600 evaluation cases are active and the database of obtained performance indicators can be expected to give a very strong insight in quality levels in Danish Construction. In parallel to this however two studies showed a serious level of quality problems (Apelgren et al 2005, SBI 2005).

As a consequence of these developments a series of “quality institutions” has been embedded in building processes in a Danish context. They can be understood as the pinpointing of a number of critical junctions, who are assumed will assure the production of design-, conformance- and operational-quality. The following activities are some of the critical junctions: Design review, project review, Auditing plans, begin- and end-controls (relating to operation processes), 1 year audit and 5 year audit (post construction). It is common place prior to construction to develop a manual for quality assurance, structured according to the new building and its components. Critics of those measures argue that most quality assurance are carried out post festum and / or as a symbolic act. The tasks of quality management are predominantly carried out by designers and site management. In-process quality assurance as proposed by the present system is thus a innovation both in technology, organization as well as in cost structure. is shown that these may be useful for practitioners.

PREIMPLEMENTATION SOFTWARE DESIGN

Over a period at nearly half a year, before the field work, the ETJEK company tested several beta versions of the system. The researcher was invited to test these versions. Some system test on PC with ordinary browsers as well as tests with browsers especially for PDA's, was conducted. The system consists of a web based database, a communication technology and the PDA with software. The software has an overall scalability which enables the system to be used for multiple location construction sites as well as to single tasks on a site. The system is developed so it can operate on a PC as well as PDA. It was thus needed to develop software being able to operate in a PC-browser and a PDA-browser. The geographical structure of the construction site is reflected in the system through the concept of "locations". Locations can be entire buildings further detailed by floors, access ways (staircases, corridors) and single rooms. Below this level various kinds of construction components. Components can be described more less in detail depending on to how detailed the quality control has to be. The configuration requires that quality standards are associated to construction components. The standard can originate from different sources, for example quality norms from suppliers, public quality standards, or locally defined. The intention is that the operator using the basic function of the system will reject or accept the quality of work done at the single or multiple component(s) by ticking a box. The accept/reject decision is to be emailed to the site manager and other actors - normally accompanied by a "standard explana-tion". Furthermore one can attach a low resolution photo to illustrate the problem.All rejections/accepts are to be stored in the database. The system can generate various quality reports in standard layouts in compliance with norms and routines.All classical actors in a building project – inside the construction company as well as outside- including the client, consulting engineers and architects – can be granted access at defined levels, to enable "views" of the state of quality at a certain time.The ETJEK-company shared its design considerations with the researcher. A broad spectrum of matters had to systematized regarding both the user interface and more substantial decisions about how to define different control categories - e.g. all kind of elements in building and fittings related to water, heating and electricity. 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). But the company also made interviews with different craftsmen about how to constitute "good quality" for different kind of work processes which not was covered by written standards. In January 2005 the systems was ready to test. Already in the planning phase of the research project, a small to medium sized Contractor had been involved, and an ongoing construction case was now identified for the pilot project. The contractor is known for an interest in new technologies above the average for the branch. This point was important due to a relevant concern in the planning phase for the destiny of the project in a situation where the construction case would be behind schedule.

Two main interests were represented in the empirical study. First the "man – machine" interface. Was it possible - as expected by the developer - to introduce the PDA's to the daily routines of the bricklayers without a major education effort (which most likely would by rejected by the bricklayers as well as their manager)? And second, did the system itself function as planned? E.g. would it be for any practical use in bricklayers' daily work – and if not did the system have a development potential to achieve the necessary functionality.

THE INTRODUCTION OF THE SYSTEM ON THE SITE

The test task was a part of a major renovation project in the city of Copenhagen. It was decided to use the operation “tiling” in the bathrooms i.e. the mounting of tiles in a line of bathrooms as case. The building encompasses three floors with 12 apartments at each floor, in total 36 bathrooms. The tiling took roughly three weeks. In the pilot project we followed bricklayers using the PDA’s while they where working at a line of bathrooms. Data was mainly delivered by the bricklayers. The bricklayers were occupied in a small subcontractor with only a handful of skilled workers plus their manager. This subcontractor cooperated frequently with the main contractor.

The architecture of the pilot project ensured that the subcontractor’s bricklayers were in on line contact with a quality assurance database set up for the main contractor. Each bricklayer was equipped with a PDA with a web browser at GPRS speed.

It was decided by the contractors at the site, that the introduction had to be very efficient and conducted in a short time. This was partly a decision taken due to the tight timetable for the building project, but it should turn out to be a wise decision for other reasons too. Both the manager for the mason-subcontractor and the bricklayers themselves, had concerns about the risk of what they felt could be time consuming, ineffective training in the system with little practical relevance.

The setting up of the database of quality was done partly at the main contractor’s headquarters and partly by ETJEK. This proved to be a laborious task which continued until the day before the pilot test.

At the outset of the project the communication technology in focus was PDA’s with integrated mobile phones, using 3G protocols. Obviously this decision was based on the high speed offered by that technology (up to 384 Mb/S). None the less GPRS (maximum speed around 43 Kb/S) were chosen. The contractor had quite fresh experiences with the use of 3G communication among managers at various sites in Copenhagen, and the experiences were not positive! The new 3G technology was not stable and reliable and caused great irritation in the hasty environment at the site where stability, proved to be a main priority in the daily work.

With the above mentioned constraints in mind the training was arranged in the following way: 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, all setup was done, they were ready for instant use right on the spot. The training session was restricted to max. 1 hour.The training locality were an empty room in the building under construction next to the place were bricklayers were working.All examples (regarding menus etc) were drawing directly on the “real data”. Only to bricklayers participated, and it was prioritized to have a high degree of interactivity (the use of reel data facilitated this) with an open an trusty atmosphere

Immediately after training, the bricklayers went back to their work with PDA’s accompanied by a couple of instructors. The use of the system started right away.

The bricklayers took very actively part in the training secession. The practice oriented approach apparently generated an open atmosphere where limits and opportunities were exploited on the basis of practical examples. The “how to use” introduction to the PDA were more smooth than expected by the ETJEK developer and by the bricklayers site manager. Although the bricklayers apparently possessed average IT competencies, there were no kind of barriers at all related to the handling of the PDA. The extensive use of mobile phones, home PC’s, digital portable sound devices,

Photo 1 From the training session - the bricklayers are working with the PDA on site

satellite receivers etc. etc. had turned this part of project to a non controversial domestification of a technology which no longer could call for any nervous minds, but only for a grounded strategy based upon an "trial and error" approach.

The bricklayers accepted the system quickly. And the basic functionality in system was in fact used by them, being quite sympatric to the idea that they themselves should control the quality of the walls before they went further on with their work (the tiling). After a couple of days a feed back meeting was held between ETJEK and the bricklayers. The bricklayers raised a central critique against the user interface in situations were several rooms had to be controlled in the same way – according to them, the system needed an alternative entrance menu which would secure a faster and more flexible system. The critique was discussed with ETJEK and it was agreed that ETJEK had to add such an entrance to the program. Unfortunately it was major correction which first could be finished after the test period.

Photo 2 (below) illustrates one of the failures that the bricklayers reported online via internet. The picture shows a marked difference in level between two adjacent gypsum plates. The plates were mounted at a light weight steel skeleton by carpenters. The bricklayers evaluated the jump in level as a serious failure which clearly was the responsibility of the carpenters. It would be impossible to mount the tiles crossing the different levels. In normal cases, without the ICT system, the procedure for the bricklayers would be to evaluate the failure with their own manager using the mobile phone. It would then be decided if they should use the extra hours to fix the problem themselves, or they shout refuse to go on, and involve the site manager from the main constructor. With the ICT system they just navigated the system on the screen to their present position in the building and 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, depending on how system setup was made, also to the carpenters.

Photo 2: Unacceptable jump in level at the base for mounting of tiles

In the pilot project special agreements were made concerning how to adjust the wage systems (the piece rate), to the new function, that the bricklayers were conducting.

In the interviews with the bricklayers they explicitly pointed at the wage system as a vital part in organizing the new work setup.They didn't regard the adjusting of the wage system as a complex or difficult, task but on the other hand, they were quite convinced that it would be nearly impossible to introduce the PDA's if the wage system didn't allow for time using controls as a part of pice rates.

The central conclusions are that the system is operational and the introduction on the workplace was smoother than could be expected. This is closely related to certain conditions in the learning situation. The learning has to take place on location - the learning issue has to be directly related to actual work on the workplace - the preparation of the training has to be meticulous in order to keep the training session short and concentrated - the number of participants should be kept low - the form has to be informal to ensure an open two way dialogue - the practical use of system has to commence immediately after the training, and supported by the teachers The perspective of the evaluation is that the PDA system not only enables in-process quality assurance, but also integration and data transfer between building workers , foremen, managers and the construction company. A smoother and more efficient handling of errors and competence development amongst building worker is enabled.

The apparent main result of the test on site was however relatively quickly contradicted by the participating contractor deciding to abandon the system with reference to a high level of current contracts.

DISCUSSION

Although our international study found a number of experiments and implementations of mobile technologies on, and related to, the building site, the international status seems to be characterized by relatively limited implementations (Buser et al 2006).

This should commence a reflection upon which barriers are to overcome if the potentials are to be exploited. This could draw on experiences with mobile technology implementation in general as well as specific construction site problems. Typical problems for mobile service implementation projects in general are the complexity of mobile deployments is underestimated, solutions are built upon flawed assumptions, business and IT priorities is misaligned, hardware dependent approaches are doomed to fail and mobile solutions deployers' loose sight of end result (Adesso 2005). Some

of these experiences fail to explain the present case. The software house in question here has an unusually close understanding of quality assurance processes in construction projects, since the main driver of SW-development works as a quality manager in construction. On the other hand business and IT priorities were indeed misaligned as the main contractor chose not to continue using the system with reference to overflow of ongoing projects. Another issue could be the lack of fit with construction site work. Pica & Sørensen (2005), in their study of police use of mobile technology thus argue that mobile information systems would have trouble, where tasks have to be carried out in an active and structured manner, whereas passive and unstructured work would fit better. Following this classification bricklayers normally initiate their work by checking the results of the previous process, which in this connection is an unstructured passive situation, then carry out a rather structured process of bricklaying using their hands and minds (normally even pace controlled by a piece-rate wage) and finally end- up their part by removing tools and equipment. Following this line of argument, the ETJEK system for quality assurance should indeed fit with the passive and less structured passages of work (before and after the main process). However the payment of workers and site managers related to quality management would encourage site management to maintain the quality assurance task, whereas the construction workers do not automatically get reward from doing the quality checks. Moreover the potential of mobile technology is rather closely related to the deployment of an integrated ICT architecture of the construction project. Here the different companies employ systems that rarely can communicate, and technologies that would provide integration such as project web often falls short of joint investment. Thus we contend that the business environment is still a very substantial barrier; the fragmented and temporary "constellation" of, managers, employees, enterprises, and their ICT-systems, cultures, contracts, the use of labour only-workers. It should be mentioned finally that technical barriers are still prevalent. The systems are vulnerable toward communication problems and seamless synchronization is expected. Our international study and another recent Danish study (Heldgård 2005) also found technical problems, which thus cannot be neglected as barriers. Finally barriers for use could be removed by a stronger pressure from the authorities and/ or clients demanding better quality and documentation of quality in-process. Despite signs of improved quality in the Danish Construction sector, the debate recommenced in 2004, with new public initiatives.

CONCLUSION

The test case rather clearly shows that the competences of the building workers need not to be pre assumed as a barrier. However misalignment with business strategy, technical problems and suboptimal human computer interface all proves to be barriers.

The introduction at the workplace was smoother than could be expected. The learning situation was attractive. Training took place on location - directly related to the actual work - the preparation was meticulous in order to keep the training session as short and concentrated as possible – only a few participants - the form informal ensuring an open two way dialogue - the participant started practical use of the system immediately after training, and they were thoroughly supported by the teachers.

The potential use among building workers, opens up the perspective of in-process quality in a classical Demingian sense. Moreover the systems possess a large potential for improving coordination, speed and reliability of the transfer of quality assurance data. As mentioned quality assurance and management tends to dangerously balance

between redundant externalized paper work and real life problems in everyday processes on the site. This discrepancy could be dissolved with mobile systems.It is rare that building workers act as quality surveyors, and requires change in work organization and contracts, more than it requires a development of competences of the building workers, as our study has shown. The system clearly improves coordination between building workers, foremen, manager and the construction company. Hereby a smoother process and a more efficient handling of errors and other issues are enabled. There is finally a need of much more profound experiments with mobile technology, organization and coordination on site and between site and company and directed towards other actors. Such experiments should attempt to exploit the mobility and should be designed to overcome the above sketched barriers.

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