2008

Mobile Technology in the Finnish Construction Industry – Present Problems and Future Challenges

Sonja Leskinen
Turku Centre for Computer Science (TUCS), and Institute of Advanced Management System Research Department of Information Technologies (IAMSR), Åbo Akademi University, Sonja.leskinen@abo.fi

21st Bled eConference
eCollaboration:
Overcoming Boundaries through Multi-Channel Interaction
June 15 - 18, 2008; Bled, Slovenia

Mobile technology in the Finnish construction industry – present problems and future challenges

Sonja Leskinen

Turku Centre for Computer Science (TUCS), and Institute of Advanced Management System Research
Department of Information Technologies (IAMSR) Åbo Akademi University, Finland
Sonja.leskinen@abo.fi

Abstract

This paper studies the added values, both qualitative and quantitative that can be gained by using mobile devices at a construction industry. Some pilots have already been made in the Finnish construction industry that involves the usage of mobile devices. The problem is still to locate the "bottlenecks" that the construction industry has and find a suitable mobile solution that could help in the problem. Here we will report the findings from an interview study done with different companies, involved in either information technology or in construction industry. The main objects of the interviews were to find out the users' and service providers' view of the problems, expectations and future hopes.

Keywords: construction industry, telecommunication, mobile telecommunication, mobile phones, information systems, wireless networks, mobile devices, construction sites, future solutions, RFID

Introduction

Mobile technology has leapt forward in terms of software and hardware development during the past ten years. We have come to the point where, technologically, almost everything and anything is possible. But it is not plausible that every idea can succeed in the tough world of economics and marketing. We must remember to ask ourselves: which features do people want and what are they willing to pay for them? But above all we must remember the Braudel Rule; "Freedom becomes value when it expands the limits of the possible in the structure of everyday life", (Keen and Mackintosh 2001, p. 31) when searching for new business patterns for mobile technology.

The main objective of this paper is to find out how mobile technology can and has been used in the construction industry. This information will enable further research on the quantitative and qualitative benefits that mobility can generate. The aim is also to pinpoint areas in the construction industry and construction projects where mobile functionality would be beneficial.

The main research problem of this study is to find out what added values, if any, the use of mobile technology - i.e. mobility - could generate for the construction industry. This can be studied by identifying the values mobility can create in a construction project and for the companies involved. The research topic is a very current problem since both the construction industry and the mobile

industry need more information as well as answers. In order to answer the main research problem, the following questions need to be answered:

- How and when could mobile devices be used in a construction project and are the devices durable enough for their planned purpose?
- What are the "bottlenecks" in a construction project that could be prevented with the suggested technologies?
- Can mobile technology be of assistance in managing human, administrative and equipment resources for a construction company?
- Will the economic and other benefits of using mobile technology be enough to validate the costs?

The Tekes' (Finnish Funding Agency for Technology and Innovation) VAMOS (Value Added Mobile Solutions) (Tekes 2008) seminar in Helsinki on 4.10.2005 and other events showed that construction companies are still hesitant about using mobile technology, because it is considered too expensive in comparison with the benefits that it can bring. This is why this paper aims to reach better knowledge of what the possible economical and other benefits are in using mobile technology as a help tool at a construction site.

This paper is divided into 6 sections. Section 2 will introduce related research and different theories on how to evaluate IT and how mobile technology has been so far used in the construction industry. Section 3 presents the methodology used in this study. This is followed by section 4, which presents the results from this study. Section 5 summarizes all the important information for a conclusion and discussion. The research problems are answered and further research challenges are discussed.

Related Research

Related research has been done in the field of construction industry and facility management with mobile applications and how it can be used to gain business value. In the latest years special emphasis has been on the use of RFID (Radio Frequency Identification) technology in the construction industry, since it can enable mobility in various industries.

According to interviews done for this paper (see section 3) and other material, such as Era Builds final report on RFID in Construction (Era-Build 2006) some of the greatest challenges in the construction industry are: fragmentation, no dominant ICT solutions enforcer, the industry is project orientated => ICT has to be deployable and profitable within one project, frequent changes in the technology and lack of standards in ICT in a construction process. The Era build report introduced some RFID projects that had been done in the EU and in the USA. This report also includes some information on possible future solutions. Also Solidsofts white paper tackles these issues (Holloway 2006).

The problems studied in this paper correspond to the problems highlighted in the state-of-art study by Haapasalo and Kanerva (2005). They studied how people use mobile technology and from this basis, they then analyzed in more detail the mobile technology usage possibilities in construction- and real estate industry. Overall their results indicated at the time being, that mobile technology and its usability in the construction industry, was new and there was very little experience of it. Some parts of the construction- and real estate industry did not yet understand what could be done with mobile solutions, and vice versa mobile technology experts did not know what to offer the industry (Haapasalo and Kanerva 2005).

So's and Chung's case study in their paper, although more emphasizes the IT questions in the property management, also brings up similar discussions as will be handled in this research. In their paper they studied how mobile IT infrastructure can link different enterprises together, for performance improvement. One of the largest issues was how to reduce the locating, tracking and monitoring time for 200 different estates (So and Chung 2005). The same kinds of tracking

problems are also in discussion of this paper. Furthermore tracking and positioning problems in the construction industry, is one of FIATECH's undergoing projects (Fiatech 2004).

The business Value of mobility in manufacturing companies

Kornak, et.al. (2004) studied some specific areas in which manufacturing companies can achieve benefits with mobility. According to them, there are primarily two mobility areas in which a manufacturing company can get tangible benefits; (i) the possibility of remote connection and control of equipment, and (ii) bundling mobile functionalities with sold equipment to improve performance (Kornak et al. 2004).The first area (i), remote control, would be best suited for moving equipment, such as forklifts, trucks and passenger hoists. With a mobile device one can remotely monitor and obtain information such as mileage, last inspection time and oil levels. In this way the equipment can be handled and used in a correct manner, and if complications occur, all relevant equipment information is available. (ii) Wireless monitoring can be done by bundling mobile functionalities with suitable equipment.

The business value of mobility can for example be divided into two categories: quantitative/tangible and qualitative/intangible benefits. Many of the benefits gained from mobile functionality first seem to be of qualitative nature but might in the end be of a quantitative nature. The problem is how to identify and measure the quantitative benefits with accurate, reliable figures. The tangible values that can be gained with mobile functionalities are difficult to assess because tests would need to be conducted in order to gain reliable results. Without proof of tangible values, no solid business case can be built and upper management will be hesitant to make the investment. Figure 1 lists some quantitative and qualitative benefits that have been identified as generating benefits in a manufacturing company (Kornak et al. 2004). Table 1 represents expected benefits that could be achieved with RFID technology (Era-Build 2006).

Quantitative Benefits		**Qualitative Benefits**
Cost reduction in administration	⟺	Better knowledge on where and when each employee is needed
Improve efficiency – *More tasks can be performed per day*	⟺	Fewer errors – *especially at tasks where mobility reduces the amount of paper reporting*
Reduce logistical costs	⟺	Faster and more accurate communication and information
Improved cash flow – *lead time when invoicing will be reduced*	⟺	Reliable and accurate inventory control

Figure 1: *Benefits gained in a manufacturing company*

▪ Labour efficiency/savings ▪ Out-Of-Stock Management ▪ Inventory Management ▪ Receiving shipping accuracy ▪ Reduced claims ▪ Reduced not saleable items ▪ Reduced diversion ▪ Product recall management ▪ Better visibility ▪ Better fulfilments ▪ Product integrity ▪ Increasing capacity utilization and yield ▪ Reducing cycle time ▪ Increasing labour productivity ▪ Improving product quality	▪ Ensuring timely preventative maintenance ▪ Reducing product obsolescence costs ▪ Tracking and managing spare parts inventory ▪ Facilitating statistical process control ▪ Enabling lot/batch track and trace ▪ Ensuring worker safety ▪ Reducing returns and warranty claims ▪ Reducing scrap, waste and obsolescence ▪ Better planning and forecasting ▪ Better processes in VMI systems related to reordering ▪ Traceability and safety of products for counterfeiting and maintaining copyrights ▪ Better asset management and handling of returnable assets
Source: A.T. Kearney (2004) & Chappell and Ginsburg et al (2003) & DTI, RFID Centre (2005)	

***Table 1**: Expected benefits of RFID (Era-Build 2006, p. 25)*

The construction industry and mobility today

Mobile technology and Internet at construction sites

Usually at construction sites mobile phones are used for calling or SMS (Short Messaging Service) messaging. Also technologies, such as GPS, GPRS and WLAN, are usable to improve a construction site's mobility. Many of these technologies are already implemented into mobile phones, so it would be easy to take them into use. With GPS one can locate equipment, mobile worksites, such as road construction etc. WLAN, on the other hand, can be used especially at remote construction sites to obtain wireless internet and maintain easy communication. GPRS is used for data transportation, but since today's amount of data that needs to be transported is rather large, GPRS will have to evolve to accommodate the growing need. Even the best technology can not survive, if it can not keep up with the teeth of time. Some applications that use these technologies have at least been piloted at larger construction sites.

Methodology

This research includes an in-depth study of what mobile technology and mobile networks have to offer for the construction industry. There are several questions that need to be answered, such as, does mobile technology add freedom in the construction industry, or what are the fixed expenses and what type of benefits can be achieved? To find answers to these questions, we must first study the present situation and map out possible future solutions. The research bases mainly on interviews with different players in the construction and mobile industry.

The qualitative interviewing for this research was conducted in accordance with what Patton describes as "The Interview Guide" (Patton 2002). The same list of questions and issues was used throughout the interviews. This type of interviewing technique was chosen because it keeps the interviews systematic, at the same time as the interviews remain conversational and situational. Two different kinds of interviews were conducted, one focused on (i) the service providers and the other on (ii) the service users. By having a specific outline to the interview, which the interviewee could study beforehand, the accidental omitting of important and salient topics was reduced. The service provider group (i) consisted of representatives from a Finnish building and facility management company, Buildercom, and from the international telecommunication service company, TeliaSonera. The service user group's (ii) interviews were done with four of Finland's largest international construction companies' representatives. These interviews were conducted

with management level personnel in order to get an accurate and reliable picture of construction companies' mobility today. These people represented the following occupations: Information management, development management, business development, security and safety. For the study, it was important that the people interviewed had knowledge that was tangential with either IS or areas where mobility had or could be used. Some of them had also been involved in mobile application pilots, and therefore knew how mobile technology was perceived by workmen, company management and other parties involved. The service user groups companies had tried some of Buildercom's and/or TeliaSonera's solutions at least in a pilot level. A site foreman, from a smaller construction company, was interviewed by the author of this paper, to get a better perception of how a construction site works. All the interviews were held in February and March 2006, where the interviewees' insights and views were recorded on site then later collected and analysed. The interviews were held by the author of this paper and also for (ii) a researcher from VTT (Technical Research Centre of Finland).

Results

Throughout this research we found that too much time is consumed on paperwork within the construction industry. Time is squandered in booking, writing reports, making notes and then often rewriting and confirming the same documents. This type of double work takes too much time and is not reliable, since papers get easily lost and handwritings are often incorrectly interpreted. Mobile applications would be needed to support the construction process, and reduce the paperwork.

Service provider Group

Mobile applications now and in the future

Material has to come to a construction site within specific time ranges so that the construction project does not get delayed because of late material distribution. When the material arrives, either the site foreman or somebody appointed by him acknowledges receipt. According to the construction companies, the site foreman might daily have to do up to two hours of logistics-related paper work. TeliaSonera did a "Jobsite logistics" pilot in Finland with Skanska, RKL A. Taskinen Oy, Fenestra Oy, Enterprixe Software Ltd and Nokia. The pilot got an overall positive feedback from all parties involved (Nikulainen 2005). The main objective for this project was to find new options that make logistics more fluent. In the Job Logistic pilot project, windows and some concrete elements were RFID tagged and tracked in real time through the whole supply chain – design, manufacturing, transportation, reception at jobsite, installation and acceptance. Nokia 5140i model phones with RFID reader shells (Nokia 2008) were used to read the RFID-tags, and for all information transactions. The pilot project was considered successful since it enhanced supply chain visibility and transparency for all the participants in the project. Information flow was accurate and assisted in keeping the project on schedule. Correct items were in the right place at the right time, which also led to savings in labour costs throughout the project. Nokia's 5140i worked nicely at jobsites and in factory environments and the RFID tag reader was easy to use because of its "touch the tag to read" function. (Nikulainen 2005). After the first pilot Skanska had such positive feedback, that it decided to further incorporate this recognition technology and production modelling into its projects. At the "Reimantorni" construction site (ca Feb 2006-Aug 2007) RFID technology and 4D production models were used. Several elements were RFID tagged, so that the design, the production and the installation of elements could be monitored in almost real-time. This information combined with the 4D modelling made it visible to assess how the construction project was progressing (Hörkkö 2006; Rautiainen 2007).

Commonly the site manager or the site foreman checks every day to ensure that safety precautions have been taken and that all the equipment used is according to the safety regulations. Labour protection authorities also make regular visits to the site to supervise industrial safety. Buildercom and TeliaSonera have conducted a pilot project, using mobile phones, in the building industry that

assists construction site safety-monitoring (Työturvallisuus lähikuvassa (A Closer look at Work safety) 2004). The site foreman or another responsible person noted the safety measurements on his mobile phone and if the sighting was defective e.g. scaffolding incorrect, he sent an error message including a photograph of defective area to the responsible person and the underlying backend system. In this example the person responsible of scaffolding, would acknowledge the defect and send a report on repair with his mobile phone to the safety monitoring backend system. All information that is collected during the safety monitoring, including photographs are stored and monitored in the company's information system's database. This application has gained popularity since its initial pilot stage, and is still in use at several construction sites (Työmaan turvallisuustaso kännykkään 2008).

There are different phases of a construction that need to be monitored. For example when a cement-concrete base is laid, the drying process requires specific temperatures for the whole drying time. Apart from the actual building also workforce, equipment and vehicles should be monitored. Today in Finnish construction sites all workers have to wear identifications and some more dangerous jobs, such as welding requires a special permit. RFID technology is seen as one possible solution to this. On the RFID tag information about the workman, and what permits he has can be stored, and checked when necessary. Larger construction companies have several workers and subcontractors in different locations. If it is precisely known when and where a worker is, his upcoming work schedule in various construction sites can be better planned. The same applies to equipment and vehicles. Buildercom has recently started to develop an application for mobile phones that will assist in identification and precision localization (Aspinen 2007).

Material inventories are considered unnecessary at small and medium-sized sites because new material is normally used within days, or a few weeks. Equipment, such as power tools are accounted for, so that the company knows approximately which site each power tool is at. In Finland equipment and material theft has not been perceived as a problem, but news from the other side of the Atlantic is very different. Larger, more expensive equipment, such as earthmovers, are usually rented. Equipment inventories are checked regularly at large sites. The use of rental equipment has increased, since scaffoldings are often replaced by versatile cranes and person lifts. It is important to keep an exact inventory of them, so that the correct machine gets returned at the agreed time and that the machine gets regularly maintained. If an accident would happen, those logs would be of upmost importance.

Service user group

Extent of Mobility in Company

All of the interviewees reported that mobile phones were in daily use in the form of calling and SMS messaging in their company. To some extent, e-mailing via mobile phones was also in use for key personnel. Mobile phones with camera functions had been in use at construction sites, and they were considered a most appropriate tool for documenting and reporting construction development and problems. Overall, the extent of mobility was still rather low and apart from a few pilot applications, only the standard uses had been implemented in the daily routines.

The value of mobile applications

There were rather conflicting views on the value of using mobile applications. In some cases there was insufficient knowledge on the technology opportunities offered by mobile technology, and thus it was not clear what values could be obtained. The group was however rather unanimous in their opinion that the right type of mobile service could generate value once the basic processes worked properly. Most of the interviewees considered the applications they had piloted or used well designed and logical. The reason why the piloted mobile applications added value was because the application was easy to learn; even the worker using the application obtained benefits, and this motivated him to continue to use the application.

Mobile devices and applications

Despite concerns about the mobile phones' durability and usability, it did not create problems amongst the users. This was also partly due to the fact that workers found the applications useful, and therefore took care of the mobile phone, so that it would not brake. Durable PDA devices had been tried by some of the companies, but they were not considered useful. The device was deemed clumsy to handle, workers had difficulties in learning the system, the PDA was not as familiar as mobile phones and information got lost if the wireless connection crashed.

Mobile applications were attempted to be used in areas where the construction process had bottlenecks due to excessive paperwork. The main problem with the mobile applications that had been tried seemed to be that the bottleneck only moved to another area of the process, e.g. before the data was written on paper and then inserted manually into the system. Now the data from the mobile application did not always automatically transfer into the system and for the most part, had to be inserted by hand. So, even though the initial entries could be done faster with the mobile application, they still had to be inserted into the company's computer system manually. However this could be remedied once the mobile application is working flawlessly with the rest of the company's IS.

Present obstacles to using mobile applications

The obstacles were considered to be related to the mobile application, not the devices themselves. Here are some of the critiques that came forth: The application does not yet fluently operate with the company's IS, the service is too expensive, sufficient safety measures have not been taken and the maintenance & development of the system is too complex and laborious for the company's IT department. All the interviewees believed that the present obstacles will be overcome, but there were great differences with regard to the timescale of this. At one company, the interviewees perceived the obstacles regarding safety measures too severe and did not believe in rapid improvements.

Requirements imposed on mobile solutions

The whole group considered the service costs too high, and this above all was considered to be one of the main factors hindering the development of mobile applications at the moment. The price of the service and the devices need to be at a reasonable level. At two companies the opinion was that the present data transfer speed and sizes were inadequate, but would most likely be up to speed once mobile applications become more common. One company also felt it important that the safety measures against viruses and espionage get notably improved. Interviewees believed that for mobile solutions to work there needs to be all-extensive applications, not a number of small ones implemented into the supply chain.

The interviewees hoped that the mobile application service would be provided, developed and maintained by an IT company or similar. They felt that their own company's IT department's capacity is not sufficient enough for these tasks. New players are required in the construction industry to ensure working information systems and mobile solutions. Apart from new players, the old players would have to adapt to the new situation. Many mobile applications that would be beneficial for the construction industry require that the whole co-operation network is involved.

The future challenges of mobile functionality in the construction industry

The common belief was that mobile functionality has much potential and use of it will increase in the construction industry. Mobile technology was seen to be an eligible alternative, especially in areas such as confirmations, reporting and logistics, but everybody had an individual opinion on how, in what form, and when this would happen. Some of the interviewees perceived GPS as a mobile solution that would be of use in the future, whereas others were keener on the opportunities RFID technology would bring. Positioning was a desired feature, especially for companies that also have a road building department. The overall opinion was that mobile applications could

generate benefits, when used in recurring daily routines, but they would not provide strategic solutions for the core business.

Even though mobile phones are preferred in the industry at the moment, other device options in the future are not ruled out. Many believed that once the next generations of workers, who are more accustomed to computers, enter the workforce more complex devices and applications can be handled. The mobile devices' overall functionality will then get more attention. At this point PDAs could come into the picture once again. Devices operating with Microsoft Windows could gain popularity, and mobile solutions would have to adapt to the situation. Also, at some point, once mobile applications become more popular, it could be assumed that public pressure will demand mobile applications that can be used in several mobile phone models and brands and maybe even on other mobile devices.

Some of the future opportunities were seen to revolve around RFID, GPS and more efficient use of mobile phone's cameras. These new technologies can bring benefits to processes and a range of uses that have not been possible or even noted before. The interviewees' common belief was that the logical and practical development and use of these technologies will increase the significance of mobile solutions in the construction industry. There was, however, still debate on when these technologies can be effectively used.

Comparison of service provider and service user groups' interview data

Where and when are mobile applications required?

The findings points to mobile applications being best suited to repetitive functions outside the core business, such as reporting. The site safety monitoring application on mobile phones is considered useful and effective, but prices must be reduced considerably for it to overtake the traditional paper reporting method. Laws and regulations have forced the industry to improve the monitoring of their own workforce and sites. Both groups agreed that more information is needed in many areas to make the site more efficient, safe and worker friendly. RFID is seen as one possible solution in this problem, since much information can either be stored directly in the tag (active tags) or in the backend system. With the help of RFID technology, large equipment, such as cranes, could be monitored, to ensure that maintenance and inspections are done according to the regulations. This conclusion is also supported by ERA Build's research on the most important driving forces for RFID in construction. They are: *1.* Tracking and tracing of components, vehicles etc. *2.* Supply chain management and logistics *3.* Product ID – so that the right component and device is used *4.* Maintenance of service systems and *5.* Track recording of components (Era-Build 2006).

Both interview groups thought mobile applications a good and efficient solution for different types of monitoring and control functions. Some monitoring applications, such as the site safety monitoring presented earlier, have already been tested. Monitoring functions could also be expanded to areas such as work progress, personnel, installation time, and quality. TeliaSonera also indicated some ideas for security and targeted environmental monitoring; the existing "Sonera Alerta" system could be tailored to meet the construction industry's needs for anti-theft and fire alarms as well as water and temperature monitoring.

There were indications in the service provider data that both positioning (e.g. GPS) and a wireless local network would be appropriate and useful for construction sites. This was confirmed during the service user interviews, but it was seen as a function that will not be necessary until far into the future. The interviewees understood the potential and possibilities that positioning and wireless network could bring, but at the moment these technologies were not considered essential for construction sites. The source material indicated that positioning would be useful for larger construction companies or equipment lessors. Vehicles and other equipment can be monitored, which would make logistics more effective, since usage and transfers to other construction sites, can be done more cost– and time-effectively. Fiatech has done various researches on positioning and tracking of personnel and equipment in the U.S.A (Fiatech 2004).

Which mobile devices are to be used?

According to both the service users' and the service providers' data, mobile phones had the best price-quality-usability ratio at the moment of this research. This is partially due to a mobile phone's communication ability and the device's versatility. Since a phone's basic functions are well known to most of the Finnish workforce, new applications can be more easily adopted than e.g. an application on a PDA. When the application is simple enough and generates benefits for the user, he is motivated to keep on using it. From the construction company's point of view, most of the required functionality can be found in both mobile phones and PDA devices. Buildercom hopes that a mobile application could be used with any brand of mobile phones, but so far all their pilots have been done with a Nokia phone since Nokia has either been involved in the project or the application has been designed for Nokia phones.

A rugged mobile device would be the most logical and appropriate choice to a construction site's harsh environment. This was also confirmed during the service user interviews, but so far the applications used and piloted have been done with "normal" phones. The reason non-rugged phones were used was because the existing mobile applications were built onto Nokia's Symbian S40 or S60 series' platform (Nokia 2008). The service user group considered the fragility of a "normal" phone not to be a problem, so far. Even if a phone breaks, the cost of replacing it is small in comparison with the budget for the entire construction project. In the long run, however, construction companies would favour rugged mobile devices. Naturally, when mobile functionality gains a greater foot hold in the industry, there might be a need for functions that require larger screens than a mobile phone or PDA device can offer, such as laptops. Viewing the blueprints and other material on a laptop could be useful for construction inspectors and designers, but the construction sites' carpenters and other personnel will most likely continue to use blueprints in paper format for a long time to come.

What are the benefits?

To date, the mobile solutions for the construction industry have primarily been used on a pilot level and in large construction projects. The possible tangible benefits generated from these solutions have not been measured. Neither the service provider nor the service user group felt it necessary to measure the tangible benefits since the financial costs and possible revenues are very small in comparison to the whole construction project budget. However both groups have noted what intangible benefits there are and have also identified the tangible benefits generated from using mobile applications.

The safety monitoring pilot:

- Improved time efficiency during safety monitoring rounds; accurate time and place information supported by photographic evidence; less paperwork; speedy acknowledgement and resolution of problems; increased transparency and more accurate monitoring

The Jobsite logistics pilot:

- Improved time efficiency because of site preparedness; accurate, real-time information throughout the process; less paperwork; speedy rectifications of false or faulty material; easy, accurate and speedily done status reports and identification of arriving material; better transparency in the supply chain and enhanced B2B relationship.

Future challenges were considered to be, to find mobile solutions that will induce some of the following benefits: easier monitoring of personnel, licenses, permits, equipment and materials; improved time efficiency for all types of inspections; simpler and faster ways to grant permits and update personnel information; easier to find reports; accurate equipment, personnel and vehicle positioning; and better and more time efficient human and material logistics.

Conclusion and Discussion

The main research questions were presented in the introduction to this paper. These questions have been studied in this research and presented to support the conclusions on the respective research question. The following sections present the results on the four research questions.

One of the questions in hand was to find when and where mobile devices could be used in the construction industry. All the presented material from the construction industry's and the mobile technology industry's point of view indicates that mobile applications are best suited to and most needed at the construction site. A mobile application can support or even replace paperwork on recurring processes that are not part of the core business and a mobile application can also be used in monitoring.

Since today's mobile devices, and, especially, mobile phones support a vast variety of different functionalities, many new application forums could be found. Camera, RFID, GPS, GPRS and WLAN are some of the technologies that can be found in a mobile phone and that could be used in a construction project to make it more efficient. Many of these technologies have even been used already, at least on a pilot level, at construction sites. New application areas and ideas have also been presented from both the construction industry and the mobile phone industry – for example, various types of monitoring functionalities: everything from material, equipment and quality monitoring to personnel, inspections and work permit controls.

From the literature collected for this paper, it was considered important to have durable mobile devices. Interestingly enough, information received from the service user group indicated that the device's durability was not considered to be a problem. From the service users' and service providers' point of view, it is more important that the mobile applications are easy and logical to use. This ensures that the user, i.e. the workman, can effortlessly learn the new application and is motivated to use it. The current mobile phones and presented mobile applications contain these features.

At the moment, most of the bottlenecks in a construction project are caused by redundant paperwork at the construction site and lack of information. Some of this paperwork could be replaced with mobile applications. The aim would be to prevent the bottleneck and not just shift it to another area of the process; mobile applications must work flawlessly with the rest of the IS. One of these bottlenecks is also quality control in all forms; material and installation quality is not sufficiently monitored due to time pressure. Even if some material has a flaw there is usually no time to replace it, so, as long as the construction regulations are met, the workers make do with what they have.

Another big problem in the construction industry is managing human, administrative and equipment resources. This paper addresses the need to be able to locate and monitor equipment, vehicles and personnel. A company that has equipment and/or personnel at several construction sites constantly has a "travelling salesman problem". Moving equipment and personnel between sites can be better planned when there is better information on their whereabouts and different construction sites' needs.

From this study it can be seen that mobility generates qualitative benefits in the construction industry. There is also evidence that quantitative value can be generated, but this statement can not yet be proven. An in-depth empirical research should be done to get accurate results of the quantitative values, or lack of it. It is not currently possible to either measure the monetary values of mobile technology or compare them with the costs. Table 2 lists some of the tangible and intangible benefits that different mobile applications and technologies can generate. This table is composed from the study done in this research.

	Usage	Tangible benefits	Intangible benefits
Safety monitoring pilot	Construction site safety inspections	Less time needed on inspection rounds and paperwork speedy repair of problems => safer construction site	Simple, logical work process Increased transparency More accurate monitoring
Jobsite logistics pilot	Material identification. Fabrication, arrival and installment reporting	Improved time efficiency because of preparedness, fast setoff, fast rectification and less paperwork	Accurate, real-time information Improved transparency to whole supply chain Better B2B relationship
MMS & camera	Taking and sending photographs	Evidence	Support material
RFID	Identification of whole batch of items or material, equipment, personnel and place identification	Time efficiency Improved logistics	Easy monitoring Accurate, sufficient information
GPS (positioning)	Equipment, and vehicle positioning	More time and cost effective logistics planning	
GPRS (data transfer)	Transferring various types of data to IS	Less paperwork => time savings	More accurate information
WLAN (internet)	Communication		Real-time information, transparency

Table 2: *An example of benefits that can be gained from mobile applications and technologies in the construction industry.*

Further Research

The quantitative values could not be measured in this research. To ensure an increase in the use and development of mobile applications it would be practical to measure the quantitative and tangible benefits. This could be done with before and after observations, so that the time required with the mobile application can be scientifically compared with the time required for doing things in the conventional way.

Once mobile applications are in more common use in the construction industry, further research in the form of formative evaluation would bring new insights. This type of research primarily relies on qualitative data and is done to improve the existing products. Industry-specific details are taken into consideration in formative evaluation research so that the results - i.e. new and improved products - match a construction project's and company's needs.

One of the future challenges is the upcoming new EU waste legislation (EU waste legislation). There is a need for research on how RFID technology in particular could be used throughout the building's entire lifespan. Today, a building's lifespan is divided into three sections: construction, usage (facility management) and demolition. There are different operators for all these sections. Recently the construction industry and facility management sectors have started to cooperate, to find solutions for e.g. building waste problems. There is much that can be done with mobile technology in all sectors to make the processes more efficient and to improve customer service.

In the USA, where large construction companies can have sites spread out over vast geographical areas, positioning, local networks and mobile solutions could be very useful. Some studies have already been done on the use of mobile technology in the construction industry in the US (Fiatech 2004). Still, the mobile technology research done in Finland could also aim for the US market, since it would generate a more diverse research basis than could be obtained here.

References

Aspinen, J., (2007): Uudet haasteet ovatkin mahdollisuuksia (New Challenges are Actually Opportunities), Buildernews, (1/2007)

Era-Build (2006): "RFID in Construction (Review of the current state of Radio Frequency Identification (RFID) Technology, its use and potential future use in Construction)", Danish Technological Institute, Salford University, Greater Manchester University, UK, VTT, Technical Research Centre of Finland, Prolog Bygglogistik AB, Malmö and Lund University, Dept. Of Industrial Management and Logistics, Sweden. http://ebst.dk/file/8260/rfid_in_construction.pdf

EU waste legislation. Retrieved 21.2.2008, from http://ec.europa.eu/environment/waste/legislation/index.htm

Fiatech (2004): "Intelligent and Automated Construction Job Site (IACJS)" Capital Projects Technology Roadmap, FIATECH.

Haapasalo, H., Kanerva, J., (2005): Mobiiliteknologia rakennus- ja kiinteistöalalla (Mobile Technology in the Construction and Facility Management Industry), Technology report No. 187/2005. Tekes, Helsinki.

Holloway, S., (2006): Potential of RFID in the Construction Sector (White Paper) Solidsoft.

Hörkkö, J., (2006): Tuotantomalli Betonielementtien toimitusketjun hallinnassa (Production of Modeling for use in the Management of the Chain of Supply of Prefabricated Elements), betoni, Vol. 2 2006 pp. 46 - 47.

Keen, P., Mackintosh, R., (2001): "The Freedom Economy: Gaining the M-Commerce Edge in the Era of the Wireless Internet", Osborne/McGraw-Hill Berkley, California.

Kornak, A., Teutloff, J., Welin-Berger, M., (2004): "Enterprise Guide to Gaining Business Value from Mobile Technologies", Wiley Publishing Inc, Hoboken, NJ, U.S.A.

Nikulainen, P., (2005): Final Report Jobsite Logistics (mobile RFID), TeliaSonera, Helsinki.

Nokia (2008): Nokia 5140i. Retrieved 13.2.2008, from http://www.nokia.fi/A4312236

Nokia (2008): "Nokia Platforms", Forum Nokia, Retrieved 14.2.2008, from http://www.forum.nokia.com/main/platforms/index.htmlTekes (2008): VAMOS - Value Added Mobile Solutions 2005-2010 (VAMOS - Liiketoiminnan mobiilit ratkaisut 2005-2010). Retrieved 12.2.2008,
from http://www.tekes.fi/ohjelmat/vamos/

Patton, M.Q., (2002): "Qualitative Research and Evaluation Methods" (3rd ed.), Sage Publications, Inc., Thousand Oaks, California, U.S.A.

Rautiainen, A., (2007): Reimatorni vie paikallavalurakentamista eteenpäin (Reimatorni Supports Development of Cast-in-situ Construction), betoni, Vol 2 2007, pp. 86 - 92.

So, H.W.T., Chung, W.W.C., (2005): Mobile infrastructure in value network development: a case study of property management business, Production Planning & Control, Vol. 16**,** No. 6, pp. 586 - 596.

Työturvallisuus lähikuvassa (A Closer Look at Work Safety). (2004). builder news, pp. 3.

Työmaan turvallisuustaso kännykkään (Construction Site's Security Level into the Mobile Phone). (2008). JOKKA, Vol 1/2008