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Mobile Solutions and the Construction Industry
Is it a working combination?

Sonja Leskinen



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Abstract

Since mobile technology, foremost mobile phones have become part of our everyday life it is just a question of time before this technology will also be used as a helptool in our work. Naturally we already use our mobile phones for communication, but mobile devices could also be used for certain worktasks, e.g. confirmation, information and monitoring.

This work studies the possibilities and the economical aspects of implementing mobile devices into the construction industry. To do this, we first need information about the current situation and what kind of devices and applications are needed and in which situations they would be used. After these aspects are studied it is essential to assess the negative and positive impacts that the introduction of mobile technology would bring to the construction industry. This above mentioned research has been conducted through interviews, document analysis, and to some extent, observations.

In this study it became apparent from both interviews and other material that mobile devices could be used in the construction industry, and the trialed mobile application pilots were considered successful. Currently however, very few companies have implemented mobile applications into their daily routines. Mobile phones were preferred over other mobile devices, since they are familiar objects, so it was easy to start to use them even for other tasks than just communication. Early on it though became apparent that not all benefits from the usage of mobile applications can be measured in monetary values. Many of the benefits were considered to be of qualitative value rather than quantitative value.

Tiivistelmä

Mobiiliteknologia, etenkin matkapuhelimet, ovat osa jokapäiväistä elämäämme. Onkin vain ajan kysymys milloin mobiililaitteet tulevat myös osaksi työssämme tapahtuvia päivittäisiä rutiineja. Jo nyt puhelimia käytetään tehokkaasti eri aloilla kommunikointivälineinä, mutta niitä voidaan myös käyttää moneen muuhun tehtävään työmaalla, kuten kuittauksiin, tiedon välittämiseen ja valvontaan.

Tämän tutkimuksen tavoitteena on kartoittaa mitä voidaan saavuttaa tuomalla mobiililaitteita osaksi työrutiineja rakennusteollisuuteen etenkin taloudelliselta näkökannalta. Tutkimuksessa ensin selvitetään rakennusteollisuuden nykytilannetta ja minkä tyyppisiä mobiililaitteita sekä mobiilisovelluksia tarvitaan ja mihin prosesseihin ne soveltuisivat. Tämän jälkeen, kun on saatu selvitys sopivista laitteista, sovelluksista ja käyttötarkoituksista, selvitetään rakennusteollisuudelle saavutettavat hyödyt. Tämä tutkimus pohjautuu sekä havaintoihin ja kirjallisiin lähteisiin että haastatteluihin molempien alojen edustajien kanssa.

Tutkimuksessa havaittiin että mobiililaitteita voidaan käyttää onnistuneesti rakennusteollisuudessa. Lähinnä mobiilipuhelinten kanssa tehdyt pilotti sovellukset koettiin onnistuneiksi, mutta toistaiseksi hyvin harva rakennusalan yritys käyttää näitä sovelluksia päivittäisissä työrutiineissaan. Tutkimuksen aikana kävi myös ilmi että matkapuhelimet olisivat sopivin alusta sovelluksille, koska ne ovat jo entuudestaan tuttuja laitteita ihmisille, joka näin ollen alentaa käyttöönottokynnystä. Jo varhaisessa vaiheessa tutkimusta huomattiin että kaikkia hyötyjä, mitä mobiiliteknologia voi tuoda rakennusteollisuudelle, ei ole mitattavissa kvantitatiivisilla (rahallisilla) arvoilla, koska mobiilisovellukset johtivat myös kvalitatiivisiin hyötyihin.

Preface

This thesis was completed within VTT's Mobile Facility Management Services (FACMA) project. FACMA is VTT's strategic research project that started in September 2005 and will continue until year 2008. FACMA is a strategic research project which aim is to find viable business modles solutions for facility management. This is done by first evaluating existing and future FACMA services and investigating and implementing new business models. The aims of the project are to promote FACMA technology and create FACMA business blocks for markets. FACMA can be loosely divided into two areas, namely construction industry and facility management.

This research was done during the spring of 2006 and it attempts to find possible business ideas and business models in the area of construction, bearing in mind a buildings future facility management problems. This work also sheds light on the current situation in the construction industry as well as the bottlenecks in a construction project that need to be more efficient.

I would like to thank senior researcher Päivi Jaring for all her help, support and guidance during my work. I would also give my warmest thanks to professor Pirkko Walden at Åbo Akademi University, for all help and support she has given me, not only involving this work but also during my studies at Åbo Akademi University. I would also like to thank everybody who has helped me in my thesis at VTT, especially Tua Huomo and Tapio Matinmikko. Last but not least I could not have done this all without the support of my family, Jukka-Pekka, Katja, Ruusa and Oskari.

Oulu, 18th August 2006

Sonja Leskinen

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Abbreviations

2.5G	2.5 Generation
B2B	Business-to-Business
B2C	Business-to-Consumer
CDMA2000	Code Division Multiple Access
CF	CompactFlash card / slot
EDGE	Enhanced Data Rates for Global Evolution (also known as EGPRS)
EMU	European Monetary Union
EU	European Union
FACMA	Mobile Facility Management Services
FIATECH	Fully Integrated and Automated Technology
GHz	Gigahertz
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
IC	Integrated Circuit
IS	Information System
IT	Information Technology
IEEE	Institute of Electrical and Electronics Engineers
JIT	Just in time
Kbps	Kilobytes per second
LAN	Local Area Network
MMS	Multimedia Messaging Service
MHz	Megahertz
NFC	Near Field Communication
NPV	Net Present Value
OFDM	Orthogonal Frequency-Division Multiplexing

PC	Personal Computer
PDA	Personal Digital Assistant
PoC	Push to Talk over Cellular
RFID	Radio Frequency Identification
ROI	Return on investment
SD	Secure Digital memory card / slot
SEK	Swedish Crowns
SMS	Short Messaging Service
TDS	Tripod Data Systems
Tekes	Finnish Funding Agency for Technology and Innovation (Teknologian kehittämiskeskus)
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
VAMOS	Value Added Mobile Solutions
VGA	Video Graphic adapter
VTT	Technical Research Centre of Finland
WAP	Wireless Application Protocol
WDI	World Development Indicators
WLAN	Wireless Local Area Network

1. 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?

During my studies I have learned much about the construction industry, and with that knowledge I have come to believe that the introduction of mobile devices into the industry has potential. The technology that would be suitable is for the most part already on the market, although some modifications and new applications would be needed so it could be used in the construction industry. One of the remaining problems is finding devices that are durable enough for a construction site environment. Much development in this area has been carried out, and mobile phones that have enhanced durability and resistance are now available, such as the Nokia 5140 (Nokia 2005a). Even pocket PCs, such as "TDS Ranger", are made for heavy-duty use and harsh environments (TDS n.d.). These and some more durable mobile devices will be discussed in more detail in Chapter 4.2.

The Tekes' (Finnish Funding Agency for Technology and Innovation) VAMOS (Value Added Mobile Solutions) 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 thesis 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. The main business area in the construction industry is to build various types of buildings. Information technology (IT) merely has a support function in the construction industry, and mobile technology can be used to support IT. This is why outright economic benefits are difficult to measure.

This thesis is done as part of VTT's (Technical Research Centre of Finland) FACMA (Mobile Facility Management Services) project.

1.1 Aim of the thesis

The main objective of this thesis 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. This thesis also aims to pinpoint areas in the construction industry and construction projects where mobile functionality would be beneficial.

1.2 Methodology

To better understand what the market needs, this research will first examine what is involved in a construction project, in which elements mobile technology could be naturally introduced and in which areas mobile technology has already been piloted. This research also studies different mobile devices that could be suitable for use at a construction site as well as some technologies and networks that could be used. This information is found from different reference material interviews and from a framework analysis.

At the time of writing this thesis, Buildercom and TeliaSonera have already introduced mobile solutions aimed at construction projects. Interviews conducted at these companies give insight into how the service providers and construction companies perceive the use of mobile technology. More on this topic can be found in Chapters 5.1.2 and 5.1.4. Furthermore, this research conducts interviews at construction companies that have used either Buildercom's or TeliaSonera's mobile solutions in their projects. The aim of these interviews is to find out the pros and cons of working with mobile technology and, respectively, without it. Today's ways of managing equipment, human resources and administrative details are also part of the discussion.

This research includes an in-depth study of what mobile technology and mobile networks have to offer. There are several questions that need to be answered, such as how durable does the mobile device have to be, what are the fixed expenses, what type of benefits can be achieved, etc. For this, up-to-date information on various mobile devices and past experiences of the different mobile devices' suitability for construction sites is studied. Information available from similar cases is also included in the research.

1.2.1 Research problems

In this thesis I will study the use of mobile solutions in the construction industry. The main research problem is to find out what 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. The problems studied in this thesis correspond to the problems highlighted in the state-of-art study by Haapasalo and Kanerva (2005). Their research was conducted as part of Tekes' VAMOS technology program, and the main material was collected at a work-shop, held in Espoo, Finland, on 3.5.2005.

In order to find out if mobile technology could generate value for a construction project as well as for a construction company, the following main 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 - e.g. with a local network - and thus reduce the overall costs?
- Will the economic and other benefits of using mobile technology be enough to validate the costs?

1.2.2 Scope of the thesis

Although construction companies' operations are somewhat similar worldwide, the cultural, economic and geographical differences cannot be ignored. Because of Finland's geographical location, the buildings' isolation needs have to be

taken into consideration during construction. The same situation does not apply if we are building in Thailand, where there are other elements that need to be taken into consideration during the construction. This is why countries outside Scandinavia are beyond the scope of this thesis and this study will mostly concentrate on the construction industry in Finland. Of the large construction companies that operate in Finland at least four operate outside Finland, in other parts of Scandinavia. Furthermore, Finland's isolated location, geography and weather conditions make it an excellent ground to study elements in extreme conditions. The results of this research can, to some extent, then be implemented in other countries.

The research on different mobile solutions aimed for construction sites will concentrate on solutions that already have been piloted in Finland. Visions of future developments and applications will be included to give a more in-depth perception of the situation.

1.2.3 Research methods

This research primarily studies mobile technology's qualitative values in the construction industry, so an evaluation must be made to identify the values mobile technology has and can generate. According to Patton (2002), *Qualitative Research & Evaluation Methods*, there are three kinds of qualitative data, namely Interviews, Observations and Documents. Patton also divides evaluation research into two sub-areas: summative and formative. Summative research is used to judge the overall effectiveness of an intervention, whereas formative evaluations aim to improve programs (Patton 2002).

In this thesis the research is primarily done by summative evaluation, since it is important to first determine the effectiveness of the use of mobile technology in the construction industry. Once this intervention has been determined effective, further research could be conducted in the form of a formative evaluation (see Chapter 7.1). This research relies heavily on qualitative data, which is not normal for summative research, but not unheard of. To conduct a more accurate summative evaluation, the attempt is to identify quantitative values and find the means and tools to measure these values. This information will then have a supporting role to the known qualitative values.

The formative evaluation research is done by means of “evaluability assessments” - i.e. it is conducted through interviews, document analysis, and to some extent, observations. This is done to make sure that mobile technology and its usability in the construction industry can be clearly identified. The interviews are conducted with two target groups: the service providers and the service users. The results from both groups’ interviews are then analyzed and compared with each other and other reference material. A general picture and conclusions can be obtained from this analysis and comparison. According to Hirsijärvi S and Hurme H in their work “Teemahaastattelu” (Subject interview) (1993), a Norwegian researcher, Mon (1978), found that by an analytical comparison of the similarities and differences between the interviewed groups, one can make initial conclusions on the subject and start building theories.

The qualitative interviewing for this research is 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 the service providers and the other on the service users. The interview guides are included in the appendices for both these interview types (see appendix 1 and 2). By having a specific outline to the interview, which the interviewee could study beforehand, the accidental omitting of important and salient topics was reduced. Table 1 lists the people and companies interviewed. More detailed information on how the interviews were conducted is presented in the respective chapters (Chapter 5.1.1 and Chapter 6.1).

Company	Turnover	Employees	Market	interviewees name	role in company
Buildercom Oy	Private company, information not available		Finland	Juha Aspinen Matti Luhtanen	CEO Branch director
TeliaSonera	1,45 million €*	27 403	The Nordic countries, the Baltic states and Eurasia	Pasi Nikulainen	Director of large corporate customers and global accounts for TeliaSonera Finland Oyj (Finland)
Team Danielsson oy and Rakennus Luukila	Private companies, information not available		Finland	Henrik Danielsson	Site foreman
NCC Group	5,2 billion €*	21 000	Nordic countries	Riitta Takanen Ari Törrönen	Director of information management for NCC Construction Ltd (Finland) Development manager and business development for NCC Construction Ltd (Finland)
Skanska	13,2 billion €*	54 000	Sweden, the US, UK, Denmark, Finland, Norway, Poland, the Czech Republic and Argentina	Aila Vuoria	Director of information management for Skanska Oyj (Finland)
SRV Group	431,8 million €*	671	Finland, Baltic states and Russia	Jari Korpisaari	Security and safety Manager
YIT Group	3,0 billion €*	21 194	The Nordic countries, the Baltic states and Russia	Juhani Nummi	Development manager ICT for YIT Construction Ltd. (Finland)

* Turnover for whole Group

Table 1 Facts of companies and personnel interviewed for this thesis

1.3 Outline of the thesis

This thesis is divided into seven chapters. Chapter 2 will introduce different theories on how to evaluate IT and how it will be used in this thesis. Then both the construction industry and mobile technologies are studied to better understand the main elements of the thesis (Chapters 3 and 4). What is involved in a construction project is outlined to give a better general understanding of the process, and different mobile devices that could be used and have been used at construction sites are also introduced. Here there is also further discussion on the

pros and cons of different devices. Chapter 5 concentrates on piloted and future mobile solutions at construction sites. The service providers' points of view are also introduced in this chapter. A qualitative analysis is conducted by means of an interview analysis is conducted in Chapter 6. These interviews were conducted with the service users. The analysis results are also compared with other information introduced in the thesis. Chapter 7 summarizes all the important information for a conclusion. The research problems are answered and further research problems are discussed.

2. The value of information

An Information system (IS) can be defined as an interconnected set of information resources under the same direct management control that shares common functionality. An information system normally includes hardware, software, information, data, applications, communications, and people. It is rather evident to see that for instance to amazon.com, a well-honed information system has played a major role in their success. But for many industries, IS has a purely supporting role. Information technology, which is only one sector of IS, is used to efficiently handle everyday routine tasks, such as billing. This is the same in the construction industry. IT has replaced manual work in many areas, but the monetary value of this change is difficult to count.

Mobile technology opens up new options for the construction industry, where sites are often far away and communication between a site and head quarters is vital. Typically, mobile technology is used for voice and Short Message Services (SMS) with mobile phones, but there is so much more that could be done with mobile phones. Some mobility options, ideas and views that could generate value are studied in this thesis. Mobile technology at a construction site would support IT, so in essence it would have a supporting function to a supporting function. This section introduces some theories on how to evaluate IS as well as mobile technology.

It is difficult to make direct assessments of what mobile technology would cost and how it would benefit the construction industry. The majority of the physical products and mobile systems are already 'off the shelf' products - i.e. systems and software programs that can be used as is, without further development or modifications - but special applications aimed at specific needs are not and the services needed for a working mobile solution are not yet available or their prices are unknown. On the other hand, it is also very difficult to put a price tag on certain construction site job tasks; therefore, no comparison can be made between the traditional method and a new method. How much is it worth for the company, the project, the worker that certain routine tasks can be done more accurately, faster and even easier? Of course, if mobile technology can bring significant cuts in working time, this would also indirectly affect costs. But, so far, nobody in the construction industry has attempted to measure this.

According to Remenyi's (Remenyi 2004) research there are four major areas that have contributed to the problems with IT benefit measurement and management, namely:

1. Benefits and identifiable performance improvements
2. The issue of information systems' reach
3. Tangible and intangible benefits
4. Benefit evolution.

He also adds that "...it is seldom possible to produce a definite statement of all the benefits that an information systems development project will produce" (Remenyi 2004 p. 2). One must remember that all kinds of IT solutions can produce benefits that might even be intangible in financial terms, but still contribute to the success of an organization. There is usually no direct value to an IT investment, but it can produce derived value. Originally identified plausible IT project benefit suggestions might turn out to be false hopes, whereas unforeseen benefits can emerge during the project. The final value of an IT investment depends upon the way it has made the organization more efficient and effective. (Remenyi 2004).

2.1 Benefits of an Information System

One of the problems in measuring the value of information is because it is difficult to distinguish tangible values from intangible values. The intangible values cannot be measured with quantitative models, since they are of qualitative form. In Robson's work (1997) Clarke McKee Management Consultants survey on behalf of Prudential Corporation 1991 is presented. In this survey it came forth that for over 80 per cent of the organizations, intangible benefits accounted for at least 30 per cent of the value resulting from their IS investments. Figure 1, shows the most important intangible benefits rated in the survey (Robson 1997).

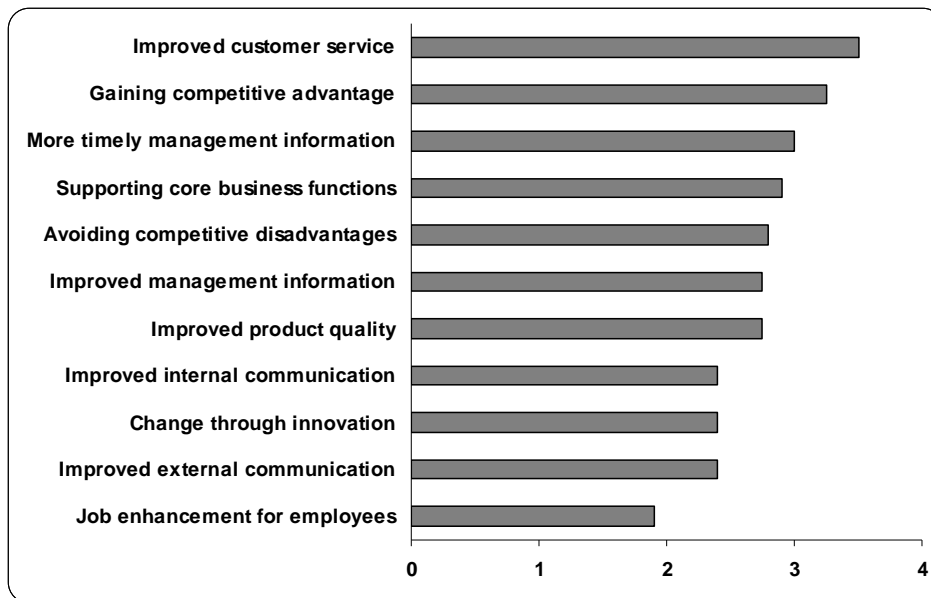


Figure 1 Relative importance of some intangible benefits in IS (Robson 1997)

The scale in the figure indicates how important a benefit is perceived to be, so that 0 represents unimportant and 4 stands for very important. As can be seen, the most important intangible benefit amongst the study group was improved customer service. All the benefits listed in Figure 1 are also of importance for the construction industry, since they can generate positive qualitative values within business-to-business (B2B) or business-to-consumer (B2C) functions.

2.2 When is the optimal time to invest?

In “The New Industrial Engineering”, Davenport and Short (1990) developed a simple model of how IT can benefit a company’s business. The basic design is that information technology must support the business structure and not be used just for the technology’s sake. At the same time, the company must be able to detach itself from old operation models, i.e. re-engineer, so it can support the

opportunities that IT brings. The model is illustrated in Figure 2 (Davenport and Short 1990).

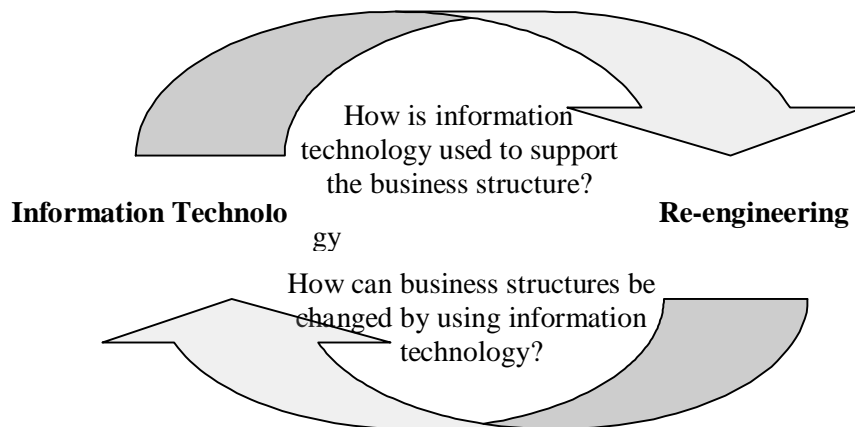


Figure 2 Information Technology (IT) and business re-engineering (Davenport and Short 1990).

Many companies struggle with the same question: when is the right time to invest in a new technology? Naturally the same problem occurs when the question is about IS investments. But when it comes to IS investments, decisions can generate added concerns since it is crucial to make the correct investment and at the optimal time. Information technology is still a rather new development in the grand scale, and thus how it will develop in the future is uncertain. Company decision makers often forget that after the initial investment in IS, several additional investments must be made in order to achieve, and maintain a quality system.

IS benefits are achieved when the balance of the costs incurred and the value gained is maintained, which is not a simple task to accomplish. Figure 3 illustrates this paradox. At first the costs rise sharply, but quality is hardly gained. Then, when the quality improves, a rise in value can be noted. The dashed line shows the optimum point, where the positive difference between

expenses incurred and value gained is greatest, and is, therefore, where the best balance is obtained (Robson 1997).

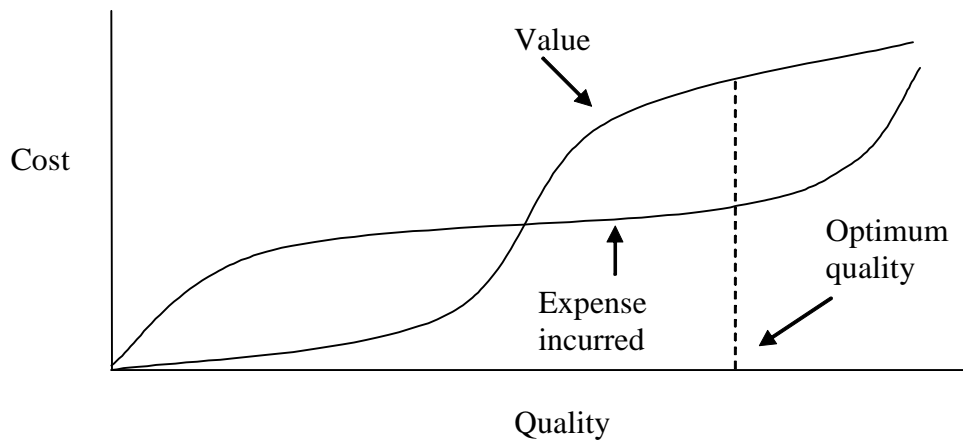


Figure 3 Balancing IS costs and benefits (Robson 1997)

2.3 Information Technology investment

Let's assume that, after careful studies, a company has decided to go forward with their planned IT investments. Unfortunately, the problems do not stop there, because now the IT must also be implemented in the company's everyday life. The list below gives some of the problems that might occur when implementing information technology into the business (Holopainen, et al. 1999).

1. The road to learn how to properly use IT is rough. At first there is always the problem of bad applications, disorganized business re-engineering and weak productivity that the company has to overcome.

2. It is difficult for the staff to adapt to new procedures. Every new concept takes time to digest; this is why it might still take many years until IT is considered to be part of every day life, like light bulbs or cars.
3. IT applications have various critical masses. First, when the utilization rate is high enough, tangible benefits can be noted. For example the first telephone had no value, since you could not call anywhere, but then the value increased with every new telephone connected. This is graphically represented in Figure 3.
4. The effects might be indirect. It is easy to see the direct benefits and effects of a computer, but it is difficult to predict what indirect effects and benefits might occur from integrating trade programs via extranet for better business-to-business co-operation.
5. The tangible benefits are often short-lived. IT does not usually distribute long-term advantages, because the commodity is within everyone's reach.
6. IT benefits cannot merely be measured in financial profits. There are so many variables that affect a company's profits that it is not possible to single out IT profits or losses within it.
7. IT is merely a tool that can be used either rightly or wrongly, but on its own, it does not do anything. Profits cannot be measured with causal models (A causes B), since IT, when used properly, can contribute to the causal chain but not be part of it (A causes B, when IT is used).

Figure 4 illustrates the development and structure of IS investments throughout a timeline; the changes in costs and value of the investment are represented on a timeline. For this figure to work, it is assumed that proper research has been done before making the decision to invest - e.g. NPV (Net Present Value) analysis. The same basic idea applies to all investments though.

- I) Costs rise sharply when the initial IS investment is made. The value of the investment does not increase at first, since it takes time to get the IS

operating in the desired way - e.g. personnel have to be trained and the system has to be tuned to support processes and business.

- II) At some point the company can efficiently use their IS, and even the value of the IS has increased to the desired level. Naturally, smaller additional investments must be made throughout the timeline to maintain an effective system. Once the use of IS yields financial value for the company, it also gains a return on investment (ROI), i.e. book income as a proportion of net book value (Brealey and Myers 2000). Naturally, maximum value should be targeted and obtained for as long as possible (compare Figure 3).
- III) At some point the value of the investment starts to decrease. There are several reasons why this happens, here are some examples: The company's business operations have evolved or changed in such a way that the IS does not efficiently support the altered processes
 - a. The technology is old and is not operating at an efficient level
 - b. The technology that once was unique has become a commodity, thus decreasing the value
 - c. The competition has risen to the same level by using the same or similar technology
 - d. The competition has a more effective IS, and can thus offer a better and/or cheaper service.

This type of value decrease can be exemplified with the value of wired telephones today. Initially, each telephone added significant value to the telephone manufacturer and the users, but today this value is rather minimal since there are already so many phones in the world. Currently the value for phones is actually decreasing, since mobile phones have increased their market share.

- IV) When the value of the IS decreases to a certain point, management once again stands at crossroads: make a new major investment or not (vertical line

in Figure 4). If they choose the latter, the value of the IS will continue to decrease (downward pointing dotted and dashed lines). This decision, and the consequences of it, should have been taken into consideration when making the initial investment analysis and decision. If however, a new IS investment is decided upon the costs increase and shortly after also the value (upward pointing solid and dashed lines). In a way, the same figure will repeat itself, but now both the cost and value levels are at the initial stage higher. Furthermore, past experience should enable a more rapid value increase, than during the first round.

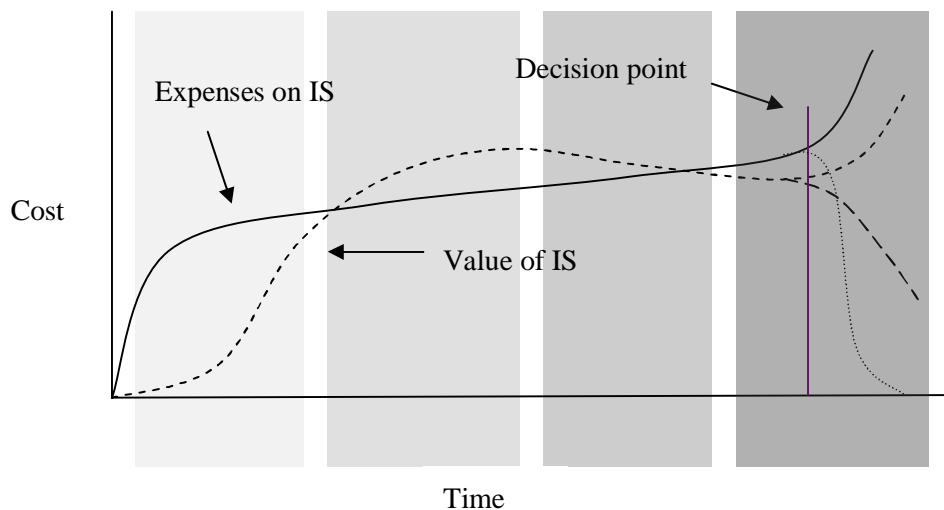


Figure 4 IS costs and value in a timeline

2.4 Values generated from Mobile technology

This chapter discusses in more detail how mobile technology, mobility and m-commerce can be used to gain business value. As with IS, benefits from mobile functionality can also be measured as tangible and intangible benefits and values. Some basic ideas of how mobile functionality can work in a manufacturing company are introduced (Chapter 2.4.1). The next chapter (Chapter 2.4.2) discusses how the value generated from mobile functionalities can be calculated.

Mobile commerce (m-commerce) refers to access to the internet via a mobile device, such as a cell phone or a PDA device (Learnthat.com). The survey, “Adoption of 3G+ services in Finland”, made in Finland in May 2002, studied the barriers and benefits of adopting m-commerce. In Table 2 the main benefits that the adoption of m-commerce was perceived to generate are listed. The survey consisted of 487 Finnish consumers which varied between ages 16 and 64. The sample group was asked about their perceptions, intentions and current experience with m-commerce and mobile internet. For the answers a 5-point Likert scale was used (5=strongly agree, 1=strongly disagree). In the table the first column represents the mean value. The next two columns represent the percentage of people who responded ‘strongly agree’ or ‘agree’ respectively ‘strongly disagree’ or ‘disagree’. (Carlsson, et al. 2006)

<i>Benefit</i>	<i>Mean</i>	<i>Agree (%)</i>	<i>Disagree (%)</i>
Enhanced communication features	3.74	68.9	18.9
Flexibility (anywhere, anytime)	3.73	64.9	14.9
Convenience and handiness	3.40	55.4	25.7
New dimensions of communication	3.07	43.1	33.0
Reminder and information services in real time	3.01	41.4	36.4
Uniqueness: exclusively mobile services	2.98	41.9	36.1
More effective use of time	2.78	37.8	44.0
Lower prices/special offers	2.72	29.7	41.2
Personalized information and services	2.24	22.7	64.1
Entertaining features	2.15	17.7	65.5
Being trendy/ahead of my time	2.04	15.4	68.8
Lack of proficiency with computers	1.89	16.5	75.1
Only connection to the internet	1.84	13.7	75.2
Accentuation of social status	1.65	8.4	81.3

Table 2 m-commerce Benefits (Carlsson, et al. 2006)

2.4.1 Mobile functionalities in manufacturing companies

This chapter introduces some methods of how a construction company can gain business value from mobile technology through studying manufacturing companies in general. Kornak, et.al. (2004) studied some specific areas in which

manufacturing companies can get benefits with mobility. According to them, there are primarily two mobility areas in which a manufacturing company can get tangible benefits; the possibility of remote connection and control of equipment, and bundling mobile functionalities with sold equipment to improve performance (Kornak, et al. 2004). The first area, remote control, would be best suited to moving equipment, such as forklifts, trucks and passenger hoists. With a mobile device one can remotely monitor and obtain information such as mileage, when the last inspection was, oil levels, etc. In this way the equipment can be handled and used in a correct manner, and, if complications occur, all relevant equipment information is available, and by bundling mobile functionalities with suitable equipment, wireless monitoring can be done. Some car manufactures, e.g. BMW, have already installed an inboard computer in their vehicles, so that the driver can wirelessly send a distress signal to the nearest authorized repair shop when a problem occurs. Before the repair shop even gets the car in, it already has an idea of what is wrong and which spare parts will be needed for repair. The tangible benefits here are that the repair shop is prepared for an incoming vehicle, so they can get their job done faster, and, as a bonus intangible benefit, customer service is improved.

It is easy to see how the first area can be used in a construction company, since equipment such like forklifts, etc, is used but how can bundling of mobile functionalities with sold equipment generate benefits? If a house could send out a distress signal when a pipe breaks, the construction company will at best only get the blame, not the benefit, since it is most likely that a plumbing company would take care of the repair. Since the construction industry is based on hundreds of specialist companies - cement-, metalwork-, electrical-, plumbing companies, and so on - mobile bundling should be used to increase co-operation within the industry, i.e. B2B. With the evolving RFID (Radio Frequency Identification) technology in particular, there are more opportunities for mobile functionality bundling. There are some pilots in this area, discussed in 5.1.5, and some possible further development ideas in 5.2.

2.4.2 Business Value

There is a logical model of how mobile functions affect the results. The effects can be either positive or negative, and at the same time, tangible or intangible

values (see Figure 1, Table 2 and Table 3). This same model will be used in Chapters 5.1.3 and 5.1.5 when studying existing and piloted mobile functionalities in the construction industry.

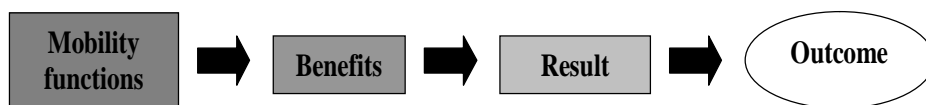


Figure 5 The effects of mobile functionality

As with IS, so the business value of mobility can 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 often to get reliable results. Without proof of tangible values, no solid business case can be built and upper management will be hesitant to make the investment. Here are listed some quantitative and qualitative benefits that have been identified as generating benefits in a manufacturing company (Kornak, et al. 2004).

Quantitative Benefits

Qualitative Benefits

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

3. Construction industry in general

This chapter studies what is involved in a construction project in general, and some of the details of the construction industry that are important for this research will be introduced.

The study handles both small and medium-sized construction companies as well as large construction companies. Usually, a smaller construction company has smaller construction projects, or brings specialist knowledge to a larger construction site as a subcontractor. Larger construction companies also have many small construction projects, but they are usually capable of handling larger projects as well. A small or medium-sized company is defined as a company that has less than 250 workers, an annual turnover of less than 40 million € or total assets under 27 million € and no large company owns more than 25 % of the stocks. This division is according to the EU (European Union) Commissions recommendations (96/280/EY) (Central Statistical Office of Finland, Tilastokeskus 2003). Whatever the size of the company or the project, the basics are the same for all.

3.1 Construction project

The following chapters are based on my interviews with different people working in the Finish construction industry as well as relevant literature. The interviewees are mainly involved in development and data administration and work in large construction companies. For more practical insight, Mr Danielsson, who works in a medium-sized construction company, offered a view from a site foreman's angle.

The saying "well planned is half done" applies even in the construction industry. The timeframe of the planning section (grey colour in Figure 6) depends on the size, shape and place of the building, the material choices and the project's price negotiations. Once the construction company and the client have reached an agreement, and all the licenses from the municipality are in order, the actual constructing begins.

The timeframe of the construction depends on the size of the building and the material choices, as well as the season and the type of building that is being constructed, e.g. warehouse or offices. Part of the construction phase is the finishing and interior section. This can be time consuming since it involves everything from building the walls, to installing the electric wires and water pipes.

Figure 6 is a simplified picture of a construction project, showing the various participants and their tasks at different phases of the project. The user does not necessarily have to be a physical company or person, but the potential users' needs have to be taken into consideration during the whole process. The developer has the main responsibility for the whole construction project. The architecture naturally handles the drawings and blueprints, whereas the constructors actually construct the building. The authorities inspect the project in many different ways and at several times to ensure that everything is being done according to the regulations (The Building Information Foundation RTS, Rakennustietosäätiö 1989).

		Production tasks				
		User	Developer	Architecture	Construction	Authorities
Construction project	Requirements	Expense, and requirements for the construction				
	Project planning	Insight on use and functional needs.	Budget and schedule	Pre-planning, option research	If required, gives insights and know-how	Draft briefing
	Investment decision					
	Construction planning	Planning the use	Steering and organization	Ideas, drafts and various blueprints	Production know-how and contract bidder	Construction license proceedings
Construction decision						
	Construction phase	Implementation preparations	Piecework contract, Construction supervision and final inspection	Execution plans	Piecework contract and construction	Various inspections, and final inspection
Accepting the building						
Use	Implementation	Implementation and organization		Usage and maintenance instructions	Possible warranty repair	
Warranty inspection						

Figure 6 Simplistic figure of a construction project (The Building Information Foundation RTS, Rakennustietosäätiö 1989).

Figure 7 outlines the time needed to make the building plans and construct the building (dotted pattern in Figure 6). The dashed lines mark the interval within which planning and construction should be completed. The black line is the probable timeframe for the tasks (The Building Information Foundation RTS, Rakennustietosäätiö 1989).

The time variation depends, amongst other things, on the purpose of the building, interior details, haste and seasonal differences.

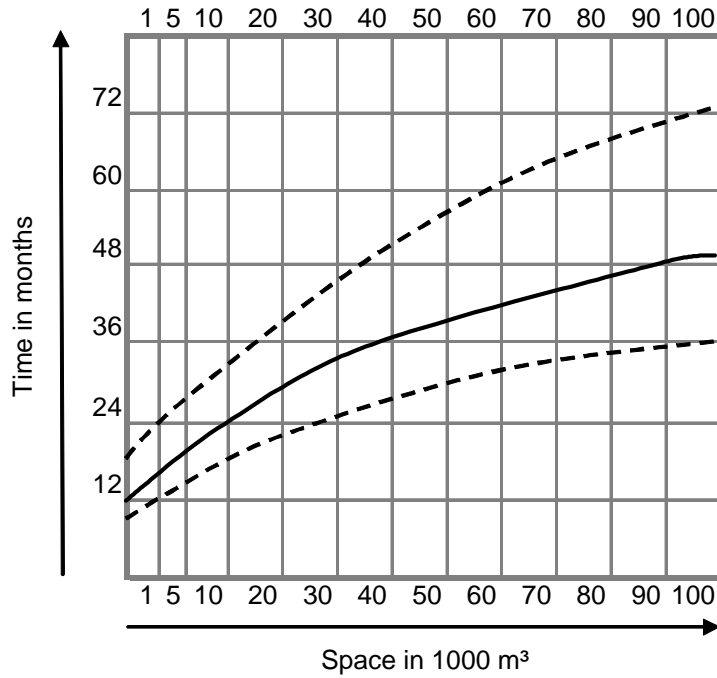


Figure 7 Time frame for a construction project (The Building Information Foundation RTS, Rakennustietosäätiö 1989).

Figure 8 is another visual representation of how much of the whole project's time is needed for planning and building. The lower line is the time needed for planning, and the higher line represents the time needed for the actual building process. (The Building Information Foundation RTS, Rakennustietosäätiö 1989)

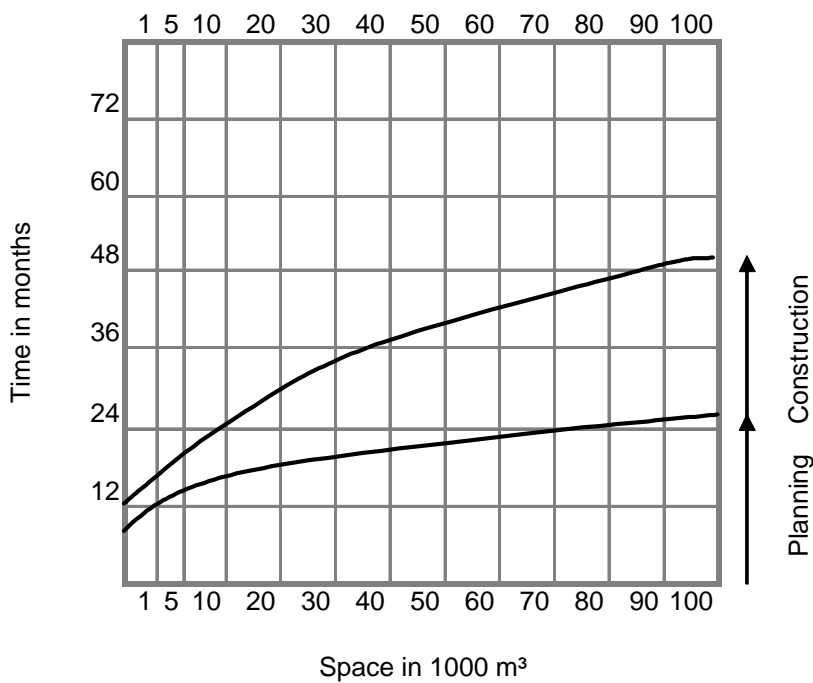


Figure 8 Time frame for planning and construction (The Building Information Foundation RTS, Rakennustietosäätiö 1989)

The time needed for requirements and project planning – i.e. the first two rows in Figure 6 – largely depend on the users' needs and financial opportunities. Therefore no standardized timeframe can be represented for these two project sections

3.2 Construction site

Once all the planning is done, new players enter the arena - the constructors. At the actual construction site are representatives from various fields, such as carpenters, electricians, plumbers and many more. Without strict regulations, schedules and know-how, a construction site would be chaotic. Some of the areas and activities of a construction site are presented in the following chapters. The information for these chapters was primarily obtained from interviews with Mr Danielsson and the service user interview group.

3.2.1 Logistics at a construction site

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. This is why a preliminary timetable is given to all the suppliers, subcontractors and lessor at the beginning of the project. Ordering is usually done by phone, fax, e-mail or mail, after which the supplier sends an order acknowledgement to the main offices. The acknowledgement that confirms the order is then forwarded to the person responsible, e.g. the site foreman.

When the material arrives, either the site foreman or somebody appointed by him acknowledges receipt. At this point the material should be inspected, but this is not always possible. Any claims for refund must usually be made within a week of receipt. In a worst-case scenario the whole site might have to wait for the correct material to arrive. This does not happen very often because if there is something wrong with the material, or if the material is incorrect, etc, there are other things that can be done at the site during this time. Usually, there is no

time to change incorrect material, so, if possible, it is used and compensations are made with a credit note.

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. Larger, more expensive equipment, such as earthmovers, are usually rented. Since the initial time schedule is also given to the equipment lessor, he can make sure that the equipment is available at the right time. This kind of foresight supports the Just in Time (JIT) strategy.

More companies are involved in larger projects and timetables are of the essence, which is why the relationship between the developer and the subcontractors must work fluently. Especially for projects that are within city limits, it is essential that everybody respects the timetables because there is usually no room for storage at the site and traffic to the site can be difficult. Equipment inventories are checked regularly at large sites. Scaffolding is often being replaced with more versatile cranes and person lifts. These and other large equipment are usually rented. Since the use of rental equipment has increased, it is important to keep an exact inventory of them, so that the correct machine gets returned at the agreed time, etc.

3.2.2 Safety and monitoring

It is very important for construction companies that the sites are safe, for everybody. There are regulations that state what can and cannot be done at a site. For example, every phase that involves fire, such as welding has to be done by professionals who have so-called "hot work licenses", and the welding area has to be accepted as safe for work involving fire. This fire work area permit is time-limited. At smaller sites the site manager or 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. Larger companies often appoint somebody whose job is to make these inspections. Labour protection authorities also make regular visits to the site to supervise industrial safety, and the labour protection district can conduct random checks.

Since 1.2.2006 it has been mandatory for everybody working at a construction site to have a pass complete with the worker's photo (Industrial safety law, työturvallisuuslaki 23.8.2002/738 chapter 6 § 52). The law was passed to ensure better monitoring and to hinder illegal workers at sites. For developers and main constructors of construction projects, this has brought new problems, because they have the responsibility for the site and that its legality. Monitoring can be extremely difficult, especially in a larger construction project, since there are workers from many different companies at the site. Even hundreds of subcontractor companies can be involved in a single construction project. These subcontractors have their own staffs, who have to have site passes, including photographic identification, to be allowed to work there.

Since construction sites are mostly outdoors, valuable items lay out in the open. However, robberies during daytime are not that usual. Some smaller articles disappear from sites, but large losses, such as can occur if the site has been robbed, are reported. All the more expensive equipment, such as power tools, are kept locked in a site hut outside of working hours. The hut is usually equipped with a burglar alarm, which is GSM (Global System for Mobile communication) based. If required, the end customer or developer can arrange additional security. The site is always insured against fires and there has to be extinguishing equipment available.

There are different phases of the work that need to be monitored at a construction site. For example when a cement-concrete base is laid the drying process requires specific temperatures. During winter the temperature might be too low, so a heater, covers, etc., are used to secure optimal temperatures. There are various types of cements, so if the concrete base is laid in the winter; cement that can be dried in colder temperatures is preferred. These kinds of cement are usually more expensive and therefore raise the cost of the concrete base. Fast-drying cement usually dries within one or two days, so the monitoring of it is easy. If the cement gets frozen in between, the concrete will be weaker and will not fulfil the required strength exigency.

3.2.3 Mobile technology and Internet at construction sites

The Internet is believed to be unnecessary at smaller construction sites, whereas at bigger sites it has been noted as handy. Sites do not normally have their own phone lines, etc. This is why the use of mobile phones has made many things easier in the construction industry. A lot of the arrangements with distributors, workmen and others are done by telephone, which is naturally much easier now that there are mobile phones. At small sites mobile phones are not used for other than actual calling or SMS (Short Messaging Service) messaging. At larger sites some mobile applications have been piloted. These pilots will be discussed further in Chapters 5.1.3 and 5.1.5. Today, the company arranges a mobile phone for some of the personnel to use, if their work requires it.

3.2.4 The completed construction

After the building is completed it usually has a warranty time. This time varies according to the building's size and what is stated in the contract. For smaller buildings the warranty time lasts two years after implementation. A site journal is maintained during the construction, so that what was done each day can be checked. Any changes that were made from the original plan are also marked here. If the completed building has construction mistakes or problems, the information about when the part in question was done and any possible changes from the original plan, etc., can be checked in the journal. For the most part, any problems that occurred during the construction are not noted but are based solely on the memory of the workmen at the site. Problems often occur because there is a flaw in the installation of the material or the material itself, which, in the latter case, is the responsibility of that specific materials supplier. Because one project can have many suppliers and materials it is very difficult to actually find the reason behind the problem or who is responsible for it.

3.2.5 Costs and time consumption

Most constructions are basically done in the same manner, i.e. planning, groundwork and finally interior. How much time each building step will take depends on the time of year, building type and size, and where the site is located.

During the actual construction phase, the construction of the basis of the building and the outer walls are the most costly. This is also dependent on which materials are chosen. To some extent, the environment and time of year dictates what kind of materials can be used to get the desired result. Building the interiors on the other hand takes the most time, but is dependent on the type of building. More time is needed for houses and offices than for a warehouse, since they have more specific details.

At an ideal construction site materials arrive at the right time and the workmen needed for specific tasks are in the right place at the right time, but this is not what happens in reality. Materials and people are not always where and when they should be and incorrect or damaged materials can slow the process significantly. Most delays are due to human errors as well as internal and external problems.

Apart from the direct problems mentioned above, mandatory tasks might also take lot of time. Paperwork in all its forms takes time, and is not even necessarily directly part of the main business. Furthermore, the constructor or developer has to ensure that different inspections according to the regulations are conducted throughout the entire construction project. A construction site also has wiring for electricity, phone lines and security monitors. Wiring and re-wiring in pace with the construction progress is time consuming and, to make matters worse, loose wires can easily be snapped by heavy equipment.

4. A mobile and wireless construction site

This chapter studies mobility and what is required to get a wireless construction site. In all honesty, this cannot be done with the present technology, but some parts of it could be wireless, like communication and data transfer. According to The American Heritage Dictionary, wireless is defined as “having no wire or wires” and mobility is defined as “1. Capable of moving or of being moved readily. 2. Changing quickly from one condition to another” (The American Heritage Dictionary 1992, cited in Kornak, et. al. 2004). According to these definitions, a car is mobile and an apple is wireless. This is naturally true, but in this context the words mobility and wireless need a more accurate definition. According to Kornak, et.al. (2004) mobility can be defined as:

The application of mobile devices and wireless technology to enable communication, information access, and business transactions from any device, from anyone, from anywhere, at anytime (Kornak, et al. 2004 p. 4).

This definition of mobility and wirelessness concurs with the scope of this research. Wireless applications are separated into public and private sections (Kornak, et al. 2004). For this study, the public section is more interesting, since it handles networks, location-based services, positioning systems, etc.

Mobile technology can be divided into four sub-areas: mobile business solution, mobile application, mobile service and mobile work (Alahuhta, et al. 2005). A mobile business solution is a business-oriented solution that uses mobile devices. Functions on a mobile device, such as data storage and –processing, are part of the mobile application. The service providing the previously mentioned solutions and applications are a natural part of the mobile service. Mobile work is the whole working environment that enables workers to work when and where they want.

Today's society is becoming gradually more "mobile". Over 53 % of the Finnish population uses the Internet, and, according to WDI's (World Development Indicators) 2005 statistics, there are approx. 442 computers per 1,000 people (WDI 2005). In 2004, 66 % of all calls made in Finland were made with a mobile phone (Central Statistical Office of Finland, Tilastokeskus 2005). The overall statistics for EMU (European Monetary Union) countries is about the

same, but the more important fact is that the number of personal computers (PC's) and mobile phones are and have been rising for many years, and in 2004 there were 96 mobile phone subscribers per 100 people in Finland (Central Statistical Office of Finland, Tilastokeskus 2004). With so many mobile phone users, one would think that mobile commerce is also part of everyday life, but this is not the case. Businesses and consumers are still reluctant to adopt m-commerce. Table 3 lists the main barriers preventing m-commerce adoption among consumers, and how they perceived them. The survey was done in Finland in May 2002 part of a study on “Adoption of 3G+ services in Finland” (Carlsson, et al. 2006).

<i>Barrier</i>	<i>Mean</i>	<i>Agree (%)</i>	<i>Disagree (%)</i>
High operating costs	3.95	73.7	13.4
High initial costs	3.81	69.5	18.6
Limited capacity of mobile devices	3.77	63.8	10.0
Slow connection and/or data transfer	3.68	54.2	10.4
Fear of privacy invasion	3.56	58.6	20.6
Security risks	3.55	57.9	22.6
Uselessness of services	3.50	52.9	18.9
Small screen size of mobile devices	3.50	59.7	25.2
Poor coverage of networks	3.37	48.4	20.9
Complexity involved in using mobile services	3.34	45.4	21.5
Complexity involved in operating mobile devices	3.01	37.1	36.4
Lack of new mobile devices on the markets	2.88	25.7	31.5

Table 3 m-commerce barriers (Carlsson, et al. 2006)

A 5-point Likert scale was used (5=strongly agree, 1=strongly disagree) for the answers. In the table the first column represents the mean value. The next two columns represent the percentage of people who responded ‘strongly agree’ or ‘agree’ respective ‘strongly disagree’ or ‘disagree’. (Carlsson, et al. 2006)

Computers and mobile phones have also spread into different professions and industries. Today, work without a computer would be nearly impossible in some branches. A mobile phone and/or a portable computer (laptop) allow the worker more freedom which is way many companies offer their workers laptops. The

trend can be seen in Finland, where the number of laptops with comparison to the number of table computers has increased since the beginning of 2005 (Kotilainen 2005).

From the interviews with people working in the construction industry it can be concluded that computers and, to some extent, mobile technology have become a part of everyday life in this industry as well. Usually, people who are in charge of the construction site, or have other managerial responsibilities, rely on laptops and/or mobile phones. Much of the information exchange with subcontractors, suppliers, etc., is done via a mobile phone, either by calling or by SMS-messages. A laptop is useful when one person has to manage several construction sites. The laptop can be easily transported, making it practical to collect information from everywhere. Chapter 5.1 describes more specifically how mobile devices have been used in the construction industry so far.

4.1 Wireless Networks

The different network possibilities that a construction site might have are discussed in this chapter. Most wireless network technologies offered are for indoor use, so this chapter will shed some light on networks that can be used outdoors, since construction sites are outdoors. Wireless networks would be preferable at construction sites because cables easily get tangled or snapped and they need to be moved many times during the construction process.

The wireless network should be convertible, so that it can evolve simultaneously with the construction. It has even been suggested that in the future there will be demand for a network that is used during the construction and then remain behind for use by future inhabitants of the completed building. At the moment this is not possible, since electric cables for the construction site's use are entirely separate from the building's electric cables. Cables used during construction are removed once the construction is completed.

Existing network technologies that are already included on smart phones are mainly mobile communication technologies. These include GSM, GPRS (General Packet Radio Service), EGPRS or EDGE (Enhanced Data Rates for Global Evolution), UMTS (Universal Mobile Telecommunications System) and

CDMA2000 (Code Division Multiple Access). Short-range networking technologies are primarily IEEE (Institute of Electrical and Electronics Engineers) 802.11B WLAN (Wireless Local Area Network), and Bluetooth. The latter two technologies can often be used on PDA (Personal Digital Assistance) devices. (Kornak, et al. 2004; Penttilä, et al. 2005)

4.1.1 2.5 Generation: GPRS, EDGE and CDMA 2000

At the end of the 20th century the big hype was the so-called third generation of wireless industry technology. It was a bold idea, but the mobile industry soon noted that the time was not quite ripe for such an advanced technology. GPRS, EDGE and CDMA 2000 are part of the so-called 2.5 Generation (2.5G). This is practically "...an intermediate solution to third generation networks" (Kornak, et al. 2004 p. 67).

Part of the functions that 2.5G provides is speed of data access. Better data access allows us to send photos and files, which plays an important role in some of the mobile technology pilot cases at construction sites. These will be introduced in Chapter 5.1. GPRS enables an "always-on" capacity in the wireless network. Broad-band Internet, in comparison with modem connections, makes faster connections and larger data file transfers between computers possible. GPRS does the same thing for mobile phones, but naturally the speed is not in the same range as broad-band Internet connections. With GPRS one can transfer data at speeds in the range of 115 Kbps (Kilobytes per second). EDGE is simply a faster version of GPRS. With EDGE technology data can be delivered at rates up to 384 Kbps. These speeds already enable functions such as downloading videos on mobile devices (Kornak, et al. 2004).

4.1.2 Local networks

The IEEE 802.11 local networks, which also go by the names WLAN and Wi-Fi, are meant for indoor use. Outdoor use would require much more of the actual physical nodes, since they would have to be able to withstand wind and rain. The basic idea is the same though: with the help of 802.11 networks you can connect computers and other mobile devices to each other and to the Internet with the

help of radio signals. The coding technique is known as orthogonal frequency-division multiplexing (OFDM) (Kornak, et al. 2004).

4.1.3 Bluetooth

Bluetooth is a short-range wireless technology that can connect several different kinds of electronic equipment to each other. It is designed to exchange data, and can do this up to speeds of 720 Kbps. Bluetooth's range is up to 10 meters, depending on what type of Bluetooth is used. In comparison with GPRS and EDGE, Bluetooth is a bigger security risk because it is easy to probe information from a Bluetooth device, and the range within which it can be properly operated is limited. (Kornak, et al. 2004)

4.1.4 RFID

Basically an RFID system contains tags, readers and an application host. The readers communicate with the tags to obtain information wirelessly. There are two kinds of RFID tags, passive and active. A passive tag harvests energy from the reader's communication signal, while an active tag contains both a radio transceiver and a button-cell battery to power the receiver. (Ni, et al. 2003; Penttilä, et al. 2005)

4.1.4.1 Passive RFID tags

As mentioned above, passive tags do not have their own power source: therefore the reader controls the communication since the tags are not able to take the initiative. Often, the tag's IC (Integrated Circuit) is programmed so that it needs to receive the reader's request first. Most RFID systems enable both single tag and simultaneous multiple tag identification. Passive tags are mainly used to replace bar codes (Ni, et al. 2003; Penttilä, et al. 2005). Even though passive tags can not contain much information, the idea is that one can search additional information from the integrated IS's back and end system with the tag's identification number.

Nokia's RFID solution is part of its NFC (Near Field Communication) technology. It uses passive RFID tags, and operates in the 13.56 MHz (Mega hertz) RFID frequency range over a distance of a few centimetres (Nokia 2005a). The following diagram is an architectural representation of how Nokia's NFC technology works.

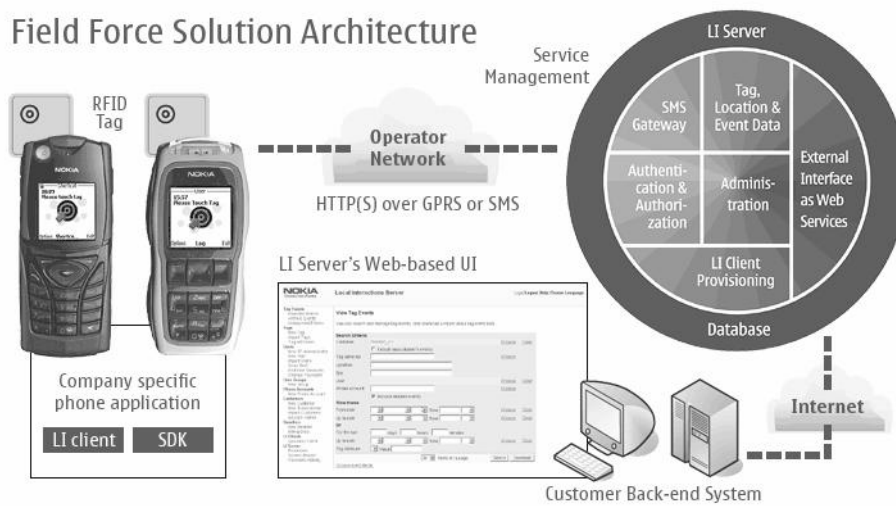


Figure 9 Nokia's Field force solution architecture (Nokia 2005a)

4.1.4.2 Active RFID tags

Unlike passive tags, active tags contain a button-cell battery to power the tag's radio transceiver. Because of this onboard radio, active tags have more range than passive tags (Ni, et al. 2003). The problem with active tags is that the tag is more expensive than the passive tag and has a limited life expectancy because the battery can not be changed. Recent studies and developments to make a more flat battery that could be installed directly into the tag are ongoing. At present, the battery's life expectancy is 5 years (Wikimedia Foundation 2006).

4.1.4.3 Wal-Mart, leading the way of RFID

Wal-Mart Stores Inc. became one of RFID technology's forerunners in 2003 when the company announced that by 2005 its 100 key suppliers must use RFID to track goods through the supply chain. The first main target for Wal-Mart was that this technology would improve inventory management. Since Wal-Mart initialized the use of RFID, other retailers have also used the technology, such as Marks & Spencer PLC and Procter & Gamble Co. (Turban, et al. 2005).

The launch of the use of RFID was a success for Wal-Mart in many ways. RFID journal reported that, according to a study done in University of Arkansas, many promising results were found - e.g. by using RFID there was a 16 per cent reduction in out-of-stock products (Roberti Oct. 14, 2005). After such encouraging results, many companies have started to plan, test and even use RFID in their line of business to save time and be more efficient.

4.2 Mobile devices

This chapter further studies the kind of mobile devices that could be used in a construction site environment. The information is gathered from various sources, such as interviews and various reference materials. The preferable device would be durable and able to withstand the harsh weather and dust particles that are common at construction sites. The device should also be easy and logical to operate (e.g. big buttons, touch screen and/or high-density display), since construction workers often wear gloves that obviously limit the hands' finer functions. The desired optimal mobile solution would enable the worker to perform routine functions even while wearing gloves. Furthermore, the mobile device should to some extent tolerate impacts with a hard surface, which might occur if the device were dropped.

Apart from the device's physical requirements, there are also software requirements. At workshops conducted on 3.5.2005 it was considered important that the devices can be easily linked together and that the user interfaces are as similar as possible in order to increase the usability (Haapasalo and Kanerva 2005). Some features could become useful at a construction site are GPS (Global Positioning System), GPRS, Bluetooth, RFID-reader, compatibility with

common computer programs (e.g. Microsoft Windows or similar), and communication and Internet access via WLAN or similar. These features could be used in many routine tasks at a construction site, such as information distribution to subcontractors, suppliers, head office, etc., checking-in products, security checks and communication.

Naturally, one device can hardly possess all these abilities, and still be within a reasonable price range. Therefore it seems reasonable to consider the option of having different kinds of devices at a construction site. There is, though, the possibility that this will increase the costs, since some of the more advanced products are relatively expensive and not commonly used. Therefore it is important to note that not every worker would have to have a mobile device, but key people at a construction site should have access to them. Further research and user opinions on the device, and who would need them, will be further studied in Chapters 5 and 6.

4.2.1 Mobile phones

Most mobile phones are not made to endure the rough conditions that might occur at a construction site, but there has been demand for phones that can tolerate more rugged handling, and these have emerged onto the market. Rugged phone manufacturers promise better resistance against dust, water, being dropped, vibration, etc, than the "normal" mobile phones. Mobile phone manufacturers such as Ericsson, Nokia and Siemens have had or still have phone models that are advertised as being "tough" (mPhone n.d.). In an Internet search, the so-called outdoor phones from Sony-Ericsson could not be found. It also seems that neither Samsung nor Motorola have mobile phones that are designed for outdoor use. The mobile phone market is constantly changing though and it is uncertain what models will be available in six months' time. Nokia's and Siemens' "outdoor" mobile phone models are presented below. The prices given are the average price according to this thesis author's price study at four of the larger Finnish stores selling mobile phones. These stores were Elisa shop, Päämies, Gigantti and Viestimaa.

4.2.1.1 Nokia

Nokia's so-called "rugged phones" that are available at the moment of writing this paper, are the 5100, 5140 and 5140i models. Of these, the most recent studies show that the models 5100 and 5140 have been discontinued (mPhone n.d.). According to Nokia's information, the 5140 and the 5140i have "Xpress-on™" shells that provide protection against splashes and dust. The shells also give improved durability against bumps, and protect the inner module. Even the connectors are protected by a bottom flap (Nokia 2005b).

Basically, the 5410 and the 5410i are the same phone, at least on the outside, but they have differences in software, etc. The main diversities between these two models are mostly entertainment-based. Both the phones have a 27.3 mm x 27.3 mm display. The models incorporate an MMS (Multimedia Messaging Service) and SMS text messaging camera and GPS. (Nokia 2005b)



Figure 10 Nokia 5410 (Nokia 2005b)

What makes these models interesting for this study is the fact that an RFID reader can be integrated into them. Why an RFID reader is integrated into the phone is because of the premise that mobile phones will soon be carried by almost all customers, and this makes a mobile phone a suitable platform (Penttilä, et al. 2005). The RFID reader can read the 13.56 MHz (Mega hertz) frequency and is operational within a few centimetres of the tag. How Nokia's

RFID reader and NFC technology works was presented in Chapter 4.1.4 (Figure 9). At the time of writing this paper, a 5140i phone costs approximately 201 €

4.2.1.2 Siemens

Siemens has four so-called outdoor models: M75, ME75, M65 and M65 Rescue edition. All these models have improved dust and water splash protection and shock resistance. They all have what is presently perceived as the standard mobile phone operations, such as calling, SMS and MMS messaging, camera and GPRS. They also all have an infrared interface, and data exchange with a PC is possible through a USB (Universal Serial Bus) cable. Only the M75 has Bluetooth and none of the models have RFID or GPS (Siemens 2005). According to this thesis author's price study at the time of writing this paper, a Siemens M75 costs approximately 282 €, an ME75 199 € and an M65 159 €



Figure 11 Siemens M75 (Siemens 2005)

4.2.2 Comparison of Mobile phones

Table 4 lists, among other things, the above-mentioned features that a mobile phone should have at a construction site. The information in the table is collected from Chapter 4.2.1

		Nokia		Siemens		
		5140	5140i	M75	ME75	M65
Communication	GSM	Tri-band	Tri-band	Tri-band	Tri-band	Tri-band
	"walkie-talkie"	PoC	PoC	no	no	no
Messaging and imaging	SMS	yes	yes	yes	yes	yes
	MMS	yes	yes	yes	yes	yes
	Camera	VGA	VGA	1,3 Mega pixel	VGA	VGA
Mobile access	WLAN	no	no	no	no	no
	WAP	2.0	2.0	2.0	2.0	2.0
	e-mail	yes	yes	yes	yes	yes
Data transfer	GPRS	53.6 kbps	62.4 kbps	53.6 kbps	53.6 kbps	53.6 kbps
	Bluetooth	no	no	yes	no	no
	RFID	accessory	accessory	no	no	no
Positioning	GPS	accessory	accessory	no	no	no
Display	pixels	128 x 128	128 x 128	132 x 176	132 x 176	132 x 176
Price	Base unit	-	201 €	282 €	199 €	159 €
accessories	RFID	approx.	approx.			
	13.56 MHz	140 €	140 €			
	GPS	129 €	129 €			

Table 4 Mobile phone comparison

All phones have GSM communication, but both the Nokia 5140 and 5140i models can also be used as a "walkie-talkie" with the help of the PoC (Push to Talk over Cellular) function. No mobile operator is needed with PoC, it costs nothing to use. As can be seen, all these phones have a camera, which is handy if there is a need to photograph a faulty element for example. The mobile phone's camera function has already been used at construction sites. A pilot case on mobile applications where the camera is used is presented in Chapter 5.1.3.

Siemens' M75 has Bluetooth, which will ease communication with other devices, but for the other phones data can be transferred with a USB cable or GPRS. There are some differences in the GPRS data transfer speed. The Nokia 5140 and 5140i models have EDGE, which allows Mobile broadband access with up-load and download speeds up to 177.6 Kbps (kilobytes per second). So basically it is a more advanced GPRS with faster data transfer. These models can also be used for GPS positioning and they can read RFID tags if used with the proper accessories.

4.2.3 Portable computers (laptops)

There are some rugged portable computers on the market. However, during interviews it came forth that usually only the site manager, and at larger sites also other key personnel, need a portable computer. Since these people can mostly do their computer work indoors, the computer does not have to tolerate so much dust, etc. However there does seem to be a rather large market for rugged portable computers, which is understandable since the US military and other armed forces use durable computers. Panasonic, Promarc Technology and Getac are a few of the brands manufacturing rugged laptops (Technology n.d.). The interviews with the service users made it clear that at the moment, and in the near future, there is no need for rugged laptops. Therefore, the matter will not be further studied here.

4.2.4 PDAs and other handheld computers

In the handheld computer market, such as Personal Digital Assistant (PDA), Palm, Pocket PC, etc., there seems to be some devices that could be used in the construction sites' harsh environments. Tripod Data Systems (TDS) designs and manufactures hardware and software for mobile computing. The handheld devices are designed for extreme outdoor conditions and are used in the United States by the military, law enforcement and the construction industry (TDS n.d.). At the moment there are three products that could be suitable for construction site work: "Ranger", "Recon" and "DuoTouch". These products are briefly presented below.

4.2.4.1 Ranger

TDS Ranger comes in two different models: 300X and 500X. Both models have the same physical size, 26.6 cm x 13.1 cm x 4.8 cm. They also have Microsoft Windows Mobile™ 2003, a touch screen, and an integrated speaker and microphone as standard features. The Ranger models are operational down to -30 °C and they meet the US military's MIL-STD-810F standards for drops, vibration, humidity, altitude and extreme temperatures. They are also sealed against water (1 m for 30 min) and are impervious to dust. Integrated Bluetooth is a standard issue in the 500X, but is an optional feature in the 300X. Integrated 802.11b (WLAN) is an optional feature for both Ranger models, as well as a variety of other accessories. An RFID reader can be connected to the Ranger models via one of the two CompactFlash (CF) slots or the Secure Digital (SD) memory card slot. Both models also have a USB client port. (TDS n.d.)



Figure 12 TDS Ranger (TDS n.d.)

Additional computer programs can be downloaded to the TDS Ranger models so they can be customized according to individual needs. The TDS Ranger can be used as a "walkie-talkie" but does not have mobile phone functionality. Wireless communication with a central computer is possible via Bluetooth or the optional WLAN interface. The latter also enables wireless Internet access. (TDS n.d.)

Information about TDS products in Europe was received in e-mail correspondence with Sofia Löfblad and others at Handheld Europe AB. Ms. Löfblad also provided the recommended selling prices for TDS Ranger and other

products. In the 2005 July pricelist the Ranger 300X price was 20,692 SEK which is approximately 2,188 € (based on Nordea Bank's 8.12.2005 exchange rate of 1eur = 9.4577 SEK). The Ranger 500X price in the same list was 25,867 SEK, which is approximately 2,735 €. The optional WLAN 802.11b for Ranger 300X, which would give wireless Internet access, costs 1,875 SEK = 198 €. For the RFID reader, the device needs both the reader and an extended CF-cap (CompactFlash cap). These cost 4,281 SEK for a 125 kHz RFID and CF-cap, and 3,053 SEK for a 13.56 MHz RFID and CF-cap which is 453 € and 323 € respectively.

4.2.4.2 Recon

Similar to the Ranger the Recon has the same endurance and meets the MIL-STD-810F standards. It is smaller than the Ranger, with a physical size of 16.5 cm x 9.5 cm x 1.75 cm. The Recon also has Windows Mobile 2003 as a standard feature, and other software can be downloaded to the device. An RFID reader can be inserted into the Recon, as well as a Bluetooth kit or a socket communications 802.11. (TDS n.d.)



Figure 13 TDS Recon (TDS n.d.)

If there is need for many of the optional features at the same time, such as, Bluetooth, WLAN and RFID reader, this would not be the optimal device. Recon can only support one or two of these accessories at a time. The more limited features in comparison with the Ranger can be seen in the price. The

price varies from 11,696 SEK to 14,336 SEK or 1,234 €- 1,516 € according to Nordea Bank's exchange rate on 8.12.2005. The RFID readers, including the extended CF-caps, have the same price for Recon as for Ranger. A socket Bluetooth CF card costs 1,440 SEK = 152 € and WLAN (802.11b) with the required midsize CF-Cap costs 1,374 SEK, which equals 145 €. There are two RFID readers for this model, a 125 KHz and a 13.56 MHz reader. The 125 KHz reader with the required CF-cap costs 4,281 SEK, which is approx. 453 € and the latter, with the required cap, costs 3,053 SEK, or 323 €

4.2.4.3 DuoTouch

DuoTouch differs from Ranger and Recon since it does not have a keypad. As the product's name implies, it has a touch screen, on which most of the operations are done. The touch screen has both active and passive functions. Communication is possible with implemented GPRS, WLAN and Bluetooth. As with the two previously presented devices, this device also meets the US military specifications to tolerate drops, etc., and it is also water and dust resistant to some extent (TDS n.d.).



Figure 14 TDS DuoTouch (TDS n.d.)

The operating system for the DuoTouch is Microsoft XP Tablet Pc edition. An RFID reader can be attached to DuoTouch via a UBS port or Bluetooth. According to the June 2005 pricelist provided by Sofia Löfblad from Handheld Europe AB, the DuoTouch base unit's price is 25,560 SEK, which, according to the previously used exchange rate, is 2,703 €. An integrated Bluetooth price is approx. 92 € and an integrated 802.11b for WLAN is approx. 209 €. The RFID reader would cost approx. 225 €. GPS and GPRS are also available as optional accessories. The GPS costs 3,080 SEK = 326 € and the GPRS costs 5,720 SEK = 605 € (TDS n.d.).

4.2.5 Comparison PDA's and other handheld computers

Table 5 compares some of the important functions of handheld computers needed at a construction site according to the specifications mentioned at the beginning of Chapter 4.2. The information in the table is collected from Chapter 4.2.4.

		TDS			
		Ranger 500X	Ranger 300X	Recon	DuoTouch
	max operation time	30 h	30 h	15 h	15 h
processor speed		520 MHz	312 MHz	200 MHz	1,1 GHz
Communication	GSM	via internet	via internet	no	via internet
	"walkie-talkie"	yes	yes	no	yes
Imaging	Camera	accessory	accessory	accessory	
Mobile access	WLAN	optional	optional	accessory	optional
	e-mail	via internet	via internet	via internet	via internet
	GPRS	accessory	accessory	accessory	optional
Data transfer	Bluetooth	yes	optional	accessory	optional
	RFID	accessory	accessory	accessory	accessory
Positioning	GPS	accessory	accessory	accessory	optional
Amount of CF or SD slots		3	3	2	1
Amount of USB-ports		1	1	1	2
Display	special features	Touch screen and outdoor readable	Touch screen and outdoor readable	Touch screen and outdoor readable	Touch screen and outdoor readable
Price	Base unit	2 735 €	2 188 €	1234-1516 €	2 703 €
accessories	Bluetooth		198 €	145-152 €	92 €
	WLAN	198 €	198 €	145 €	209 €
	WLAN + Bluetooth		297 €		
	RFID 13.56 MHz	323 €	323 €	323 €	323 €
	GPRS			298-564 €	605 €
	GPS			265-333 €	326 €

Table 5 Comparison of PDAs and other handheld computers

Of these products, no single product could be seen as inferior to the others, since they all have features that could be useful. Even though some of the models are bigger and/or heavier than others, they are still relatively easy to operate and can be carried in a big pocket if needed. With the accessory features, any one of these devices could be used at a construction site. The question is, how many of the desired accessories can be used on the device at the same time - i.e. how many input slots can be used and how many accessory devices can the product handle without losing functionality and processing speed?

4.2.6 Comparison and summary

This chapter discusses the differences between the mobile devices presented in the previous chapters. This does not exclude the use of other devices with similar software or other features, but these devices would have the durability required at a construction site. Tables 4 and 5 listed the functions most likely to be of use in the construction environment, so the differences in the entertainment aspects, etc., are not listed. The prices in the tables have been obtained from the various sources presented in the corresponding chapters.

According to information from the Central Statistical Office of Finland, (2005) almost everyone in Finland has a mobile phone, so it is logical to assume that

most of the workforce at a construction site also have a mobile phone. This is why a new mobile phone application could easily be implemented into the everyday work routine. According to the interview material, mobile phones had a more positive response from the workforce at construction companies where both PDA's and mobile phones had been tried. Since the basic functions of mobile phones are already rather well known to the workmen, new applications and programs would not be difficult to adopt, but the basic logic behind the functions of a PDA or other handheld device is less familiar.

It seems that mobile phones and PDAs have many similar functions and are developing towards a mutual goal, but the devices' original business concepts are very different (Kornak, et al. 2004). Some key elements need to be considered when comparing PDAs with mobile phones, such as size and utilization of the device, compatibility and ease of data transfer with onsite or head quarter computers, PC compatibility, communication options, barcode or RFID-tag readability and positioning, etc. The pros and cons of the different devices are:

- Size, weight, form etc.: The TDS devices are bigger and heavier than mobile phones, but are designed to fit in the hand. Even though mobile phones are easier to carry around, they have much smaller keys and screens than TDS devices; the worker would have to take his gloves off to use a mobile phone's keys. A Touch screen could be especially handy at a construction site since it could be used with a touch screen pen. All the studied devices would most likely be durable enough for use at a construction site.
- Ease of use: Mobile phones are used almost daily, so new usage areas would be easier to implement. TDS devices are not in common use and would require some training before they could be used with the same ease as mobile phones. The mobile phone also has added value since it can be used for personal purposes.
- Data transfer: All the discussed mobile products can transfer data wirelessly via GPRS, although some need appropriate accessories for this. Data transfer speed is considerably higher for TDS devices than for mobile phones. Of mobile phones, only the Siemens M75 can transfer

data via Bluetooth, while all the TDS devices have this option at least via accessory devices. Both TDS products and mobile phones can also transfer data via cable.

- PC compatibility: The studied mobile devices have PC compatibility, but the TDS devices also support Microsoft Windows Mobile which is similar to Windows on computers. Since TDS devices have a bigger memory capacity than mobile phones, they can have more programs that are compatible with PC programs. If the device needs to have high compatibility, the TDS devices are the preferred option.
- Communication options: Apart from TDS Recon all the devices have some sort of voice communication possibilities either via the Internet or as a "walkie-talkie". Communication with GSM is very easy with mobile phones, while there is a need for an Internet connection to get similar communication with TDS devices. Nokia's 5140i devices can also be used as Walkie-talkies with PoC, but they can only communicate with other PoC devices. The TDS Ranger also has a "walkie-talkie" function.
- RFID-tags, barcode, etc., readability: Nokia's 5140 models and TDS models can be used to read RFID tags. TDS products can also be used to read barcodes.
- Positioning: GPS is only available for Nokia's 5140 models and as optional or accessory features for TDS devices. This feature is handy if the device needs to know where it is. An example of such a function is presented in Chapter 5.1.4.
- Camera and picture quality: Today's mobile phone models are almost always equipped with cameras, mostly because of its entertainment value. A camera can also be included in the work task and is already being used at construction sites for documentary purposes, etc. The TDS devices do not have cameras, but can handle pictures.

Whatever the device, it has been found important that the user - i.e. the worker - finds work with the help of the mobile device more appealing than the old

system. The change to a new system must be justified to the worker, and the application must be both user-friendly and efficient. This can be achieved if two main issues have been kept in mind while planning the application, namely: how, when and what type of data is being captured, and how will the presentation of the information be adapted to the process? (Kornak, et al. 2004)

It is also possible to have an assortment of different mobile devices at a larger site. Then it becomes important that the different devices interact well together. It is questionable whether a construction company would provide all its workers with mobile phones, or other mobile devices, since this would be relatively expensive. Mobile devices with many usable functions should be provided for some key personnel. If incoming material is labelled with RFID tags, bar codes or similar, the people who have authorization to sign in the material would have the necessary equipment to do it with etc.

Of all the presented products, the mobile phones are the cheapest. With a relatively small price tag you can get a product that has many useful functions. A mobile phone is also already a known product so it would be easier to take into use in new areas. One problem would be to decide which workers need a special work phone, and how the use of the phone could be monitored. These aspects and other views on mobile technology from the constructions industry's point of view are discussed in the Qualitative analysis section (see chapter 6).

5. Mobility at construction sites

In today's society, time is of essence. The JIT concept must work for a construction company to gain customer satisfaction and remain competitive. Every detail in a construction project must be done effectively, accurately and in minimal time. At the same time, new EU Directives are laying the entire construction process responsibility, from site safety to personnel identification, onto the developers (Haapasalo and Kanerva 2005). On the other hand the developers feel they should not have the liability, since they cannot in any way monitor all the subcontractors' workers, etc. Intense discussions are still ongoing, but one thing is for sure: the legislative pressures towards the construction industry are increasing.

The current and future mobile solutions are studied next. The current solutions section introduces Buildercom's and TeliaSonera's views on today's construction industry's mobile functionality, piloted solutions, opinions and future developments. The future mobile solutions chapter is largely based on Jussi Kanerva and Harri Haapasalo's report " Mobile technology in construction and facility management" (Mobiiliteknologia rakennus- ja kiinteistöalalla) (2005), and other reference material and interviews.

5.1 Current solutions

The following chapters list the solutions and future plans for Buildercom and TeliaSonera. These two companies have conducted pilot projects that involve mobile technology with several construction companies in Finland, and are, therefore, the forerunners in this aspect. Chapters 5.1.2 – 5.1.5 are primarily based on interviews conducted with people at Buildercom and TeliaSonera, and other reference material. These companies form the service provider group of the previously mentioned interview groups. The following chapter introduces the interview methods for this group, after which both Buildercom's and TeliaSonera's general views, opinions and some specific ideas will be introduced.

5.1.1 Interviewing methods for the service provider group

The interviews for the service provider group were conducted in January 2006. Buildercom and TeliaSonera have conducted pilot projects with the companies in the service user group. Therefore, these companies were a logical choice for the service provider interviews since the results from both interview groups would support each other. The people interviewed at Buildercom and TeliaSonera were chosen because of their field of activities and their personal contributions to some of the pilot projects. The interviews were conducted by the author of this thesis, according to the “interview guide” method. The questions are presented in Appendix 1. The interviews lasted for approximately 1½ hours and were recorded on a digital player. The material on the tapes was then transcribed, not word-for-word, but just the main points and ideas. This method allows the interviewer, who knows the material best, to collect the material into a logical entity.

Company	Interviewees name	role in company	Interviewing location	Interviewing date
Buildercom Oy	Juha Aspinen	CEO	Jyväskylä, Finland	9.1.2006
	Matti Luhtanen	Branch director		
TeliaSonera	Pasi Nikulainen	Director of large corporate customers and global accounts for TeliaSonera Finland Oyj (Finland)	Helsinki, Finland	9.1.2006

Table 6 Service provider interviewing table

5.1.2 Buildercom

Buildercom is a Finnish company founded in 2000. It offers innovative building and facility management solutions and services. Some possible future developments in the construction industry from both Buildercom's and the mobile industry's point of view came forth during interviews with Juha Aspinen (CEO) and Matti Luhtanen (Branch director). The construction industry is rather conservative, and it is unlikely that the introduction of mobile technology into

the industry will bring anything new to the core business. But this is not even the point; the idea is to use mobile technology to make the construction industry more efficient in some of the critical areas. Mobile technology should support existing work models and not create new ones, and is therefore ideal to support the JIT model and time-consuming routine tasks.

At the moment, Buildercom has a database service into which all information on a project can be inserted and used via the Internet. It costs approx. 500-1,000 € to open a project and thereafter, depending on the number of users, 300-500 € per month. For recurring customers and licensed customers the fee is negotiated. At Buildercom they approximate that adding mobile services, such as safety monitoring, to the service would cost an additional 100-200 € per month. Buildercom would only provide the service; the client has to supply the required physical devices and the mobile subscriber connection. The developer usually buys the database service, sometimes even the contractor. The owner then decides who can use the system since not every small item supplier has to have access to the database. In Jyväskylä there has even been a pilot program where the authorities had access to the database, which was useful when monitoring inspection notes.

In Buildercom's opinion the benefits mobile technology can bring to the construction industry are that the project's efficiency, transparency and manoeuvrability will increase, giving better control over the project. Their database solution already increases efficiency and transparency, but mobile devices would bring added value to the existing system. Mobile technology and a suitable application is even considered to be of use when monitoring logistics - e.g. people, material and equipment

Mobile phones have been preferred over other mobile devices so far, since they enable communication as well as the taking and sending of pictures. At the moment, according to Buildercom's views, the main problems with mobile phones are that they have small screens, small keys, limited memory capacity and phone models, as well as their software getting renewed at a very rapid pace. When the programming code gets changed very often it becomes increasingly problematic to design working software into the mobile phone's code - e.g. the same software will not necessarily work with models made at the beginning of the year by the end of the year. Buildercom has started negotiations with Nokia

to remedy this type of software problem. An additional argument for mobile phones is that it is a more intimate device than, e.g., a PDA. A PDA device would most likely be owned by the construction site or company, whereas a mobile phone is more personal and would be taken better care of since it is also the means of communicating with other people. The question of what in the end would be the most suitable mobile device - a phone, laptop or PDA - is still under debate.

Laptops are good devices when there is a need to use a bigger monitor - e.g. when blueprints are to be inspected, etc. The idea that every carpenter would have a laptop with the building blueprints on it instead of the usual paper ones is still a very futuristic idea though. However, designers, inspectors and construction authorities could have use of a laptop. Every aspect of the building and much more can be stored in a computer's memory. A laptop is easier to carry and work with, even in a changing environment, than big, bulky paper rolls that the wind can blow away.

5.1.3 Buildercom's state-of-the-art pilot projects

5.1.3.1 Safety Monitoring Pilot

According to the decision of the Council of State, every construction site must regularly conduct site safety monitoring (Council of the State, Valtioneuvosto 1993). This type of monitoring has already been widely used in other industry sectors, but is rather new to the construction industry. The idea is that hundreds of sightings are made during a safety monitoring inspection, and recorded in a site safety document. Correct and incorrect work attire, scaffolding information, etc, are noted in this document. When the inspector notes that a workman does not have his safety helmet on, he makes a note of it, but he also makes a note when he sees a workman with the proper attire. The same idea also applies to machinery and structures; the inspector documents both scaffolding that is in accord with the safety regulations and that which is not. At bigger construction companies some areas, such as site safety, are concentrated on key personnel, who monitor several construction sites. A construction site is considered to be safe if over 85 % of the sightings are flawless.

Mobile phones were chosen for the site safety monitoring pilot project with mobile devices on the grounds that people are most familiar with them. The majority of Finnish people use their mobile phones daily, so it is easy to learn new applications that implemented in them. A Construction company, SRV, first tried to use PDA devices in the pilot, but the devices were soon disregarded because, among other problems, workmen had trouble learning how the device worked.

Buildercom's site safety monitoring pilot was done with Nokia phones, but there might be interest in the future to get the same type of system working with other phone brands since some companies use a specific phone brand. However, this, as well as phone operator choices, is more up to the construction company to decide, not Buildercom. The mobile phone used in the Pilot project was from Nokia's S60 series. These phone models are not rugged phones, such as the 5140 and 5140i are. The S60 series was chosen because the site safety application builds on the existing Symbian Java software.

Here is an example of how the pilot worked: A railing is missing from the scaffolding. The inspector makes a note of it on his mobile phone and, by means of checking off the right box, he also takes a picture of the incorrect scaffolding. He then sends this information to either the person responsible or to an e-mail address, depending on pre-agreement. When the person who is responsible for the scaffoldings gets the message, he should fix the problem. When the missing railing is put on the scaffolding, the repair is noted in the safety monitoring document via the mobile phone. In some pilots, because the mobile functionality was connected to the database offered by Buildercom, the safety monitoring could even be in almost real time monitored via Internet (Buildercom 2004).

Usually, the safety monitoring at construction sites is documented on paper and added to the site reports. The inspections are time consuming and the papers might get lost. With Buildercom's pilot, the whole safety monitoring process can be done much faster. It is evident that there is a need for a better system since BookIT, a company that amongst other things, specializes in intelligent SMS technology, has also conducted a construction site monitoring pilot.

Following the initial Buildercom pilot, several other construction companies have also tried the mobile safety monitoring system. Some companies even use

the system regularly at large construction sites. Further views and opinions on this pilot from the construction industry’s angle will be discussed in Chapter 6.

Figure 15 represents the effects the safety monitoring mobile application has on a construction company. The model for this figure was presented in Chapter 2.4.2.

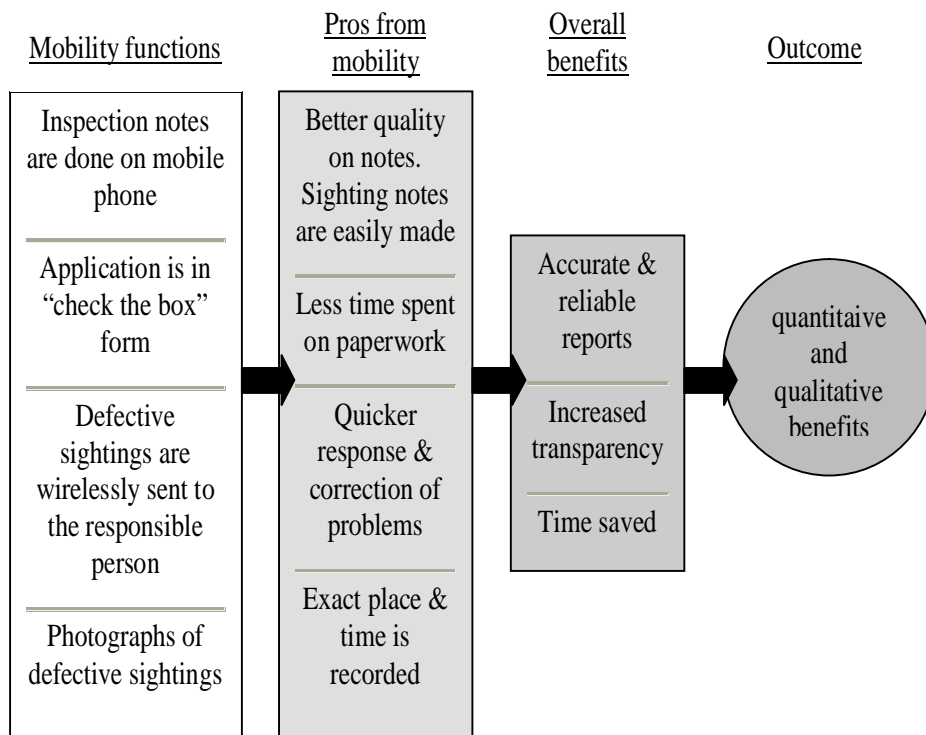


Figure 15 Effects of mobile safety monitoring application

5.1.3.2 Quality Control Pilot

At the time of writing this thesis, Buildercom's Quality Control pilot is not yet complete. SRV Viitosen has used the Buildercom mobile pilot at the "Ideapark" shopping centre construction site. Ideapark has a very large indoor area with a vast amount of tiling. In this pilot, the quality of the ground tiles is being monitored with the help of mobile phones. Since this is still an ongoing pilot, the results have not yet been published. (Buildercom 2005)

5.1.4 TeliaSonera

According to TeliaSonera's business concept:

TeliaSonera provides reliable, innovative and easy-to-use telecommunications services for carrying and packaging of voice, images, data, information, transactions and entertainment (TeliaSonera 2005).

At TeliaSonera the interview was conducted with Pasi Nikulainen, who is the director of large corporate customers and global accounts. He has also recently been involved in pilot projects with the construction company Skanska and others. During interviews about possible uses of mobile technology at a construction site a few focal points came forth, such as wireless network, logistics and site monitoring. Currently he considers one of the larger problems to be that sites have their own budgets and it is hard to get new technology to fit into that budget: any changes made should happen throughout the whole construction company.

5.1.4.1 General views

At TeliaSonera there is a strong belief that wireless connections are the future. Wires at a construction site get easily tangled up or broken by machines, etc. Larger sites nowadays have Internet connections, but usually it is not wireless and only the main contractor can use it. There is however a need for the other contractors to be able to use the Internet as well. In this way, time would not be lost with checking e-mails, paying bills, etc.

The typical WLAN nodes are meant for indoor use, and do not tolerate harsh outdoor weather conditions. Furthermore, these nodes are connected via wire. What a construction site needs is nodes that are meant for outdoors and do not require wiring. This type of wireless network could easily get moved simultaneously with the building's progression, and then used at the next construction site. At the moment the prices are still so high for this technology, so it is doubtful that a construction company would be willing to invest. There is also the problem of who would pay for the devices and the service, since it could possibly have several users.

An Internet connection at a construction site could also be helpful for consultants, designers, inspectors etc. Blueprints or even live footage of the site could be checked via the Internet if it was available. Naturally, protective measures must be taken so that only authorized personnel could access the website.

5.1.4.2 Monitoring

TeliaSonera already has a working alarm and monitoring package called "Sonera Alerta". This is mainly used for completed buildings, such as homes, offices and warehouses, and is not directly suitable for construction site conditions. The alarm package can include not only fire and burglar alarms but also different kinds of monitoring systems, such as temperature and hygrometer, depending on the client's needs. There is sometimes a need to monitoring temperatures at a construction site, e.g. when it is vital to get a certain strength of concrete base. The concrete will not be strong enough if the temperatures are too low, even for a moment. But this is more of a niche service and is most likely not profitable if sold separately.

A hygrometer system or water monitoring system could be useful since new pipes might have problems because the plumber has forgotten to tighten a bolt, etc. If the leak is not detected in time, it can cause a great deal of damage overnight. Just by monitoring how much water flows in and out of the building can help to detect leaks. With the TeliaSonera system, an alarm is automatically sent to a designated phone when a problem is detected. The client would have to buy or lease the required equipment for this system. This would cost approx. 500-1,000 € However the same equipment could be used at several sites since it

is expected to last for three years. At the moment the TeliaSonera Alerta service that is meant for indoor use costs 100 € and thereafter 25 €/ month. Redirecting of the alarm via a mobile phone costs 0.29 €/ message + normal GSM fees. Mr. Nikulainen estimates that a package with robot mobile phones, which would be needed at a construction site, would cost more than the current price range.

5.1.4.3 Localization

There might be problems with positioning, especially with apartment buildings. An apartment is currently localized by the apartment's number, but if it has two bathrooms, how are you to know which tiles go into which bathroom? In these situations, errors are made too often because the exact location of some interior elements cannot be localized. Accurate positioning could also help officials and other people who need to inspect the building. TeliaSonera has two main ideas on how localization inside a building could work. One idea is to have RFID tags at the door to identify the room. Another idea is to have GPS technology in a laptop so that positioning is possible. The laptop would use GPS to search the exact location from the blueprints, so the laptop user could check that the blueprints correspond to the area he resides in. Even a combination of the two ideas could come in handy. With RFID tagging, the tiles of one bathroom could "inform" the workman where they belong - e.g. bathroom nr.1 RFID tag's information does not concur with tile package nr.1 RFID information but bathroom nr.2's RFID does. Conclusion: tile package nr. 1 should be installed in bathroom nr. 2.

5.1.5 TeliaSonera's state-of-the-art pilot projects

5.1.5.1 Jobsite Logistics Pilot

In the autumn of 2005 TeliaSonera, Skanska (Finland) Oy, Nokia Corporation, Fenestra Oy, RKL A. Taskinen Oy and Enterprixe Software Ltd. together launched a pilot project on logistics monitoring with mobile devices. The main research problem for the pilot was how to link a virtual model to the real world and physical items in real time (Nikulainen 2005). The main objective for this project was to find new options that make logistics more fluent. According to the construction companies, the site foreman might daily have to do up to two hours

of logistics-related paper work. This paper work mainly consists of checking the delivery documents to see which items have arrived and cross-referring that information with the invoices, checking reports on defected or incorrect material, and then approving the invoices in accordance with the previous information. As can be seen, this takes a large amount of his time that could be used in "real" work, not double-checking data. Furthermore, delivery documents might get lost and reports can be illegible, so the process is not foolproof. With today's technology it is possible to electronically confirm invoices for items that have already arrived, but many construction companies are not yet ready for this development.

In the Job Logistic pilot project, windows from Fenestra Oy and some concrete elements from Taskinen Oy 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 were used to read RFID tags at both the factory and the jobsite. In Figure 16 the Jobsite logistics outline is presented. The following list introduces the supply chains notification models in the pilot, which can be compared with the logistics outline in Figure 16:

1. Manufacturers send information when fabrication of an item starts and/or when an item has been completed.
2. Manufacturers inform jobsite which items are loaded on the arriving truck.
3. At unloading on the jobsite a worker uses the mobile phone's RFID reader to identify each item as being received. Any possible defects can also be reported in this phase.
4. After the item is installed a status report is made via the mobile phone. Any detected defects can also be reported in this phase.
5. A manager or foreman checks each installed item and sends an OK or defect report.

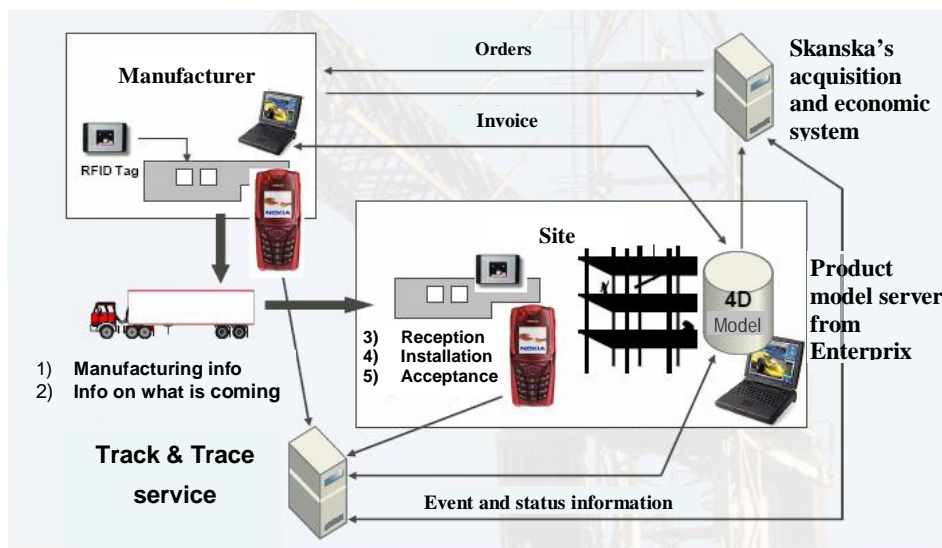


Figure 16 Jobsite Logistics Outline (Nikulainen 2005)

Mobile phones were used to read the 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 is an "off-the-shelf" product and was considered easy to use and would work well at jobsites and in factory environments. The RFID tag reader operated as it should and was easy to use because of its "touch the tag to read it" function.

During and after the pilot project many of those involved requested tags that could be read from a distance, in addition to the current tags, so that, e.g., a whole truck load of items could be read with one "sweep". This could be done with double tagging - one set of tags for the individual items and then a "main tag" for the truck or container.

Currently, there is usually no information on when or what elements will arrive at the construction site. The manufacturer packs the elements so that the truck is as full as possible, and not necessarily with the elements needed most urgently. Often there is no prior information on which elements are arriving at the site since it is decided the same morning. With windows, for example, this is not a problem since the installation period is not critical time-wise, and even if there are some flaws in the windows, there is time to correct the error. However, this is not the case with kitchen cabins, etc, which are installed a few days before the construction should be completed. Kitchen furniture is also usually very individual and, therefore, is apt to contain more flaws, and installation is also more problematic. This is why it is vital to get information on manufacturing, etc., in time.

The Job Logistic pilot also generated new ideas for possible uses of RFID tags. Fenestra sells windows both with and without Venetian blinds. However, if the client wants to install blinds later, it is not economically profitable for Fenestra to send somebody to check the window's size. If the window had an RFID tag, the real-estate manager could read the information with his RFID reading phone and send the information to Fenestra, who then have 100% accurate information with which to make the blinds and send to the client.

Figure 17 lists the effects of the job logistic pilot mobile application, according to the model presented in Figure 5.

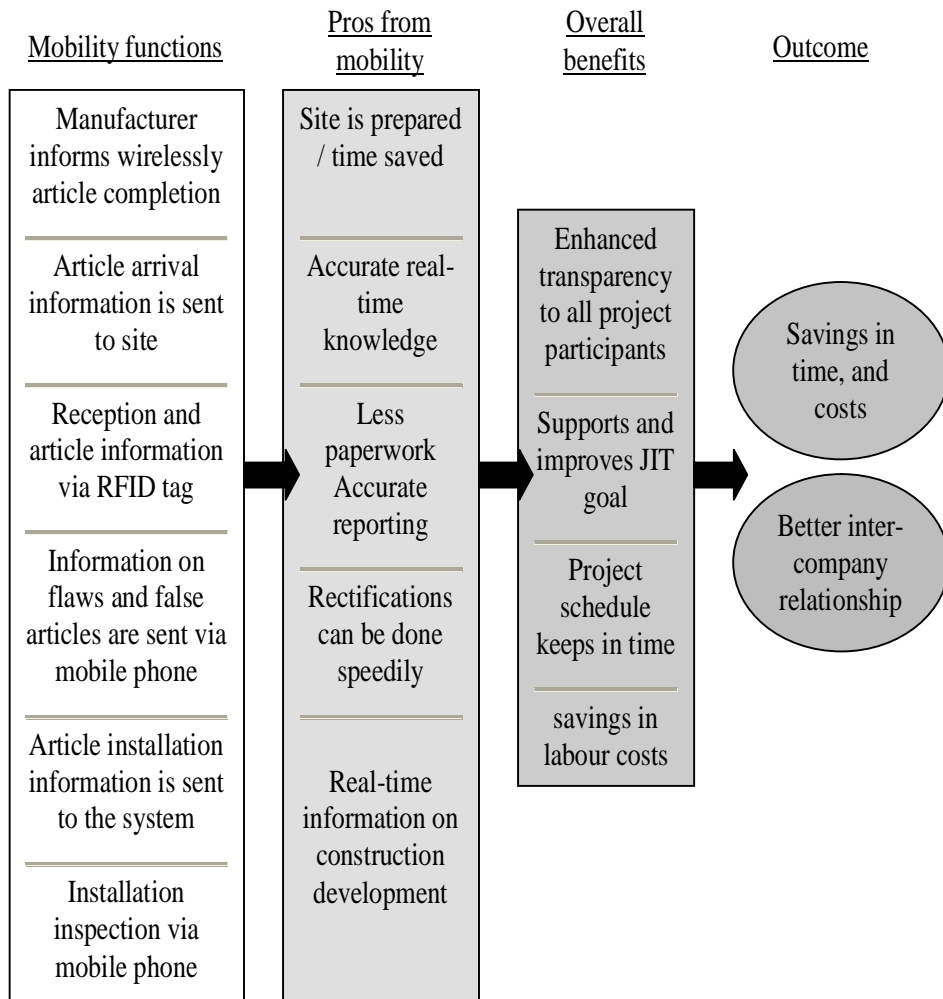


Figure 17 Effects of jobsite logistics mobile application

5.2 Future solutions

Some future ideas from around the world are discussed in this chapter. FIATECH (Fully Integrated and Automated Technology), a construction

industry consortium in the USA has conducted research on the construction industry. According to FIATECH's RFID research for the construction industry, there are six possible areas of interest: bulk materials tracking, plant equipment tracking, site security, site safety, automatic warehousing (tool and materials control) and construction equipment use. For many construction sites it is vitally important for all parties involved that everything works JIT. In other words, material, tasks, equipment, etc., have to be available at just the right time in order to obtain a good and functional construction site, and to keep within the tight construction schedule (AIM 2003a).

5.2.1 Material monitoring

According to the FIATECH research and opinions from TeliaSonera's Job Logistics, it would be ideal if a whole truckload of material could be "received" electronically as it drives to the construction site with the help of active RFID tags. Active tags are considered to be more ideal for the task than passive tags since active tags have a longer readability range. This solution is only possible if all parties are involved and e.g. the material manufacturer implements RFID tags in their products. The tag could contain information on shipping, installation, painting and even what elements are included in the product. An active tag would also be preferable for inventory purposes because of the longer readability range. Ideally, the tags would be used throughout the building's lifecycle, so that when the material is no longer useful its contents are known and can be recycled. This aspect is most likely going to be increasingly important because waste disposal regulations are getting stricter. With the help of RFID tagging it would also be easier to maintain a JIT work site, since logistics and inventory can be done more effectively. FIATECH believes that this could even yield up to a 10 % increase in scheduling efficiency (AIM 2003a).

How and with what the incoming material should be tagged in the future is another question. It seems that RFID tagging is the tagging of the future. Already US military and large department stores such as Wal-Mart and Target use RFID tags to better monitor merchandise, or, in the first case, equipment. Information on how RFID works and the standards, etc., was introduced in Chapter 4.1.4. Bar codes and 2D bar codes could also be used for material check-in, but they usually require physical contact with the monitor device, and

they contain limited information. The future might also bring new useful technologies, such as “intelligent paper”.

5.2.2 Equipment inventory

As with materials, the correct equipment and personnel also has to support the JIT model. This will enable the slacks in the schedule to be minimized. Often, big equipment is even rented from a lessor, as has been discussed in previous chapters. For the lessor it is important to know exactly when the construction company needs the equipment, so that it can also better schedule where and when its equipment is needed. Embedded RFID tags are already used in industrial forklifts, to store maintenance and repair records (Turban, et al. 2005).

RFID technology could also be used in equipment monitoring and inventory. According to Dell Construction’s report on construction sites, "...tools were frequently lost, broken or taken from one job to another without the status being reported." (AIM 2003b). This is why in 2003 Dell decided to invest in a bar code-based tracking program so that their tooling inventory would be accurate. The same tracking program can be achieved with passive RFID tags, which even bring added value in comparison with barcodes. With the RFID tags identification code, a mobile device with wireless connectivity - e.g. a mobile phone - can automatically access the information system and obtain additional information. Active tags would most likely not bring added value over passive tags because their price range is still much higher but a GPS system implemented in equipment, vehicles or tools would enable pinpoint positioning. This way we not only track the equipment with RFID, but at any given time its exact location can be pinpointed. If a construction company were to have GPS positioning on its equipment, a logical “travelling salesman problem” plan and solution could be found.

The travelling salesman problem requires finding the most efficient way (i.e. least total distance) for a salesman to make his routes through each of n cities. There is no general solution for problem, but it can be solved by finding its most efficient “Hamilton circuit” (Weisstein 1999). A construction company that has many construction sites can in the same manner solve the most efficient way to locate its assets - i.e. equipment, personnel, cranes and vehicles.

Figure 18 illustrates the travelling salesman problem. The left-hand figure is the unsolved problem, and the right-hand figure a representation of the problems Hamilton circuit.

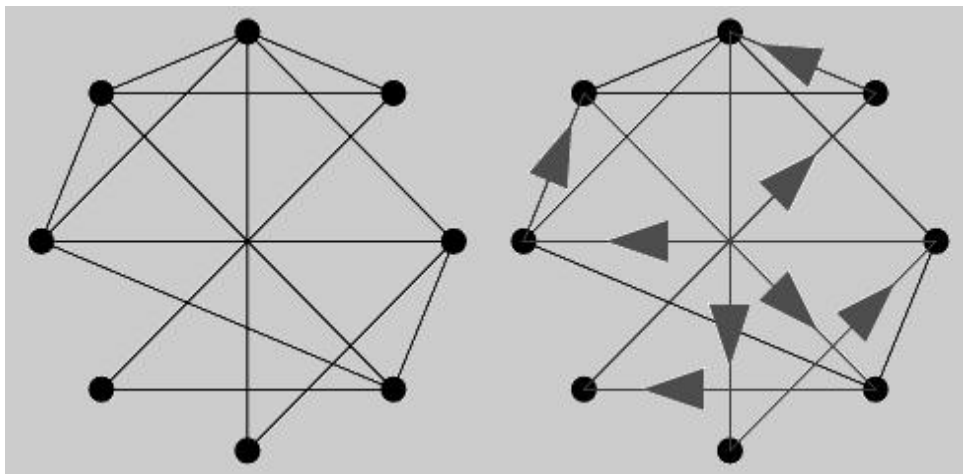


Figure 18 The travelling salesman problem (Weisstein 1999)

5.2.3 Personnel access control system

At large construction sites it is difficult to monitor who the people there are. According to the new law (Industrial safety law, Työturvallisuuslaki 23.8.2002/738 chapter 6 § 52), only authorized personnel should have access to the construction site, and this should be monitored with the help of identification tags that include the person's photograph. This law was passed to ensure construction site and personnel safety, and prevent a grey economy.

Since many subcontract workers are assigned to several developers' construction sites, a unitary identification system would be ideal for the industry. An idea for such a system is that RFID technology is used in the identification process. All people who work within the industry would be registered in a database or in their employer's database, from which authorized parties could obtain relevant

information. Everybody would also have an identification card that contains a passive RFID tag and photograph. Through the database, construction companies or developers can give workers time-limited work permits for the construction site. When the worker arrives at a site, he reports in with the identification card's RFID tag and reports out again when he leaves. This would enable better monitoring of which personnel are at the site, and their working hours.

An inspector could check with his mobile phone that a worker's identification card, and photograph on it, corresponds with the person in question and that he has a permit to work at the site. With his mobile phone he could read the worker's RFID tagged identification card and then obtain the relevant information on the worker from the database. Other information, e.g. hot work licence, construction site introduction and safety training, could also be obtained from the system. There should also be the possibility for the site foreman or the inspector to give a specific area's fire work permit to a worker wirelessly via a mobile phone. This time-limited permit (as they always are) would then be included in the workers database, so that it could be controlled if necessary.

6. Qualitative analysis and conclusions on interviews

In the previous chapters this thesis has studied different aspects of mobile technology, benefits from the use of the technology, the construction industry, and views of the service providers. In this chapter this data is analyzed and compared with data collected from users, i.e. construction companies.

6.1 Interviewing methods for the service user group

Company	Interviewees name	role in company	Interviewing location	Interviewing date
NCC Group	Riitta Takanen	Director of information management for NCC Construction Ltd (Finland)	Helsinki, Finland	17.1.2006
	Ari Törrönen	Development manager and business development for NCC Construction Ltd (Finland)		
Skanska	Aila Vuoria	Director of information management for Skanska Oyj (Finland)	Helsinki, Finland	22.2.2006
SRV Group	Jari Korpisaari	Security and safety Manager	Helsinki, Finland	1.3.2006
YIT Group	Juhani Nummi	Development manager ICT for YIT Construction Ltd. (Finland)	Tampere, Finland	16.3.2006

Table 7 service users interviewing table

The interviews for the service user group were held in February and March 2006. The interviews were conducted in Finnish by Tapio Matinmikko, a researcher at VTT, and the author. Mr. Matinmikko had prepared the interview outline - i.e. "Interview Guide" - and also primarily asked the questions. In addition to the interview outline, some additional questions were prepared that related more specifically to this thesis. The interview guide is presented in Appendix 2. Mr. Matinmikko contacted the interviewees since he was the senior researcher in the project and thus knew more about the industry, companies and the persons to be interviewed. The interviewees were asked to reserve 1-1½ hours for to interviews, of which the interview guide part would take from 45

minutes to one hour. The remaining time was reserved for questions related to this thesis and additional conversation. All the interviews were held within this time limit. Both interviewers made notes during the interview. Since the discussion was primarily led by Mr. Matinmikko, most of the notes were written by the author on a laptop computer. Later, all notes were used to make reports on each company interview in Finnish. The interview material was used for this thesis and also for writing a report that gives an insight to the use of mobility in the construction industry today. This report can be found on the FACMA project's website.

The companies in the service user group were selected because they have used some mobile applications at least at a pilot level, and these companies are large and therefore have larger budgets for development and investment in new products than an average small or medium-sized construction company. The interviews were conducted with management level personnel in order to get an accurate and reliable picture of construction companies' mobility today. 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 results of the interviews are presented in a general manner in the following chapters. No personal opinions or answers are presented to ensure the interviewees anonymity. However, this neither affects the results nor the purpose of this analysis.

6.2 Conclusions from service user group interviews

The analysis of and conclusions on the service user group's interviews are discussed in the following chapters. The frame of the analysis is organized in accordance with Patton's (2002) recommendations. The themes in the following chapters correlate to the questions in the interview guide (see Appendix 2).

6.2.1 Extent of Mobility in Company

All the companies in the interview group had tried mobile applications, at least to a piloting degree. Everybody 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 extensive use at construction sites, and they were considered a most appropriate tool for documenting and reporting construction development, problems, etc. Overall, the extent of mobility was still rather low and only the standard uses had been implemented in the daily routines.

6.2.2 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. According to the service user group, 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.

6.2.3 Mobile application problems

The problem with the 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. 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 was working flawlessly with the rest of the company's information system.

Despite concerns about the mobile phones' durability and usability, it did not create problems amongst the users. 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. With the mobile phone application, the system worked in such a way that if data was inserted in areas without mobile coverage, the information was saved in the device until the coverage was available again.

6.2.4 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. A minority of the interviewees saw the obstacles regarding safety measures as severe and did not believe in rapid improvements.

6.2.5 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. A few of the interviewees also felt that the present data transfer speed and sizes were inadequate, but would most likely be up to speed once mobile applications become more common. Some also felt it important that the safety measures against viruses and espionage are notably improved. On the other hand, others thought 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 or other company. 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. Such a mobile application is, e.g., TeliaSonera's Jobsite logistics pilot, introduced in Chapter 5.1.5.

6.2.6 The future 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 eligible alternative, especially in areas such as confirmations, reporting, logistics and workforce monitoring - although 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 more keen 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. Once mobility is common within the construction industry, more attention will most likely be paid to the mobile devices' overall functionality. At this point PDAs could come into the picture once again, unless more sophisticated mobile phones have replaced them on the market. Microsoft Windows devices could gain popularity, and mobile solutions would have to adapt to the situation. Windows

would though give new opportunities and functions to the solution, but then again once the next generation enters the workforce, in 10-20 years, what software and programs will we be using? 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.

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.

6.3 Analysis and results from interview data

The degree of mobility in Finnish construction companies is still rather low since only the voice and messaging features of mobile phones are in everyday use. Apart from these functions and the occasional use of e-mail and sending photos with mobile phones, mobile functionality is rather unknown in the industry. To a large degree, this is due to the fact that the values a mobile application generates have not been measured, and there are no appropriate methods or tools with which to do this yet. Furthermore, since mobile applications are only supporting the core business, it has not been considered necessary to try to measure the benefits they create. The intangible benefits have been noted, but there is insufficient data to measure the possible tangible benefits.

At the present, there are no clear acquisition, implementation or operational models for mobile solutions in the construction industry. The technology suppliers have the knowledge of what is possible within mobile technology, but they are still often unsure about what the construction industry desires. On the other hand, the construction industry does not know the possibilities the technology can evoke, and thus development is put on hold and mobile solution models are not made. It is also believed that in order for a mobile application to

work, the whole supply chain has to be implemented in the system. Once the supply chain and / or important parts of the subcontractors use the system, transparency between these parties will increase and work can be done more effectively. The problem is to get all the necessary parties to be involved in the mobile system. Two questions were often asked in the interviews: What are the benefits for this company? Why would we use this system if we cannot financially benefit from it? Construction companies need to evolve from this type of questioning and see the larger picture so that mobile applications can be part of the construction industry. Companies should not disregard a new system just because they are not the initial obvious benefactors of it. One must remember that benefits can also be received later in the process, and be of a qualitative nature.

Even though the common belief was that mobile solutions would be used in the future, the benefits were perceived to come from areas other than construction processes. This is probably one of the reasons why investments in mobility have so far been rather modest. Because of mobility's indirect values in construction processes, and most construction companies' limited IT resources, it would seem prudent that an outside party would provide the mobile services, at least some extent or even entirely. It is evident that the introduction of mobile functionality into the construction industry will bring new players into the field, and some of the old players will need to adapt to the new system.

Multiple versatile functions, such as RFID, camera and telecommunications, are combined into a high degree of utilization in a mobile phone, at a reasonable price. Therefore, the use of mobile phone technology in business will increase and expand in the future. It is important that the construction industry notices the benefits that mobile phone technology can bring and that it sees the use of mobile technology as necessary. This can be achieved once there are demonstrable mobile phone technology success stories with tangible economical benefits for the construction industry.

6.4 Comparison of service provider and service user groups' interview data

Earlier in this thesis, different mobile devices, possible uses etc have been studied. Also information received from the service provider group has been presented. As mentioned in the research methodology section (1.2.3), the interview conclusions from the service provider group and other material is studied and compared with the information received from the service user interviews. Special interest lies in congruent and non-congruent information, and why it has occurred

6.4.1 Where and when are mobile applications required?

Throughout this research it came evidently clear that at present 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 kind 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.

Both groups thought mobile applications a good and efficient solution for different kinds of monitoring and control functions. Some types of monitoring have already been tested, such as the site safety monitoring and quality control presented earlier. Monitoring functions could also be expanded to areas such as work progress, personnel and 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. Since most construction sites have anti-theft alarms and fire monitoring to some degree, a tailored "Sonera Alerta" system would be beneficial for construction sites with special needs or if the price were compatible with other systems.

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 “back and end system”. With the RFID technology, information is available swiftly and some applications could even be used to add information, such as granting a fire work area permit time period.

The service provider group voiced a need to make the various inspections that are made throughout the construction project more efficient. Some of the suggested technologies to achieve this were RFID and local networks. The latter could enable real-time footage and other required information of the construction site available on the Internet. Although the user group did not see a necessity for GPS or local networks at a construction site in the near future, these technologies were perceived interesting for road building projects.

6.4.2 Which mobile devices are to be used?

From both the service user and the service provider groups’ data it is clear that mobile phones have the best price-quality-usability ratio at the moment. This is partially due a mobile phone’s communication ability and the device’s versatility. Since a phone’s basic functions are well known to most of the workforce, new applications are easily adopted. When the application is simple enough and generates benefits for the user, he is motivated to keep on using it. With a PDA device, the user would first have to learn how the device functions.

It could be concluded from research material that a rugged mobile device would be the most logical and appropriate choice in a construction site 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. The fragility of a “normal” phone has not been considered a problem so far, since there have not been that many users, and 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.

From the company’s point of view, most of the required functionality can be found in both mobile phones and PDA devices, so in the end the price tag would

be the deciding factor. The possibility of having both PDA and mobile phones at a construction site is not preferred at the moment, since the devices do not interact fluently with each other, or with the rest of the system. For many companies the idea of implementing mobile phones into the system generates problems, so several different types of devices would only make matters worse. As studied in Chapter 4.2 a rugged mobile phone would cost between 160 € and 280 € whereas a rugged PDA between 1,250 € and 2,740 €, so it is obvious that the construction company would select the cheaper option, i.e. the mobile phone. Currently, all the service user group companies have used Nokia mobile phones in their mobile application projects, but this would not exclude the use of other brands - e.g. Siemens - in the future. Buildercom hopes that a mobile application could be used with any brand of mobile, but so far all their mobile phone 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. If the Siemens rugged phone were to have a platform into which it is easy to build a mobile application, it would most likely be an interesting and compatible device to the Nokia S40 and S60 series that have currently been used.

The service user interviewees did not think rugged laptops would be used at construction sites in the immediate future. The applications suggested for laptop use were considered to be futuristic, and not prioritized. Naturally, when mobile functionality gains a greater foothold in the industry, there might be a need for functions that require laptops. But still, the construction sites' carpenters and other personnel will continue to use blueprints, etc., in paper format for a long time to come. Viewing the blueprints and other material on a laptop could be useful for construction inspectors and designers.

6.4.3 What kinds of mobile applications does the industry need?

All the evidence 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, but prices must be reduced considerably for it to overtake the traditional paper reporting method. The recent events in the construction industry have also stirred the conversation on site safety. Laws and regulations have forced the industry to improve the monitoring of their own workforce and sites. Since the number of cranes, lifts, etc, has

increased in recent years, so the risk of accidents has risen, with devastating consequences. There is of course no mobile application that can prevent accidents, but, with the help of RFID technology, large equipment, such as cranes, could be monitored so that maintenance and inspections are done according to the regulations.

As has been discussed before, RFID could also be useful in various quality control functions and as a swift source of information. This type of information source also opens up new possibilities for inspections, and different permit and personnel monitoring purposes.

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 but would be useful at road building sites.

The source material indicated that positioning could be useful for larger construction companies or equipment lessors, so that vehicles and other equipment can be monitored. This could also make logistics more effective, since usage and transfers to other construction sites can be done more cost- and time-effectively with positioning equipment - i.e. positioning could help make the travelling salesman problem for equipment efficient (see Chapter 5.2.2).

Neither of the groups has used nor plans to use Bluetooth technology in mobile application projects. In a purely speculative way this would indicate that Bluetooth technology is considered insecure and inappropriate for the tasks, or that RFID and other technologies are replacing Bluetooth.

6.4.4 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.

So far, mobile solutions have been done with well-designed mobile applications, cameras and RFID technology. The following benefits from the safety monitoring pilot and jobsite logistics pilot were noted by both groups:

1. 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
2. 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.

In addition to the above, it was hoped that future mobile solutions would also have 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.

7. Summary

Throughout this research it has been evident that mobile technology can be used in most of the industries, as long as good, working applications exist. Games, logos and other entertainment applications that have been introduced to the market are generally targeted towards the younger generation. The adult working population require other services specially designed for the working environment. The applications should be independent of mobile phone manufacturers, much like computer manufacturers and software developers are today. Computer software is developed by IT companies at either a general level (e.g. Microsoft) or according to a company's specific needs (e.g. TietoEnator). The same kind of development is already present within the mobile industry and is evidently increasing. Ideally, mobile applications would be developed in the same manner as is done in the software industry - i.e. there would be some basic mobile applications but also a large variety of industry and company-specific applications.

This chapter answers the initial research questions and problems. Based on this information and other data collected during the study, further research options and ideas are presented as a conclusion to this thesis.

7.1 Research results

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

1. How and when could mobile devices be used in a construction project and are the devices durable enough for their planned purpose?

All the presented material from the construction industry's and the mobile technology industry's point of view in this thesis 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. A mobile application could also be used in monitoring Buildercom's tile quality control pilot.

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 material collected on the construction industry, it was considered important to have durable mobile devices. This conclusion was also supported by the interviewed site foreman, who had not used any of the mobile applications presented in this thesis. Interestingly enough, information received from the service user group indicated that the device's durability is not considered to be a problem, but a more durable device would be preferred. From the service users and service provider groups' 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.

2. What are the "bottlenecks" in a construction project that could be prevented with the suggested technologies?

At the moment, most of the "bottlenecks" in a construction project are caused by redundant paperwork at the construction site and lack of information. According to the service user group, the site foreman or equivalent spends up to two hours a day on paperwork. This paperwork involves reporting, double-checking various invoices and freighting documents, approving invoices and writing various documents, etc. 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.

For the current service provider companies especially, there is interest in making the various inspections more efficient. Pressure is mainly being imposed from the authority direction. The construction industry, i.e. possible mobile solution users, supports the idea, but does not see the development of such functionality as a matter of priority. For the construction industry, one of the bottlenecks is 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.

3. Can mobile technology be of assistance in managing human, administrative and equipment resources for a construction company - e.g. with a local network - and thus reduce the overall costs?

The studies in various mobile application pilots and other information from the source material and service provider interviews studied in Chapter 5 have made it clear that mobile technology is very suitable for human, equipment and logistics management. The service user group also agrees with this notion, so development in this area is to be expected in the near future. A pilot for jobsite logistics has already been launched, and the results are positive. Some ideas for human, equipment and vehicle management and monitoring, which were introduced in Chapter 5.2 are being developed, and, hopefully, will be piloted in the near future. The service providers have ideas on how GPS and WLAN technology could be used in the construction industry, but the construction industry does not yet consider it necessary to have local networks or positioning at construction sites. They see the potential in these functionalities, but are more interested in finding ways to use these technologies in road construction. This thesis has shown that the ability to locate and monitor equipment, vehicles and personnel could help in making the company's logistics more effective, and could even reduce costs. 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 site needs.

4. Will the economic and other benefits of using mobile technology be enough to validate the costs?

It is evident that mobility can generate qualitative benefits in the construction industry. There is also evidence that quantitative value can be generated, but this statement can not yet be proven. Therefore, it is not currently possible to either measure the monetary values of mobile technology or compare them with the costs. Table 8 lists some of the tangible and intangible benefits that different mobile applications and technologies can generate.

	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 8 Benefits of mobile applications and some introduced technologies

7.2 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.

Since EU regulations on waste disposal are going to tighten in the future, 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, the construction and facility management sectors have only recently started to cooperate. There is much that can be done with mobile technology in all sectors to make the processes more efficient and to improve customer service. More study involving all sectors, consumers and mobile technology is needed.

In other parts of the world there are much larger construction companies than in Finland. 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 America. 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.

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Appendix A: Interview Guide nr. 1

What, in terms of mobile technology, are the future developments in the construction industry?

What kind of mobile applications could be of use in the future?

What kinds of mobile applications do you already have that are targeted at the construction industry?

Please tell me about the pilot projects this company has conducted within the construction industry, e.g. focus, results, future developments, usability and opinions.

Appendix B: Interview Guide nr. 2

What is the present extent of mobility in this company?

- How much are mobile phones used for purposes other than talking and SMS messaging?
- What types of mobile applications are in use?
- Which technology are they based on?

What benefits/values/profits does a mobile application generate?

- Can it generate savings or does it improve various processes?

What are the problems with mobile applications?

Are the problems related to:

- technology
- usability (e.g. a phone's small size)
- integration with the company's information system
- operational costs

What, at present, are the obstacles in using and increasing the usage of mobile applications?

Are the problems related to:

- technology
- usability (e.g. a phone's small size)
- integration with the company's information system
- operational costs

What requirements do you impose for mobile solutions?

How do you see the future of mobile functionality in your company?

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