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Knowledge Management, Information Technology and Learning in Construction Projects

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1. Naaranoja Marja, Jäväjä Päivi, Haapalainen Päivi, Lonka Heikki (2005). Knowledge Management Tools – Possibilities and Obstacles. “CIB W102 – 2005, International Conference on Information and Knowledge Management in a Global Economy: Challenges and Opportunities for Construction Organisations”. F.L. Ribeiro, P.D.E. Love, C.H. Davidson, C.O. Egbu and B. Dimitrijevic, Lisbon, Portugal. CIB Publication.

2. Jäväjä Päivi, Naaranoja Marja (2005). IS Tools for KM in public Construction Projects. "CIB-W78 22nd Conference on Information Technology in Construction". Editors Raimar Scherer, Peter Katranuschkov & Sven-Eric Schapke. Published by: Institute for Construction Informatics, Technische Universität Dresden, Germany. CIB Publication No.:304.

3. Jäväjä Päivi, Naaranoja Marja (2006). Tietotekniikan mahdollisuudet ja rajoitukset. Vaasan yliopiston julkaisusarja: Rakennusprojektin onnistumisen eväitä. Toim. Marja Naaranoja. Selvityksiä ja raportteja 137.

4. Jäväjä Päivi, Naaranoja Marja (2006). Learning support of ICTs in construction projects – Case study approach. Proceedings of KMO 2006, International Conference on Knowledge Management in Organizations. UM FERI; editors: M. Hericko, A. ZivKovic. ISBN: 86-435-0780-6. Maribor, Slovenia, June 13–14, 2006.

5. Jäväjä Päivi, Naaranoja Marja (2007). Developing project management system to support active learning and communication in a construction project. To be presented in CIB W102 Conference, Information and Knowledge Management - Helping the practioners in planning and building: Meeting on October 16 – 18, 2007. Stuttgart, Germany.

Abstract

Jäväjä, Päivi (2007). Knowledge Management, Information Technology and Learning in a Construction Project.

ICT (Information and Communication Technology) usage in construction is limited when compared with other industries. This may be due to the unique characteristics of the construction industry and the tendency for late take-up of ICT solutions. The amount and diversity of information created and referenced during a typical construction project is considerable. Most people working in the construction business have been involved in projects where costs have enormously exceeded the budget, where timetables have caused problems, and where the end results have been useless or even unhealthy for people. The KM (Knowledge Management) in construction projects fails, and there is no commitment to improve the process even if productivity in the industry is very low compared to other industries. Construction professionals work in complex and heterogeneous networks of human beings and various artefacts. Productive participation in knowledge-intensive work requires that both individual professionals and their communities and organisations continuously transform their practices, develop new competencies, advance their knowledge and understanding, as well as produce innovations and create new knowledge.

This present thesis is a case study conducted within the Prolab project in Vaasa University. This study deals with the issues and problems of knowledge management in construction projects. The focus is in construction ICT and solutions that have emerged in this field. There are five published articles that relate to these themes. The empirical part for this study comes from the Prolab project interviews in five demanding public construction projects. The informants were project stakeholders; end-users of the buildings, such as nurses and teachers; architects and special designers; as well as project managers and contractors.

My conclusions are that the knowledge processing tools are in use but they are not used in as centralized or intelligent way as they could be. It seems that the solutions are not interoperable because of technical problems. In addition, I found problems related to inefficient information flow, lack of communication and project participants not being ready to utilize the modern technologies, as well as to the lack of centralised KM strategy. In order to improve the process, construction companies must integrate learning with day-to-day work processes in such a way that they not only share knowledge but also provide access to knowledge at any level. The knowledge portal systems that include BIM (Building Information Modelling) operations and perceive user and business requirements are one way to innovative project management systems. Continual discussion between customer and the application provider is necessary for the best results.

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Key words: Knowledge management, learning, e-learning, construction project, construction ICT.

1 Introduction

1.1 Characteristics of Construction Industry

Information and Communications Technology (ICT) usage in the construction sector is limited when compared with other industries. This may be due to the unique characteristics of the construction industry and the tendency for late take-up of ICT solutions (Hannus et al. 2003). The construction industry involves a set of characteristics that differentiates construction from other sectors, as reported by Hannus et al. (2003) and Kazi and Charoenngam (2003): Construction sector is heterogeneous and highly fragmented, depending on a large number of very different professions and firms, which are mostly small in size and tend to respond to local market needs. Construction is highly project oriented. Each construction project – whether to create a new facility or renovate – is typically unique. Regulations and standards are more rigorous in construction than in most other sectors of economy. The sector is very labour intensive, with high mobility of the workforce. The duration of contracts is often linked to the length of the site construction phase. Business relationships are temporary and often short-term, bringing together partners who may never work together again.

Björk (1995) states the need of ICT in the construction industry because of the complexity and size of the end product and the requirements of different know-how and materials needed to erect a project. Thus the amount and diversity of information created and referenced during a typical construction project is considerable. The use of ICT for the processing, management and transfer of data offers great potential benefits to this industry both in terms of making the design and construction process more efficient and in ensuring better quality of the resulting buildings.

According to Wetherill et al. (2002), organisations and individuals participating in a construction project bring along their own unique skills and resources, which may include proprietary and commercial applications, knowledge and data. Despite the interest and the effort put into knowledge management by many leading companies, the discipline is still in its infancy. Many practitioners and researchers have acknowledged the limitations of current approaches to managing the information and knowledge relating to and arising from a project (Rezgui 2001). Among the key reasons for these limitations are:

- A vast amount of construction knowledge, by necessity, resides in the minds of the individuals working within the domain. The intent behind decisions is often not recorded or documented. It requires complex processes to track and record the thousands of ad-hoc messages, phone calls, memos, and conversations that comprise much of the project-related information.
- People responsible for collecting and archiving project data may not necessarily understand the specific needs of those who will use it, such as the actors involved in the maintenance of the building. The data is usually not managed while it is created but instead it is captured and archived at the end of the construction stage. People who have knowledge about the project are likely to have left for another project by this time and thus their input is not captured.
- The lessons learned during the project are not organised well and they may be buried in details. It is difficult to compile and disseminate useful knowledge to other projects. Many companies maintain historical reports of their projects. Since people move from one company to another, it is difficult to reach the authors of the original reports who understand the hidden meaning of project data. This historical data should include a rich representation of its context, so that it can be used with minimum or no consultation.
- New approaches to the management of knowledge within and between firms imply major changes in individual roles and organisational processes. While they desire the potential gains, they resist the necessary changes.

1.2 Problems in Construction Industry

Most people working in the construction business have been involved in projects where costs have enormously exceeded the budget, where timetable has caused problems and where the end results have been useless or even unhealthy for people. The knowledge management in construction projects fails, and there is no commitment to improve the process even if productivity in the industry is very low compared to other industries.

Love and Irani (2004) state that rework is an endemic problem in building and construction projects. Rework is defined as "doing something at least one extra time due to nonconformance to requirements" (Love et al. 1999). Essentially, rework can arise from errors, omissions, failures, damage, and change orders that occur in projects. Research has shown that rework is the primary cause of time and schedule overruns and quality deviations in projects. Delays and cost overruns seem to be the rule rather than an exception in the construction industry. Design changes are frequent, generating costly ripple effects that create delay and disruption. Projects often appear to be going smoothly until near the end when errors made earlier are discovered, necessitating costly rework. Such rework may result in overtime, additional hiring of resources, schedule slippage, or reductions in project scope or quality. Various industry development initiatives have focused on addressing the symptoms rather than the causes of the industry's problems. (Love and Irani 2004.)

Pathirage et al. (2005) state that in recent times the construction industry has been forced to critically examine its performance as an industry that lags behind most other industries in terms of technology and productivity. A number of government and academic reports (Latham 1994, Egan 1998, Fairclough 2002) have repeatedly highlighted this issue and the necessity for a fundamental cultural and technical change in the construction industry. It is stated that the publication dates of Latham's report (1994) and Egan's report (1998) are crucial milestones for the industry because these reports address issues such as fragmentation, client dissatisfaction, low-level investment in research and development as well as the lack of skills in terms of improving productivity which adversely affects the performance of the construction industry. The reports were published in early 1990s but the problems still remain in the industry.

According to Shelbourn et al. (2006), there are difficulties in capturing, storing, sharing and re-using all the information and knowledge relating to and arising from a construction project. There are no mechanisms or processes to foster the social interaction required. It is the common experience of all construction industry professionals that problems are resolved in one project or a new solution is developed, but that these lessons are not learned. Too often the same problem recurs in another project because nothing has been done to eliminate the cause of the problem and, because the team is different, the issue is again dealt with from scratch. Commitment to continuous improvement should mean, at best, that the problem does not occur more than once, but at least that the lessons learned from overcoming it the first time are available to be applied in future. Similarly, it means that successes and innovations that are developed in one environment need to be available to be used on other projects (Orange et al. 1999).

1.3 Approach to the study

The main objective of this study arose from becoming conscious of the failures in construction projects, such as cost and time-table overruns and big messes during construction phase, as well as the failures in their results; expensive and demanding buildings have proved not to be useful and serviceable for the end users, which has caused bad reputation for the construction industry and for the quality of construction. The low uptake of information technologies and bad information management seem to be the reasons to the most problems in the construction field. Quite many of the problems could be solved by utilising modern technology. However, even the best information systems alone will not guarantee success in construction projects. There is always a need for human contribution and most failures in the construction industry involve problems in knowledge management. As Davenport and Prusak (1997) argue:

> *"Our fascination with technology has made us forget the key purpose of information: to inform people. All the computers in the world won't help if users aren't interested in the information generated. All the telecommunications bandwidth won't add a dime of value if employees don't share the information they have with others. Expert systems won't provide useful knowledge if the knowledge changes too fast to maintain – or if system designers can't even find experts willing to surrender what they know."*

Technology plays an important role in knowledge management, although knowledge management is not about technology. Technology facilitates the process of transmitting and exchanging information (Al-Hawamdeh 2002). It is not information technology itself that creates success stories but the way an organisation integrates information technology to run its work (Ellström 1999). The main purpose of this thesis is not only to explain information technology but also its substantial possibilities.

Knowledge Management (KM): Knowledge is increasingly recognised as the most important resource in organisations and a key differentiating factor in business today. It is increasingly being acknowledged that KM can bring about the much needed innovation and improved business performance in the construction industry (Egbu et al. 1999). According to Davenport and Prusak (1998), the only sustainable advantage a company has comes from what it collectively knows, how efficiently it uses what it knows, and how readily it acquires and uses new knowledge. Studies indicate that practices of knowledge management rather than characteristics of individual experts differentiate the success of projects. Projects with top experts have failed. Human thinking is very defective and deduction mistakes are common (Tversky & Kahneman 1974).

Practices of organisational knowledge management have a key role from the viewpoint of organisational intelligence. Studies also indicate that many high profile accidents and crises could have been avoided if people had effectively utilised an organisation's earlier experiences and knowledge**.** ICT could be used as the technical infrastructure for an organization’s memory by creating various databases to which experiences and knowledge of the organisation and its project teams could be stored. Analogously with human memory, the challenge of this kind of collective memory is to represent and organise knowledge in a way that enables finding relevant and critical information later on.

Providing access to knowledge alone does not ensure that the knowledge will be used. Knowledge transfer involves two actions: transmission (sending or presenting knowledge) to a recipient and absorption by that recipient. If the knowledge is not absorbed, it has not been transferred. Even transmission and absorption have no value if the ‘new’ knowledge does not lead to a new development or idea. (Patel et al. 2000).

Sveiby (1996) has proposed IT Track and People Track approaches to knowledge management. The IT Track focuses on the management of information. Its knowledge management activities comprise the construction of information management systems, artificial intelligence, data mining and other enabling technologies. In this case knowledge can be treated as objects that can be identified and handled in an information system. The People Track focuses on the management of people. Its core knowledge management activities encompass assessing, changing and improving human individual skills and/or behaviour. It is a complex set of dynamic skills and know-how that is constantly changing. However, it is too simple an approach to define knowledge management as an IT Track and People Track. This approach does not take into account knowledge embodied in processes and workflows or generated as a result of people interacting with information systems and the environment around them (Al-Hawamdeh 2002). Knowledge in the form of skills and competencies is normally acquired through training and interaction with environment. 'Know how' or implicit knowledge is a type of knowledge that can be expressed and articulated. A good example is the Xerox Eureka project (Bobrow 1999). The Eureka system gathers shared tips on service repair for technicians worldwide. The information captured in the system can benefit other technicians who might face the same or similar problem.

Learning and e-learning: Construction professionals work in complex and heterogeneous networks that consist of human beings and various artefacts. Productive participation in knowledge-intensive work requires that both, individual professionals as well as their communities and organisations continuously transform their practices, develop new competencies, advance their knowledge and understanding, as well as produce innovations and create new knowledge. Actually, the construction of a new building is a learning process where the parties learn from each other. If wisely used, the new ICTs may have an important role in meeting the challenges of learning, developing practices and creating new knowledge. Even though virtual or e-learning is a popular notion, at present, we have very little independent research-based knowledge about how information networks may be used to support the development of human competence and expertise in construction environment. From the viewpoint of cognitive science, it is narrow-minded to understand e-learning as a process of delivering digital information and study material to people by the means of ICTs. In the background there is an unrealistic assumption that learning is mainly a matter of transmitting information to the learner. This assumption greatly oversimplifies and distorts both the concept of knowledge and concept of the learning.

Haapalainen (2007) states the learning needs at an early phase of a construction project; the designers need to learn what the requirements of the end users are. This could mean that the designers have to learn the basics of the work that will be performed in the building that is to be built or renovated; only this way he can design such facilities that fulfil the needs of the end users of the building. On the other hand, the end users have to learn how the plugs are drawn in the electrical drawings or what the dimensions of the building are so that they know if the furniture fits in and how much space is needed for the future functions in the building. Love and Irani (2004) state that design-related rework in the form of change orders is the major source of rework in construction projects and that a dearth in the communication flow between the client and the design team members can result in documentation errors and omissions.

Nowadays, the young engineers have to be put to productive work as soon as they are hired. What is needed is on-site learning. The technologies, regulations and standards change all the time; thus even senior workers need to learn in order to keep their skills up-to-date. It is necessary to learn from past projects as well. Learning from good and/or bad practices and earlier mistakes and failures requires special means because the employees changes from project to project. E-learning environments are one good means to learning at work. Learning should be managed; documents in databases are not enough to serve as an e-learning possibility.

To be competitive, a construction firm has to be innovative in its use of knowledge that is created and accumulated through project activities, and share it across relative projects. Engineers and experts participating in projects act as knowledge workers, facilitating the collection and management of knowledge between current and past projects (Lin et al. 2005). For example, learning of construction project stakeholders can be supported by an e-learning platform that aids studying and understanding the construction operations in advance, before or during the construction execution (Lin et al. 2005). The project stakeholders first need skills that bring success in their current jobs. Secondly, they need memberships in professional networks that keep them up-to-date in their professions. Thirdly, they need the skills to use the new technologies to the extent that these affect their current work practice, but delivered in a way that fits into their daily lives (Burnside 2001). Eliufoo (2005) states that organisations in construction are continuously exposed to opportunities for learning. This is certainly true as each new project in construction is a new experience. That is, no two projects can ever be exactly the same because they involve different work teams, physical features, contracts and periods in time. Such variations consequently bring in different working environments and new skills, tactics and solutions for each new project.

1.4 Objectives of the study

A practical reason for this research was my ambition to find the bottlenecks and problems that occur in construction projects. In addition, I wanted to learn what possibilities there are to solve these main problems by means of construction ICT and how to minimise the obstacles that I would find in the utilisation of ICT. On the grounds of this knowledge it would be possible to develop processes and tools to better rise to the challenges. Every article in this study focuses on a viewpoint of its own and involves different questions, but in general, the questions can be summed up to the following objectives:

- What kind of problems related to information flow in a construction project do the project stakeholders highlight?
- What kind of solutions is being suggested?
- How could ICT be used to foster collective knowledge building and learning in construction projects?
- How could ICT tools be developed based on such understanding?
- What are the obstacles to efficiently administrating information and how can these obstacles be removed?

1.5 Results of the study

In the first, second, and third articles the focus is in the ICT tools that could improve knowledge sharing and knowledge management in a construction project. The knowledge processing tools are in use but they are not as centralised or intelligent that they could be. There seemed to be technical problems in that the solutions are not interoperable, and there is a need to measure the quantities of materials, as well as to calculate and feed all information many times. The information is being separated into different computers, and there may be duplicated information stored in many different places. In addition, I found problems related to inefficient information flow, lack of communication, and to the fact that the project participants are not ready to utilise modern technologies.

One solution could be the use of the Building Information Model (BIM), which is a data-rich digital representation of the physical and functional characteristics of design and construction. Its purpose is to make design information explicit, so that the design intent can be immediately understood and automatically evaluated. The use of BIM defines a common language for a project and illustrates the basis for well-functioning communication between project participants and quick availability of data in order to avoid delays and incorrect deliveries. The use of BIM in construction offers a chance to estimate time and cost expenses as well as productivity. At present, technical-constructive planning is based on alphanumeric data, is of an abstract nature, and possesses no direct graphical representation. Geometrical and spatial representations are becoming more and more significant in trying to understand and control large projects that include complex structures.

In the fourth and fifth articles the weight is in learning, e-learning and web-based project management system. Main recommendations relate to the use of this kind of systems. In order to improve their process, construction organisations should integrate learning within day-to-day work processes, in such a way that they not only share knowledge but also provide access to knowledge and information at any level and operate efficiently in response to their changing environment. The most sophisticated systems do not guarantee the success of utilisation. In addition, there is a need for knowledge managers who maintain e-learning environment and offer online courses and learning objects for project-related things. The environment should be up-to-date and provide learning for new technologies and devices and respond to learning needs during the project.

By utilising web-based project management systems firms have an ability to share information and collaborate and transact across various technical platforms and information systems. The system links all project documents to a centralised platform and allows them to be shared by all parties involved in the project. The role of an intranet varies from passive publishing of up-to-date company information to dynamic exploitation of its capabilities to integrate with social networks (Ingirige and Sexton 2006). Through their facilitatory role of locating, transferring and more efficiently using information and expertise, intranets are positioned as effective and efficient tools in organisational knowledge-sharing and learning (Offsey 1997). But the investment alone will not popularise intranet use in construction projects. The organisation strategy should take into account an appropriate culture change to alter the mindset of the people into noticing that the task relevance of intranet content is dependent on its usage and population (Ingirige and Sexton 2006).

It is easy to find applications to different tasks but the lack of the centralised knowledge management strategy brings about new problems. New ways of organising work meet resistance, and people very soon become cynical and unintended consequences of techno change failure prevent the success of the new change efforts. Many times the interviewees talked about the obsolete computers and the limits of their knowledge on ICT possibilities. At the same time they had doubts on the possible benefits of a system and unwillingness to start to utilise the new system especially if the last ICT project had failed for some reason. Based on literature we found solutions to strengthen the commitment to use the new applications by involving the users to requirements elicitation. To get the best results the continual discussion between the customer and the application producer is necessary.

1.6 Structure of the thesis

This licentiate thesis consists of five articles, which have been published in scientific conferences during 2005-2007, and this summarising report. The author's past results are to some extent reinterpreted and evaluated in the light of later developments. This report is organised as follows.

- First section: Introduction to the thesis and its topic
- Second section: Concepts of knowledge management, learning and e-learning, construction project management, and construction ICT
- Third section: The theoretical background, organisation, aims and methodology of research
- Fourth section: Summary of five published articles
- Fifth section: Discussion and conclusions
- Appendix:
    - Five articles at their full length

2 Literature review

The second section of this thesis lists and defines the concepts of knowledge management, e-learning, construction project management and construction ICT, based on the references of the published articles and including some later references and reinterpretations.

2.1 Knowledge Management

2.1.1 Main concepts of Knowledge Management

Data, information and knowledge: There are many approaches to the concept of information. 'Data' and 'information' are often used as synonyms of knowledge. However, these words have different meanings (Cong and Pandya 2003, Nonaka and Takeuchi 1995). *Data* means raw facts. To become *information*, data needs to be processed. Decisions can only be made based on information. *Knowledge,* on the other hand, is meaningful information. Knowledge is derived from information. Whether we are talking about data, information or knowledge depends on our interpretation of these concepts. Knowledge is the understanding that one gains through experience, reasoning, intuition, and learning. We expand our knowledge when others share their knowledge with us. New knowledge is created when we combine our knowledge with the knowledge of others (Cong and Pandya 2003).

Knowledge management: According to Brelade and Harman (2001), Knowledge Management (KM) means obtaining and using resources to create an environment in which individuals have an access to information and in which individuals obtain, share and use this information to raise the level of their knowledge. Knowledge management is referred to as the process of creating, codifying and disseminating knowledge for a wide range of knowledge-intensive tasks (Harris et al. 1998). In addition to this, individuals are encouraged and enabled to obtain new information for an organisation. It is increasingly being acknowledged that KM can bring about the much needed innovation and improved business performance in the construction industry (Egbu et al. 1999).

ICT and knowledge management: Information Systems (IS) combine organisational, human and information technology-based resources to generate effective and efficient collection, retrieval, communication and use of information. Information and Communications Technology (ICT) serves IS by supporting business operations and enabling new ways of carrying out organisational activities (Barret 1995). Computers can help to transform data into information, but they can rarely help with creating context, and humans are usually needed to help with the categorisation, calculation, and condensing of data. According to Davenport and Prusak (1998), the medium is not the message though it may strongly affect the message. The thing delivered is more important than the delivery vehicle. Having a telephone does not guarantee or even encourage brilliant conversations. The computational power of computers has little relevance to knowledge work, but the communication and storage capabilities of networked computers make them knowledge-enablers. Through e-mail, groupware, Internet, intranets, computers and networks, we can point to people with knowledge and connect people who need to share knowledge over a distance. Desktop videoconferencing and multimedia computing that transmit sound and video as well as text make it possible to communicate some of the richness and subtlety of one person's knowledge to another. (Davenport and Prusak 1998.)

Tacit knowledge and explicit knowledge: Under the subject of knowledge management, there are two kinds of knowledge: tacit knowledge and explicit knowledge (Nonaka and Takeuchi 1995, Kazi et al. 2001, Davenport and Prusak 1998). Tacit knowledge is seen as knowledge which is "personal, context-specific, found in personal skills, and therefore hard to formalise and communicate" (Nonaka and Takeuchi 1995). Whereas, "explicit knowledge is codified and digitised for example in books, documents, reports, white papers, spreadsheets, memos and databases" (Awad and Ghaziri 2003). The main challenge has been to identify, for example, as to how one form of knowledge could be converted to another and vice versa. The assumption here is that further knowledge is created through interaction between tacit and explicit knowledge (Nonaka and Takeuchi 1995). The conversion mechanisms have been capsulated within the SECI (Socialisation, Externalisation, Combination, and Internalisation) model by Nonaka and Takeuchi (1995) that is frequently cited in most literature on knowledge management. Socialisation is for tacit to tacit knowledge conversion, externalisation for tacit to explicit knowledge conversion, combination for explicit to explicit knowledge conversion, and internalisation for explicit to tacit knowledge conversion. Furthermore, knowledge conversion is a 'social' process between individuals, and interactions between individuals or groups are required to capture, convert, and create new knowledge from existing knowledge (Nonaka and Takeuchi 1995).

Contradicting the approach of Nonaka and Takeuchi (1995), Walsham and Barret (2005) state: *"knowledge ability is individual and based on tacit knowledge, which cannot be converted to explicit knowledge"*. According to them, this tacit power produces the deep tacit knowledge that we have about the world in which we live, and this power is different for each individual due to our different initial dispositions and experiences. Walsham and Barret (2005) argue that philosophical reflections are highly relevant in the use of ICTs for knowledge management. All databases, on-line data sources, and the contents of e-mails, for example, are 'explicit knowledge', which should not be confused with the much deeper tacit knowing of individuals, which enabled creating these items in the first place. And will they be meaningful and helpful to the others who access them? This will depend on whether they connect well to the tacit knowledge of the user and offer something new or interesting to this person.

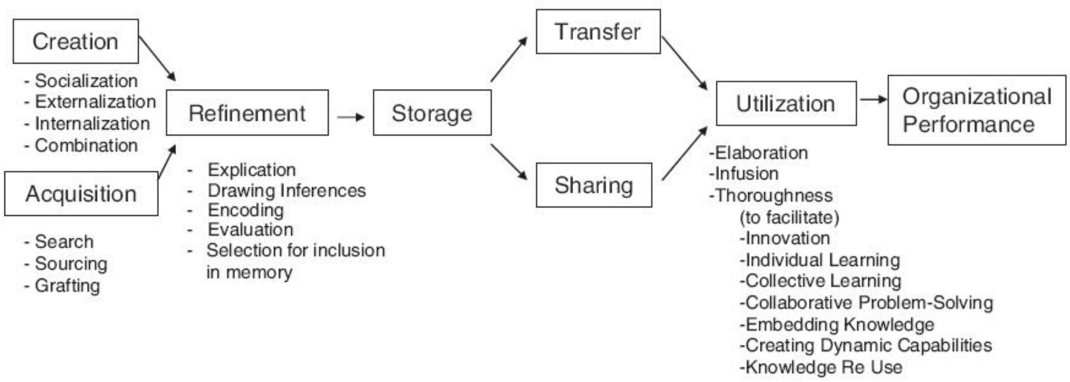

Figure 1: KM cycle model (Omega 2007).

KM Cycle Model: The editors of Omega, International Journal of Management Science (2007), have created a KM cycle model. The initiation of the KM cycle involves the stages of knowledge management by an organisation. The four bullet points under *creation* refer to Nonaka's (1998) four modes of knowledge creation—socialisation, combination, externalisation and internalisation. All of these KM stages are important in construction projects, especially during the design phase when new knowledge needs to be created and all the parties create something new together. Illustrative of these four modes, respectively, are apprenticeships, literature survey reports, lessons learned, and individual or group learning through discussions. In contrast to internal knowledge creation, knowledge *acquisition* involves the search for, recognition of, and assimilation of potentially valuable knowledge, often from outside the organisation (Huber 1999). Bullet points under *knowledge refinement* (Menon and Pfeffer 1999) suggest that tacit, or implicit, knowledge must be explicated, codified and organised into an appropriate format. Explicit knowledge needs only to be formatted, evaluated, and selected. Knowledge that enters these *stores of knowledge* becomes part of the organisation's memory. Organisational memory includes knowledge that is stored in the minds of organisational members and that is held in electronic repositories. In order for knowledge to have a wide organisational impact, it usually must be either transferred or shared. *Transfer* involves focused and purposeful communication of knowledge from a sender to a known receiver (King 2006a). *Sharing* is less-focused dissemination, such as through a repository, to people who are usually unknown to the contributor (King 2006b). Once knowledge is transferred to, or shared with, others, it may be used or applied through a process of elaboration, infusion and thoroughness in order to be useful in facilitating innovation, collective learning, individual learning and/or collaborative problem solving (King 2005). Organisational Learning (OL) is complementary to KM. Easterby-Smith and Lyles (2003) consider OL to focus on the process and KM to focus on the content of the knowledge that an organisation acquires, creates, processes and eventually uses. Another way to conceptualise intersection between the two areas is to view OL as the goal of KM. By motivating the creation, dissemination and application of knowledge, KM initiatives pay off by helping the organisation achieve its goals. From this perspective, OL is one of the important ways in which an organisation can utilise knowledge, as shown in **Figure 1**. The end of the cycle in Figure 1 depicts knowledge having impact on organisational performance. Such improvements are the primary basis that organisations use to judge the value of KM and OL initiatives.

2.1.2 Knowledge management in construction industry

Kazi and Koivuniemi (2006) state the following about knowledge conversion from the perspective of the construction industry: The most valuable form of knowledge is that which is tacit, based on the experience of individuals, and articulated through social interaction. In fact, in the construction industry, tacit knowledge has been passed from skilled workers to apprentices over the years. At the same time, however, since this knowledge is not readily accessible, and at times more often it is not in the form of rules of the thumb, or intuitions, there is a need to formalise it in a way that makes it accessible to many. In simple terms, how can experience be captured and made available in the form of good and/or bad practises that are accessible by all relevant stakeholders through, for example, a best-practices database? That is the first and very essential step, which is naturally followed by combining and internalising processes to a continuous loop (socialisation – externalisation – combination – internalisation) in order to form new knowledge.

The construction industry does not have a strong record of valuing its employees and their individual and collective contributions. This, therefore, makes it more difficult to share knowledge. Tacit knowledge tends to be regarded as personal property rather than organisational property. Hierarchical organisational structures and multi-disciplinary teams also make it more difficult to share knowledge. The introduction of new management structures to deal effectively with knowledge management may be viewed with suspicion. Likewise, radical changes in work practices are not desirable. Any task that is seen as requiring more effort will not be widely accepted. Knowledge Management will have to become an integral part of the way individuals work if it is to succeed. (Anumba et al. 2000.)

Wetherill et al. (2002) divide the knowledge classification of the construction domain into the following three categories:

- Domain knowledge: this forms the overall information context. It includes administrative information (e.g. zoning regulations, planning permissions), standards, technical rules, product databases, etc. This information is, in principle, available to all companies, and is partly stored in electronic databases.

- Organisational knowledge: this is company specific, and is the intellectual capital of the firm. It resides both formally in company records and informally through the skilled processes of the firm. It also comprises knowledge about personal skills, project experience of the employees, and cross-organisational knowledge. The latter covers knowledge about business relationships with partners, including clients, architects, engineering companies, and contractors.
- Project knowledge: this is the potential for usable knowledge and is at the source of much of the knowledge identified above. It is both knowledge each company has about the project and the knowledge that is created by interaction between firms. It is not kept in a form that promotes re-use (e.g. solutions to technical problems, or avoiding repeated mistakes), and thus companies and partnerships are generally unable to capitalise on this potential to create knowledge. Project knowledge includes both project records and the recorded and unrecorded memory of processes, problems and solutions.

According to Eliufoo (2005), there is a quantitatively continuous information flow in construction processes, which cumulatively builds on the knowledge that an organisation possesses. Petursson (1991) has indicated how organisations in construction could enrich their knowledge base by making use of what they refer to as the forward and backward flow of information. That is, if taken that information goes through an interpretative and meaningful process (Bhatt 2001, Davenport and Prusak 1998). The backward flow of information in the construction process is a significant aspect for organisations to build upon their knowledge base in both forms of knowledge. This is so since feedback on constructability, cost matters and the time factor has a chance of being incorporated into future design; and when such an action is taken, the organisation is considered to have undergone a learning process and to have learned (Argyris 1999).

2.1.3 Problems in knowledge management

The problems in knowledge management, according to Davenport and Prusak (1998), struggle somewhere within the construction culture. These researchers were looking for best practices, new ideas, creative synergies and breakthrough processes that information cannot supply, regardless of how well it is managed. They became convinced that these kinds of results could be reached only in making effective use of knowledge. In addition, it was clear to them that much of the knowledge that the companies need already exists within their organisations but is not accessible or available when required. In their book Davenport and Prusak (1998) cite one manager as follows*: "If we knew what we know, we would be three times as profitable."* That is the belief of many corporate executives which shows the obvious need to study how knowledge is managed, mismanaged and unmanaged in organisations.

According to Szulanski (2003), a large number of organisations are now attempting to transfer best practices, close internal performance gaps, stop 're-inventing the wheel', and eliminate deficiencies in performance. The rise of the knowledge economy has helped organisations recognise that knowledge assets are rapidly becoming their most precious source of competitive advantage, and that learning to better manage those assets has become a competitive necessity. Best practices are unlikely to spread if companies do not try to spread them. However, even when they do try to spread them, best practices spread less effectively than expected, because transferring them effectively is often found to be far more difficult than expected. Transfers of practices within the firm tend to be 'sticky'. Difficulties in the transfer of best practices within firms are traditionally ascribed to interdivisional jealousy, lack of incentive, lack of confidence, insufficient priority, lack of buy-in, heavy inclination to re-invent the wheel, or to 'ploughing the same fields twice', the refusal of recipients to do exactly what they are told, resistance to change, lack of commitment, turf protection, and many other manifestations of what seem to be part of the popular definition of the NIH (Not-Invented-Here) syndrome. (Szulanski 2003.)

The construction industry is a project-based industry, the delivered product changing from one project to another under the influence of many different factors. Consequently each day on the construction site brings forth a new problem and a new solution. These problems and solutions are rarely well-documented, and valuable lessons are learned only in the minds of those who experienced them (Kazi and Koivuniemi 2006). Knowledge and experience, just like good solutions from past projects, should be re-used again and again. This is however not very easy, as project partners typically change from project to project and new partners are little if at all aware of past experiences, good or bad. In the coming years the situation will become even more problematic as the construction industry will lose a large portion of its skilled force (Kazi 2006). It is not only the loss of skilled work force that is a matter of concern for the construction organisations, but also the experiences and knowledge that this skilled force will take with them. Construction organisations have experimented with different tools and instruments to capture some of the good and bad practices that are salient characteristics of a typical construction site and project. A good practice database should be implemented as a means for the capture good practices and their appropriate dissemination (Kazi 2006).

2.1.4 Knowledge management model used in this study

Nonaka and Takeuchi's (1995) four modes of knowledge creation have formed the bases of data collection and later analysis. In addition to two forms of knowledge, tacit and explicit, the knowledge created can be classified into a third category: the combination of explicit and tacit forms (Eliufoo 2005, Al-Hawamdeh 2002). This combination may be found in routines, norms, organisation structure, culture or individual memories. This 'Know-how' is the type of knowledge that can be expressed and articulated. For example, shared tips can be gathered, and the information can benefit others who might face the same or similar problem. Know-how can be seen as what Nonaka and Takeuchi (1995) referred to when they talked about tacit knowledge to explicit knowledge conversion. According to them, knowledge conversion is about interactions between explicit and tacit knowledge in continuous and spiral manner. Unlike skills and competencies, know-how can be documented and the knowledge can be transferred through an independent learning process. Al-Hawamdeh (2002) compares the situation to the process of making a cake: the ingredients and tips can be documented, and the reader might not be able to master it the first time around, but through trials he might be able to do even better than the originator.

Within the construction industry, valuable experience and knowledge are lost primarily because of the lack of proper capturing and sharing mechanisms. This thesis takes a technology-driven approach to knowledge management and it is viewed in four phases: knowledge capture and documentation, knowledge retrieval for re-use, new knowledge creation, and knowledge sharing. In selecting and implementing technology, we have to consider strategic relevance as well as the practicalities of everyday use, and how technology fits with organisational and individual practices and the habits of its users.

2.2 Learning and e-learning

2.2.1 Perspectives on learning

According to Kasvi (2003), managing knowledge is not enough. In order to be of use, knowledge has to be applied to practice by people. That is, people have to learn. Learning has become a lifelong process. The traditional way of learning has been to bring students together for lectures that occur during one's early years. Now learning is an all-time activity, it is everywhere, yet just-on-time and customised just for you. We must now train ourselves, take responsibility and develop our competences in self-directed learning. Learning has become the most important part of everyone's work. (Kasvi 2003.)

2.2.2 Learning models

Kasvi (2003) refers to Ertmer and Newby (1993) and Anderson (1980) when defining three learning models. These three are behaviourism, cognitivism and constructivism. *Behaviourism* is based on behavioural changes. The basic principle is to repeat and reinforce a new behavioural pattern until it becomes automatic. Behaviourism observes behaviour without referring to mental processes behind it. Learning is a passive process, where learner reacts to different stimuli, for example to given knowledge. *Cognitivism* focuses on the mental processes behind the behaviour. Human mind is seen as an information-processing system that commits abstract symbolic representations of given knowledge to memory, where they may be stored and processed. *Constructivism* sees learning as an individual knowledge construction process. Knowledge cannot be given as such, but it will have to be (re)constructed by each learner. Therefore, learning results are based not only on given knowledge but on learner's prior experiences and schema. (Kasvi 2003.)

2.2.3 Learning at work

According to Järvinen and Poikela (2001), research on learning at work and especially research supporting the development of work organisations has paid most attention to intervention measures aimed at improving the performance of organisations and workers. This is not difficult to understand, as the economic success of a company is the key requirement for its survival (Järvinen and Poikela 2001). The goal of learning is to improve the performance of the employee, the team and the whole organisation, develop the sense of community in the work organisation, and support the employee's personal development as well as mastery of her or his own life (Boud and Garrick 1999). Achieving this goal requires that learning at work should be simultaneously analysed as individual, group and organisational learning process. This is the most important challenge in developing and researching learning at work (Järvinen and Poikela 2001).

2.2.4 Organisational learning

Organisational learning takes place when new routines and ways of action are conceived and adopted in an organisation through individual learning and group dialogue. These routines and ways of action are not dependent on the individuals and groups that have created them but survive even after the people involved have left the organisation (Kasvi 2003). According to Marquardt (1996), learning in organisations can occur at three levels, which are *Individual learning*, *Group/Team learning* and *Organisational learning*. *Individual learning* means, according to Senge (1990), that "organisations learn only through individuals who learn". The factors that can contribute to individual learning in the organisation include among others: (i) immediate application to work, (ii) accelerated learning techniques, (iii) personal development plan, (iv) abundant opportunities available for professional development, (v) linking to organisational learning in an explicit and structured way.

Group/team learning means that work teams must be able to think, create and learn as an entity. They must learn how to better create and capture learning (learning how to learn). A successful team learning system ensures that teams share their experiences with other groups in the organisation.

Organisational learning occurs through shared insights, knowledge and mental models of the members of an organisation, and builds on past knowledge and experience, which depend on institutional mechanisms (policies, strategies, explicit models) used to retain knowledge. Though organisations learn through individuals and groups, the process of learning is influenced by a much broader set of variables, just like the performance of a symphonic orchestra is more than the sum of its individuals' knowledge and skills.

Argyris and Schon (1978) attached another perspective to organisational learning. They defined three different levels on organisational learning: (i) in *single* loop learning organisation learns when it observes an error and corrects it, but does not change its policies, objectives or thinking models; (ii) in *double* loop learning an organisation learns by correcting observed errors in a way that involves the modification of organisational norms, policies and objectives; (iii) in *deutero* learning members of an organisation reflect on and inquire into organisation's previous contexts and experiences for learning. Based on these reflections, the organisation and its members learn to learn, understand what facilitates or inhibits learning, and invent new approaches for learning.

2.2.5 Remembering organisational knowledge

According to Kasvi (2003), organisations have several potential outputs, not all of which are intentional or intentionally managed: (i) different kinds of knowledge related to the product or service or the organisation, (ii) technical and procedural knowledge concerning the product and its production and use, (iii) organisational knowledge concerning the organisation itself.

According to Kasvi (2003), organisational knowledge is particularly important for organisational learning. If the organisation fails to systematically capture it, it risks repeating its errors over and over again and losing any learning possibility taking place. Organisational knowledge is based on the good and bad experiences of organisation members, team leaders and managers when they have successfully or unsuccessfully solved problems at hand and completed their tasks. But the negative experiences are easily forgotten, and people do not usually have enough time to handle and reflect on their positive experiences (Kasvi 2003). Organisational memory is distributed throughout the entire organisation in individuals' knowledge representations and competences, and an 'Organisational Memory System' may store the memory in various forms, for example, as databases, writings, stories, learning histories, and memories in people's minds. The Organisational Memory System should be able to handle two distinctively different kinds of knowledge. It should cover substance and lessons learned; what was done and how it was done. It is not enough that an organisation collects, stores and distributes technical and procedural knowledge according to traditional knowledge management principles. The organisations involved should be able to utilise these experiences, this organisational knowledge in their future projects. If these lessons are not stored for future use, the organisations cannot understand what actually happened and why. They effectively forget what they have learned and cannot become learning organisations. (Kasvi 2003.)

2.2.6 E-learning

Knowledge management aims to help people acquire new knowledge, as well as package and deliver existing knowledge through conscious learning. Electronic learning or e-learning is a relatively new area that includes computer-based and on-line training tools. E-learning systems often include collaboration tools and support for different types of content, i.e. video, audio, documents etc. Knowledge could be delivered through a variety of presentation devices including web browsers, PDAs and mobile phones. This enables persons involved in a project to receive the knowledge when it is needed, regardless of where they are and what they are doing. E-learning will be delivered as small, focused learning objects to fit the format of the presentation devices. (Woelk and Agarwal 2002.)

E-learning offers lots of advantages for learning which are different from other ways of learning. A wave of empirical research has revealed a long list of the promises and reported benefits of computer networks for learning at work. One self-evident benefit is that computer networks break down the time and space constraints. And the delay of asynchronous communication allows time for reflection in interaction (Hakkarainen et al. 2001). Making thinking visible by writing should help learners to reflect on their own ideas and those of others ideas and share their expertise. A shared discourse space and distributed interaction can offer many perspectives. Furthermore, a database can function as a collective memory for a learning community, storing the history of knowledge, construction processes for revisions and future use. Dynamically changing business environments place completely different challenges on the learning process – it has to be efficient, just-on-time and relevant to the task (problem-dependent). This can be solved with e-learning, i.e. with a distributed, student-oriented, personalised, and non-linear/dynamic learning process (Drucker 2000).

E-learning may take place in the Internet with various technical platforms, in the context of appropriate educational systems, and in communities and networks of practice. A national e-learning environment extends to numerous organisations and should not disturb an individual learning event; on the contrary, an e-learning environment should support it. E-learning tools and organisational habits, as well as new ways to teach and study, have to be learned as a part of the e-learning community of practice (CoP). An e-learning environment that includes all the necessary tools and social structures enables flexibility of and changes to teaching and studying styles. (Koponen 2006.)

Disadvantages of e-learning include the lack of face-to-face interaction with a teacher. Supporters of e-learning claim that this criticism is largely unfounded, as human interactions can readily be encouraged through audio or video-based web-conferencing programs. Discussion forums and other computer based communication can in fact encourage students to meet face-to-face. Discussion groups can also be formed on-line. E-learning tends to work better for the student when the topic matter consists of self-learned items. When much group collaboration is required, e-learning can cause lag times in collaborative feedback if the students are not disciplined. (Wikipedia 2007.)

2.2.7 E-learning in companies

Rosenberg (2001) has evaluated e-learning practices in companies. An effective knowledge management system not only provides a means to share information, but also builds up a community of learners. Employees can use their computers to view company policies, access forms, distribute information among colleagues, share stories, access the expertise of respected sages, trouble-shoot, gain up-to-the-minute advice, teach, coach, and customise their training needs. A successful strategy involves developing a culture that is receptive towards e-learning and technology, getting key players on board, communicating the value of progress, and leadership through the change (Rosenberg 2001). The cost benefits of e-learning to large organisations are difficult to ignore. Unlike classroom training, users may repeat the e-learning course without duplicating the cost. Other advantages of e-learning are the ability to communicate with fellow classmates independent of metrical distance, a greater adaptability to learner’s needs, more variety in learning experience with the use of multimedia, and the non-verbal presentation of teaching material. Streamed video-recorded lectures provide visual and auditive learning that can be reviewed as often as needed. For organisations with distributed and constantly changing learners, e-learning has considerable benefits when compared with organising classroom training. (Wikipedia 2007.)

Ericsson (2003) states that information technology-based information systems for learning and acquiring work knowledge must be developed to fit the individual worker, group and organisation. An information system must be in alignment with learning at the work. Learning is a human capability that can be acknowledged in different ways. Production workers' learning capabilities can be acknowledged by organising work in a way that supports learning. Information technology is a tool that extends human capabilities, a tool for communication and for processing and storing records, for example (Wyssusek et al. 2002). Putting too much emphasis on information technology alone and not keeping it in line with production workers' learning on the job is insensitive towards the work of production workers and may result in creating a tool that does not facilitate learning (Braf and Goldkuhl 2002).

The training that is available for construction industry staff often fails to provide ad hoc support on up-to-date contents. Traditional face-to-face seminars can be a good introduction to a topic but they cannot help to cope with upcoming problems and challenges thereafter and cannot keep learners updated on new standards and regulations (Wohlfart and Frielingsdorf 2006). In addition, although there is a range of scientific findings on didactical models, much of traditional training does not make a real use of them. Traditional seminars are not sufficient for on-the-job support. The knowledge thus acquired is stored and can be reproduced, but it is difficult to apply it to coping with daily tasks. If learning is to be a continuous process, which needs to be integrated into work, other approaches have to be favoured that provide more of an on-demand support (Wohlfart and Frielingsdorf 2006).

2.2.8 E-learning model used in this study

The learning of the construction project stakeholders can be supported by an e-learning platform that aids studying and understanding the construction operations in advance, before or during the construction execution (Lin et al. 2005). ICT-supported learning systems can also be called knowledge management systems (Lin et al. 2005). Many organisations are now engaged in knowledge management efforts in order to leverage knowledge both within their organisation and externally to their shareholders and customers (Malhotra 2000, 2001). Valuable knowledge can be available in different forms and media, such as in the minds of experts, in operation procedures, and in documents, databases, intranets, etc. However, knowledge management in the construction phase of projects aims at effectively and systematically collecting and sharing the experience and knowledge of the project by web-based and intranet technologies (Lin et al. 2005).

On-line learning tools can be roughly divided into tools for delivering educational content and tools for communication. Educational content is, of course, always communicative. In a digital on-line environment content can be continuously reviewed and improved. It is generally recognised that workers at all levels of an organisation are a significant source of creative thinking. On-line tools could provide workers with a link to immediately capture the lessons learnt as a project progresses (Bowden et al. 2006). Off-site training formats are low-cost alternatives for on-the-job training and give a novice an opportunity to experience real working conditions (Wang and Dunston 2006). One simple version of an off-site training system are on-line video sharing sites, which allow anyone connected to the Internet to upload digital video recordings. This kind of a system supports efficient dissemination of project-related videos and virtual visits to sites (Kumaraswamy 2004), best practices, and technical operations on site, e.g. exceptional installations.

2.3 Construction Project Management

The construction industry is a project-based industry where the delivered product changes from project to project under the influence of many different factors. This chapter presents the parties and typical phases of a construction project.

2.3.1 Parties involved in a construction project

According to a guidebook called “Production Planning and Management on a Construction Project” (Koski 1995), the main parties involved in a construction project include the user, the employer, the designer, the builder and the authorities.

- User means the user of the constructed building, for example, the users of a hospital may be doctors, nurses, patients and cleaners.

- Employer is the party who owns the construction project. Project Manager is a member of the employer party.
- Designer party can include the architect, structural engineer, electrical engineer, and the HVAC designer. Their role in the construction project is to draw the plan for the construction.
- Builders (contractors) are those who are in charge of the construction of a building. Normally, there is one main contractor who is responsible for the whole construction project and controls the sub-contractors' share of the work, such as heating and ventilation systems.
- Authorities are usually officials who work in municipal or city administration. Their role in a construction project includes land allocation, construction permissions and construction control.

2.3.2 Phases of a construction project

The stages of construction development presented here may not be strictly sequential. Some of these stages require iteration, and others may be carried out in parallel or overlapping time frames, depending on the nature, size and urgency of the project.

- Project Definition: A phase where users raise the need for a construction project, alternatives aimed to satisfy their needs are discussed, and issues discussed include the project background, size and the location of the project, as well as estimation of time and costs.
- Project Planning: Compared to project definition, project planning involves a more detailed specification of needs. Objectives, schedule, space, location and cost of a construction project are the details that need to be identified in this phase. The project planning phases are: Project Organisation, Site Specification, Plans on Project Economics, Timing, Collecting Design Information, Preliminary Construction Design, and Specification of Building Plan.
- Construction Design: Architectural design starts the construction design of a building. After that and during this same phase all other designers start their work. The purpose is to provide plans for later phases in order to continue with the plans. The construction

design phases are: Organisation and Management of the Design, Proposals, Sketches, Master Plan, Preliminary Check, Contract Programme, Planning of Use, Tender Invitation, Working Drawings, Production Planning in Tender Phase, Tenders, and Building Permit Process.

- Construction: After all the design work is done, the contractors are selected and activities, such as production planning, construction work, controlling, testing, approving, and handing over, start. The construction phases are: Contract Signing, Working and Installation Drawings, Production Planning and Management, Control by Employers and Authorities, Construction, Test Run, Acceptance, Final Approval, Hand Over, and Final Inspection.
- Occupation: As the building is ready to move in to, maintenance and servicing should be provided at this stage. Instruction manual about operations and services should be provided by the constructor and the designers. The occupation phases are: Organising Moving-in, Operation and Service Instruction (the maintenance manual), Work Under Warranty, Operations, Maintenance, and Disposal of Facility.

2.3.3 Success of construction project

According to Salminen (2005), each project participant has a different view about success, which may involve technical, financial, educational, social, and professional aspects. He (2005) states, however, that few objectives are shared by all participants. Everyone expects financial profit and wants projects to be completed on schedule (Salminen 2005). The absence of any legal claims or proceedings is also an outcome desired by all. Although many success criteria from general projects apply to construction projects, the latter also have characteristics that differ from those of, for example, development, software, or marketing projects. Construction projects are primary production-oriented activities that exist for predetermined, short-term purposes, but on company level they fall under continuous project business. Even if the evaluation of project success depends on different viewpoints and expectations, many authors propose one or more general criteria for construction project success. Salminen (2005) collected construction project success elements from several sources (e.g. Ashley et al. 1987, de Wit 1998), and came up with the following list: (i) keeping to budget and profitability, (ii) schedule adherence, (iii) quality/technical specifications/low number of defects, (iv) product functionality, (v) client satisfaction with the product and service, (vi) cost and time predictability/minimisation of client surprise, (vii) contractor/project manager/team satisfaction, (viii) environmental sustainability, (ix) safe performance/low accident rates. (Salminen 2005.)

2.3.4 Project success model used in this study

The scope of this study covers construction pre-design and design operations as well as site operations, which are related to design issues, and the information flows relating to these phases, an area somewhat more limited than the whole project. However, the success of the design issues and information flow should correlate with the whole project's success, and thus the success elements of information flow are relevant for the construction site also.

2.4 Construction ICT

Information technology has become a major research topic in the construction industry for the last 20 to 30 years. The International Council for Research and Innovation in Building and Construction (CIB) formed the W78 Working Commission that focuses on IT in Construction. The three main themes covered in W78 conferences have been: computer-integrated construction, IT-supported process improvement, and decision support knowledge-based systems as well as artificial intelligence. The second group involved with building and information in the CIB is the W102 Working Commission, which focuses on the management of the whole spectrum of information in a way that reflects the realities of decision-making in modern building practise. The objective is to cover concerns that are related to information and knowledge management, both theoretical and practical. In Finland, there is a national-level strategy to improve knowledge management in construction by using new ICTs and by improving human collaboration (Visio 2010).

Sarshar et al. (2000) conducted a literature review supplemented by academic and industry workshops. This resulted in the formulation of seven themes that describe their vision for construction IT during 2005–2010:

- Model-driven (as opposed to document-driven) project information management

- Life-cycle thinking and seamless transition of information and processes between the phases of the building life cycle
- Use of past project knowledge (or information) in new developments
- Dramatic changes in procurement philosophies, as a result of the Internet
- Improved communications through visualisation during all life cycle phases
- Increased opportunities for simulation and what-if analysis
- Increased capabilities for change management and process improvement

This section includes potential technologies that could support managing knowledge and facilitating organisational learning in the construction industry. The application of information and communications technology (ICT) in the architecture, engineering and construction (AEC) sector has evolved over several years. Organisations continue to invest in ICT in their bid to harness technology and streamline business processes. However, construction organisations continue to experience perennial problems that militate against successful implementation of IT projects. This results from cultural, organisational and other operational constraints. (Ugwu and Kumaraswamy 2006.)

2.4.1 ICT in Design Management

There has been a lot of effort to describe and explain the design process and the generation of design solutions since the early 1960s (Lundequist 1992). The CAD systems have definitely brought benefits, such as the possibility to produce a huge amount of drawings in a limited amount of time, and the possibility to create highly realistic and professional representations of the design solution (Moum 2006). Another research direction is the development of virtual reality (VR), which is based on geometrical and graphical representation. VR offers the possibility to navigate within and see the objects and their relation to each other in a 3D space. The possibility to create a realistic imitation of a real-world environment, combined with the spatial experience dimension, can become a powerful future design tool (Wikforss 2003).

2.4.2 ICT and Communication

According to Moum (2006), failure in communication can cause conflicts and misunderstandings, and have a negative influence on a building project. The sending and receiving of a message (e.g. design solution) depends on the competence, knowledge and previous experiences of the participants in the communication process. If the client does not know the symbolic meaning, or the level of abstraction used, he will not understand what the architect tries to communicate, which can lead to misunderstandings and conflicts. The architect may assume that the client knows which level of totality an abstraction represents, for example the plan drawing door symbol, but a problematic case of information loss could arise if the client does not know that the two lines on the paper actually symbolise a door. The realism of visual 3D views may reduce the communication problems between architect and client. (Moum 2006.)

2.4.3 ICT and Collaboration

The importance of collaboration is growing, as globalisation and increasingly complex techniques and products require more teamwork, and the complexity of problems becomes unmanageable for one individual (Moum 2006). Network technologies, such as e-mail and Internet, have contributed to the most radical changes within the average working day of the building process participants, for instance there may arise a need to support processes that are independent of geographical and organisational borders. (Moum 2006.)

2.4.4 ICT and Information access

The network technologies enable easy and fast access to information. This has been a huge benefit in building projects and has, according to Schwägerl (2004), contributed more to the acceleration of the design processes than the CAD tools. Internet-based technologies have been an important support for handling the huge amount of documents and drawings within a building project. The pool of material is accessible to project participants, anytime. This is different from the traditional and passive way of 'getting-the-plan-with-mail'; the push for information has developed into pull of information.

Figure 2: 3D-visualisation and BIM bring about better understanding from the future building (Visio 2010).

2.4.5 3D Product Models

Another influential trend within ICT is the development of standardised communication formats between different programs and systems to ensure their interoperability. An example of such a standard is the Industry Foundation Classes (IFC) (Kiviniemi 2004). The 3D product models for construction or building information models (BIM) are based on the definition of objects that contain intelligent information. From the model it is easy to generate 'traditional' drawings, and when using a model it is possible to control the density of information (Kiviniemi 2004).

2.4.6 Critical Success Factors in ICT usage

Ugwu and Kumaraswamy (2007) state some fundamental critical success factors (CSF) that would act as enablers for successful implementation of ICT projects in construction. The top CSFs identified are (Ugwu and Kumaraswamy 2007): (i) cost of development, (ii) top management support, (iii) availability of appropriate hardware and software (e.g. bespoke off-the-shelf solutions), (iv) ease of use of IT systems, (v) development of team knowledge and understanding of construction business processes, (vi) clear definition and understanding of end-user requirements (i.e. need for end-user driven IT solutions and applications development), (vii) clear communication of IT objectives to management, (viii) standardisation issues (to enhance interoperability of dispersed systems and platforms), and (ix) change management at organisational level (especially for large organisations).

Other barriers to the application of ICT in the construction industry can be discussed under the following headings: security, safety, user acceptance, level of investment in IT infrastructure, and the development of distributed computing architectures and frameworks that are suitable for particular construction problems (Ugwu and Kumaraswamy 2007).

Security: There are a number of security concerns in deploying ICT systems, such as junk or spam e-mail, spy ware, phishing etc. The second security consideration relates to organisational information safety, since an unauthorised software agent can modify or delete data from a system leading to very significant impacts on an organisation’s business processes. (Ugwu and Kumaraswamy 2006.)

User acceptance: The construction industry is still generally slow in its uptake of new technologies. There is a need for end-user-driven system development to ensure that user requirements are correctly captured. User needs may have to to be clarified after they are presented with various options, possibly with unbiased guidelines to help them towards realistic choices. (Ugwu and Kumaraswamy 2006.)

3 Theoretical background and objectives of the study

The main goals, approach, and methodology of this study are presented in this chapter.

3.1 Framework of the Study

I participated in a project called Prolab as a researcher of computer science. The Prolab project was carried out in the years 2003 to 2005 in Vaasa University, Finland. There were two full-time and nine part-time researchers working in the Prolab project, studying e.g. the learning and knowledge management in inter-organisational construction projects (a doctoral thesis completed), network issues and project success (a licentiate thesis and a doctoral thesis completed), communication issues in a project (a master's thesis completed), and participation in the projects (a master's thesis completed). So there are several different viewpoints to the case projects. Altogether more than ten different construction projects were studied. Five of these case projects are analysed in this thesis.

The aim of the Prolab project is to develop an operational model that will improve the quality of operations and end results in construction projects by elaborating knowledge management, decision making and team work. The project seeks to find solutions on how information can be used effectively in construction project management and what kind of procedures help the management of knowledge. The project team concentrated on public construction projects and explored the proposed solutions, which were believed to help improve the process of a construction project.

This study deals with the issues and problems of knowledge management in construction projects. The focus is in construction ICT and solutions that have emerged in this field. There are five published articles that relate to these themes. The first three articles concentrate on knowledge management and ICT support, their possibilities and obstacles. The fourth article introduced the issue of learning in a construction project. The need of learning seemed obvious and seemed to relate to most problems in construction projects. The fourth article also discusses e-learning issues to some extent. In the fifth article, the prime thing is connecting the e-learning platform to the web services for a project.

3.2 Research Questions

A practical reason for this research was my ambition to find the bottlenecks and problems that occur in construction projects. In addition, I wanted to learn what possibilities there are to solve these main problems by means of construction ICT and how to minimise the obstacles that I would find in the utilisation of ICT. On the grounds of this knowledge, it will be possible to develop processes and tools to better rise to the challenges of the industry. Every article included in this study focuses on a viewpoint of its own and involves different research questions, but in general, the questions can be summed up to the following objectives:

- What kind of problems related to information flow in a construction project do the project stakeholders highlight?
- What kind of solutions is being suggested?
- How could ICT be used to foster collective knowledge building and learning in construction projects?
- How could ICT tools be developed based on such understanding?
- What are the obstacles to efficiently administrating information and how can these obstacles be removed?

Table 1: Viewpoints of the articles.

Article	Viewpoint
1. Article: Knowledge management tools – possibilities and obstacles	Classification Possibilities Obstacles
2. Article: Information System (IS) tools for knowledge management in public construction projects	Needed knowledge Wanted knowledge Offered knowledge Challenges
3. Article: The possibilities and limitations of ICT's in public construction projects	CAD-design Product model Motives to utilise ICT
4. Article: Learning support of ICT's in construction projects	Learning and knowledge management Learning needs Learning means utilising ICT
5. Article: Developing project management system to support active learning and communication in a construction project	Web-based project management system E-learning possibilities

3.3 Viewpoints of Articles

All the articles provide information, understanding and methods related to the improvement of construction projects. This information can be used to develop information systems. New rules and ways of working are being created to solve the problems of the industry. The purpose of this study is to examine how ICT can be used to support managing knowledge and facilitating organisational learning in the construction industry and what are the possibilities and limitations of knowledge management tools. Every article represents the same goals but each of them emphasises a different viewpoint of the same problem (**Table 1**).

3.4 Case Descriptions

The research is based on five case studies in public construction projects in Finland in two different towns. The number of inhabitants in these towns varies between 23,000 and 57,000. The five construction projects were:

- **Case 1:** Hospital for senior citizens: the renovation of its nursing home; total area 7,000 m^2 and budget 5.7 million euros. Project started in 1996 and ended in 2005.
- **Case 2:** Renovation and partly new construction of a school that had mould problems; total area 3,000 m^2 and budget 2.7 million euros. Project started in 1998 and ended in 2005.
- **Case 3:** Renovation of a school that had mould problems; total area 7,000 m^2 and budget of 4 million euros. Project started in 1997 and ended in 2002.
- **Case 4:** University project, 24,000 m^2. Alteration of an old factory into a university building and partly new construction. The project started in 1997 and ended in 2004.
- **Case 5:** Renovation and partly new construction of a nursing home, total area 3,500 m^2. Construction stage started March 2003 and ended February 2004.

3.5 Interviews

The empirical part for this study comes from the Prolab project interviews of construction project stakeholders in Finland. The total number of Prolab project interviews is over one hundred and the interviews were had during the years 2003–2005 on demanding public construction projects. For the five articles that support this thesis, I analysed 60 interviews (**Table 2**) from five case projects in two middle-sized towns in Finland and one town in Sweden. The interviews that have been analysed were conducted by five project researchers. Fifty-four (54) of the interviews were had in Finland about five different projects. The informants were project stakeholders; end-users of the buildings, such as nurses and teachers; architects and special designers, project managers and contractors. In addition, there were 6 interviews in Sweden where the informants were architects and project managers.

In my analysis, I used the material and transcriptions of the project researchers. The interviews and transcriptions had already been prepared before I participated in the Prolab project. Appropriate timing was my motive to select these interviews in particular to my analysis. These interviews were ready when I came to the Prolab project, and any later interviews have not been taken into the analysis.

The interview methods varied according to the interviewer; the most popular method was theme interview. In a theme interview the informants can express their opinions freely and come up with issues that the interviewer would not have understood to ask in a more formal interview. The second interview method, which is called 'Put your cards on the table', poses questions in the form of predefined words. Each word is written on a card and each card is then one by one given to the interviewee, who is free to express their thoughts and give a personal answer. All the interviews were taped and transcribed word by word. The interviews that have been analysed were conducted by five interviewers whose backgrounds differ quite a bit. One of the interviewers had a construction degree and was specialised in construction ICT, one interviewer was a student in construction, and the others were researchers of different fields that had no experience in construction or ICT. The same themes were discussed in all of the interviews.

The discussed themes were

- differentiation of project phases
- role of parties in each phase
- successes and failures experienced during the project

- challenges; especially knowledge management in the project
- arrangements of co-operation
- co-operation tools used
- important persons in the project (in order to know who should be interviewed)

Table 2: The interviews and informants.

Interviewer	Method	**Number of interviews**	Informants	Case
Researcher A	Theme	13	1 project manager / architect 1 structural designer 1 electric designer 1 HVAC designer 1 automation designer 1 interior designer 1 electric surveyor 1 HVAC surveyor 1 facility manager 1 director of social service 3 nurses	Case 1
Researcher B	Card	3	1 architect 2 end-users	Case 2
Researcher B	Card	4	1 project manager 2 architects 1 end-user	Case 3
Researcher A	Theme	5	1 school principal 1 assistant city manager 1 architect 1 head of the construction department 1 head of the nursery	Case 3
Researcher D	Theme	2	1 head of the construction department 1 site manager	Case 3
Researcher E	Theme	7	1 school principal 1 building permit authority 1 project manager (contractor) 1 head of the employer department 1 caretaker 1 head of the design department 1 teacher	Case 3
Researcher B	Card	3	1 end-user 1 architect 1 project manager	Case 4
Researcher C	Theme	10	4 site managers 2 supervisors 1 procurement manager 1 quantity surveyor 1 surveyor 1 carpenter	Case 4
Researcher F	Theme	7	7 site managers	Case 5
Researcher B	Card	6	3 architects 3 project managers	CaseX
All together		60		

3.6 Research Strategy and Methods

My research method for this study is qualitative look into the issues of knowledge management and learning among construction team members. The methodological choices emerged when I joined the Prolab project. I got extensive material (60 interviews and transcriptions) about the current situation in construction projects to use. The Prolab project seeks to find solutions for how information can effectively be used in construction project management and what kind of procedures help the management of knowledge. My approach was to seek ICT solutions to the problems of information flow in construction projects. I pointed out that technology is an instrument but not the main goal per se.

Creswell (1998) defines qualitative research as an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem. He further characterises qualitative research as “interpretative, naturalistic approach”, based on multiple sources of information and narrative approach, being emergent rather than tightly pre-figured, fundamentally interpretative and viewing social phenomena holistically, and acknowledging biases, values and interests.

The Prolab project explored several case projects in the construction industry. Cunningham (1997) says that the case method is suitable to many tasks of empirical research. He recognised nine different case methods, which he classified into three main groups: intensive, comparative and action research. I situate my research into the intensive group. The assumption behind the intensive case method is freedom to compare observations to current theories, which demands that the researcher has experience on and is familiar with the culture and organisations. Cunningham later presents four intensive case methods, which strive at profound understanding of individual, group or organisation. The result might be a description of unique experiences which could become the basis to a new theory. In this case the researcher is not able to control the arrangements of the research, and thus she or he has to use the evidence from different viewpoints and time perspectives (Cunningham 1997). In the intensive method Cunningham includes narratives, tables, and explorative and interpretative methods. The narratives are summations from interviews or single documents. The descriptions are divided into general categories according to preparative classification of the material. Tables method is similar to grounded theory, where researcher creates categories and calculates the density of their occurrence. The explanatory case method makes conclusions and deductions as journalists do. A journalist can create a story where she or he describes one viewpoint and provides details based on reasons and concepts which she or he has used in the processing. The interpretative case method is more provocative and less exact when describing new ideas and approaches. (Cunningham 1997.)

My approach to the Prolab interview material resembles Cunningham's intensive case method. The culture and context of construction industry are familiar to me because of my work experience in the construction industry. I used the explanatory and interpretative case methods for scanning the interviews. However, there is criticism about the use of case study inquiries as a research strategy. An inquiry for a case study lacks rigour, hence allowing equivocal evidence or biased views; lacks or has little ability of generalising findings; and takes a long time (Yin 1994). Regarding the critique on generalisation, case studies as well as experiments are generalisable to theoretical proposition and not to populations or universes. Yin explains both case studies and experiments in this sense as not representing a 'representative sample' and is of the opinion that the investigator's role is to make an analytical generalisation and not to make a statistical generalisation by, e.g., enumerating frequencies (Yin 1994).

3.7 Research Process and Approach

My research consists of five published research articles. The articles were written during the Prolab project. I participated in the Prolab project mainly as part-time researcher. All the articles were written by the researcher group that participated in the Prolab project. My role in the articles was the following:

- **#1 Article**

The first article is a joint article with three other researchers. We explored the knowledge management tools that were used in case projects and the possibilities and obstacles to use these tools. My role was to concentrate on the classification and possibilities of technological tools. All of the tools, such as the project management plan, were not technical.

- **#2 Article**

The second article was written together with another researcher whose role was advisory and consultative. The second article partially consists of similar components as the first one but its viewpoint is on the information that is needed and wanted by and offered for the project stakeholders in different phases of a construction project. I have deepened these viewpoints for this summary based on my experience of the current situation.

- **#3 Article**

The third article was written for the Prolab project publication. My role in the writing of this article was describing the possibilities of CAD design and product modelling, whereas my colleague was dedicated to describing the motives to utilise ICT.

- **#4 Article**

In the fourth article, the learning viewpoint was explained by my colleague and I completed with the article by describing e-learning and the e-learning platform.

- **#5 Article**

In the fifth article, we discuss web-based project management system, which serves as a good environment for e-learning. Project-web development by means of requirements engineering was a common interest to both of us.

3.8 Scope and limitations of this research

The scope of this research is between computer science and knowledge management, and its viewpoint on learning relates to the e-learning possibilities. The subject was limited to public construction projects. The results may differ significantly depending of the type of the project, for example compared to independent or private construction projects. The projects took place in medium-sized Finnish towns in rural areas of the country. Finland is considered as a forerunner in the development of construction ICT, and several innovative and development-oriented projects have taken place in the biggest cities in Finland, so it is obvious that the know-how has mostly concentrated to the capital area. The public construction projects explored in this research were all placed in the countryside, and thus the found problems may differ from those in the cutting edge of the profession. In this research, I concentrated on the problems of public construction projects situated in the Finnish countryside.

The focus of this research is on information flows and the improvement of knowledge sharing and transfer in construction projects. Other project management issues, such as scheduling, cost management and safety at work, have been delimited from this research.

4 Summary of articles

The five articles that support this thesis have been published in construction ICT and knowledge management conferences during the years 2005–2007. All of the articles address issues related to construction projects and knowledge management problems in them. The intent behind the articles was to find ways in which ICT support could help in the information flow problems of construction projects. The full texts of the articles can be found at the end of this thesis, but short summaries have been included here for casual readers.

The main goal of the articles is to explore the problems in construction projects and to elicitate the project stakeholders' opinions by means of theme interviews. In order to improve the quality of the project industry we should focus on information and the way it is handled in routine and non-routine situations. Different solutions have been presented in ICT and KM literature. Literature of construction project management, learning in projects, e-learning, and best practices in other industries, has given new ideas to apply into construction projects as well. The empirical base to the articles was taken from the Prolab project interviews.

4.1 1st Article: Knowledge Management Tools – Possibilities and Obstacles

The first article explored knowledge management tools and their possibilities, classification and how the obstacles for efficient ways for administrating information can be removed.

4.1.1 Classification

The classification of the knowledge management tools according to Laudon & Laudon (1998) is; knowledge creating tools, knowledge processing tools, knowledge sharing tools and knowledge codifying tools. *Knowledge creating tools* support the activities of highly skilled knowledge workers as they create new knowledge (CAD, analysis systems, estimating systems etc.). *Knowledge processing tools* help disseminate and co-ordinate the flow of information. These are used routinely within construction organisations (word processing, spreadsheets etc.). *Knowledge sharing tools* support the sharing of knowledge among people working in groups (intranets, video-conferencing, document management systems, bulletin boards, e-mail systems). *Knowledge codifying systems* are statistically oriented tools that excel at using data to classify cases into one category or another. They include artificial intelligence tools as well as conventional statistical analysis to advance the data interpretation and decision making based on the knowledge generated (expert systems, neural nets, fuzzy logic, genetic algorithms, intelligent agents).

4.1.2 Possibilities

The possibilities of KM tools were found presuming that IT infrastructure should be part of an integral multi-faceted KM strategy which is tailored to suit the needs of the organisation. It is recognised that good knowledge management does not result from the implementation of the information systems alone (Grudin 1995, Davenport 1997, Stewart 1997).

Kuhne and Leistner (2002) conclude that there is a substantial potential for optimising management processes in the construction industry when using a product model for a centralised data exchange. At the time the technical-constructive planning is based on alphanumeric data, it is an abstract nature and possesses no direct graphical representation. The geometrical and spatial representation is becoming more and more significant for humans for trying to understand and control large projects with complex structures. The various potential have been arranged into three areas: collaboration, data processing and controlling. *Collaboration:* The use of a product model defines a common project language and gives a basis for well working communication between project participants and quick availability of data. *Data processing:* The product model can be used in productivity calculations; heat flows, bearing capacities etc. which can have substantial influences on decision making. *Project controlling:* The possibilities are in overviews of the total project from a cost and time viewpoint; project-wide usage of product model data simplifies the tasks of the project controller.

4.1.3 Obstacles

The obstacles found were technical, human, economical, and informational. All of the obstacles were present on every level; individual, organisational and network level.

The obstacles can be divided into four main categories:

- **Technical:** continual demand for upgrading hardware and software, a lack of supporting infrastructure;
- **Human:** lack of knowledge of possibilities and overabundance of information, cynicism and defeatism, lack of project-centric or senior executive commitment, cultural or internal resistance;
- **Economic:** unclear strategic objectives, high investment costs, network effects, investment costs justification, unclear benefits, time or resource constraints, uncertainty or risk aversion; perceived no-win situations for an individual firm;
- **Information**: poor knowledge resources; not enough information or knowledge about things; how to accept a delivery electrically; increased importance of security issues (computer viruses and other uncertainties).

4.1.4 Results

In our case projects, many ICT solutions were used, such as Computer Aided Design (CAD) systems, cost estimating systems and word processing systems, spreadsheets, and e-mails. The main problem is that the solutions are not interoperable, and there is a need to measure the quantities of materials, but information needs to be calculated and fed many times. There are knowledge-processing tools in use but they are not as centralised or intelligent as they could be. The information is kept separated in different computers, and there might be duplicated information stored in many different places. The result is that project participants may not use the latest document. The documents, plans and information are mostly printed on paper and many phases are repeated again and again. Due to these problems, it would be good to have a system that is able to share all the latest documents between all parties involved and that links all the documents to a centralised platform. Knowledge-sharing tools are mostly telephones, telefax copies and e-mail. The e-mail serves as archival repository but some informants claimed overabundance of information. Knowledge codifying tools serve the top-management level of firms and affect high´-level strategies and decision making. We did not notice them in use in our case projects because our interviews just concerned the project level.

It is easy to find applications to different tasks but the lack of centralised KM strategy brings about new problems. When we come to the realisation of a solution, we seem to be fighting against industry culture. Construction industry is an old industry with very established ways of doing things. New ways of organising work face resistance, people very soon become cynical, and unintended consequences of technological failures prevent success in the efforts for a change. Many times the interviewees talked about the obsolete computers and the limits of their knowledge about ICT possibilities. At the same time, they had doubts about the possible benefits of a system and were unwilling to start utilising the new system especially if the last ICT project had for some reason failed.

4.2 2nd Article: IS-tools for Knowledge Management in public Construction Projects

The second article focuses on knowledge management tools by exploring offered, needed and wanted knowledge. The needed, wanted and offered knowledge varies from project phase to another. In the table (**Table 3**), there is a collection of stakeholders' general needs and wishes for different project phases. The project team should be able to know how the project is organised, who knows what, and which information is needed from whom and when; thus they need to know who is able to select knowledge, what knowledge should be taken seriously, what knowledge is trustworthy, and what kind of extra knowledge is still needed.

4.2.1 Needed knowledge

Usually, the users cannot clarify what are their needs; therefore, a knowledge management system can help its users make decision on what are their needs and assist the users in what should be done next as well as keep the user on track while the construction project is running on.

Naaranoja et al. (2005) have studied how difficult it is to know what kind of knowledge one needs in a project and how people filter the information they do not want to learn. This filtering may also include issues that they should learn. People do not utilise all of the available knowledge resources. These resources might be people or tools that offer new knowledge, e.g, on the state of the building they are renovating. The offered knowledge may not be trustworthy, or one does not need the knowledge at the moment. Naaranoja et al. also tried to find out the critical factors of knowledge resources and why they are accessed, or even more importantly, why they might not be accessed, and how managers can know what offered knowledge they should take seriously in the project environment.

Table 3: Needed, wanted and offered knowledge.

	NEEDED KNOWLEDGE	WANTED KNOWLEDGE	OFFERED KNOWLEDGE
End-user	• design regulations • basics of construction and design • learning to define their future needs • how one should behave on a work site in renovation project	• visualisations • mock ups • comparison of alternatives • 'common language' e.g. creating a vision for the project • project phase information	• drawings • technical documents
Architect	• end-users' needs • end-users' functions • design schedules • basics of the building which renovate • vision templates from end-users • learning to understand other designers requirements	• end-users' acceptance • current function in building which renovate • lessons learnt from the similar projects and buildings • best practices • project phase information	• employers' list of needed spaces • regulations • standards
Designer (special)	• architect plans • basics of the building which renovate • design schedules • learning to understand other designers requirements • structural: discussion about constructability • HVAC: learning from the future functions of the building	• end-users' acceptance • lessons learnt from the similar projects and buildings • best practices • project phase information	• regulations • standards
Contractor	• communication with designers • to be involved in design process • more developed document management • more controlled plans from the designers • end-user functions in building which renovate	• drawings and documents on time • better design quality • constructability • lessons learnt from the similar projects and buildings • best practices project phase information	• poor designs – not on time • changes of the drawings at very last moment • folders of paper documents
Project manager	• plans to check • more developed document management • owner acceptance	• information flows • project phase information	• folders of paper documents
Owner	• information for facility management • information models of the buildings	• usability • optimised life cycle properties • building maintenance documents in digital form	• folders of paper documents

4.2.2 Wanted knowledge

People spend a lot of their time in searching for different types of information related to their projects. In big construction projects there are thousands of drawings and other documents and their management is difficult without any computer-based information sources.

4.2.3 Offered knowledge

There is a lot data and digital documents on hand but most of them are in a wrong format and nobody is able to put them into use. The data is usually not managed while it is created but instead it is captured and archived at the end of the construction stage.

4.2.4 Challenges:

Love et al. (2004) classify construction rework challenges as follows: design changes, construction changes, client, design team, site management, subcontractor, project scope, contract documentation, project communication, procurement strategy and design management. We used Love’s (2004) classification in our findings in the case projects:

- **Design changes:** The lack of cross-checking of the plans incurs the need for design changes.
- **Construction changes:** Constructability problems occur because the contractor may not take part in the design phase and co-operation between designers and contractors does not work.
- **Client:** The needs of end-users (client) change all the time because they are not able to define what they want and communication with the designers fails.
- **Design team:** Price competition in the selection of designer brings about problems that have to do with design quality, tight schedules, communication, and insufficient negotiation between members of the design team.
- **Site management:** Team work may fail because of lack of management, communication problems with designers, poor design quality, delay of drawings to the site, and constructability problems.

- **Sub contractor:** There is lack of co-operation between the main contractor and designers and information does not flow as it should.
- **Procurement and contracting strategy:** The best design group has worked together before. Maybe it would be best to make a design agreement with the group of designers and not with every designer separately.
- **Design management:** There is a lack of schedules and special designers have to wait for the main designs for too long. Design quality is not good enough and a lot of details are missing at the start of construction.

4.2.5 Results

It is difficult to know what kind of knowledge one needs in a project and how people find it and filter the information they do not want to learn. This filtering may also include issues that they should learn. People do not utilise or are not able to utilise all the available knowledge resources.

Quite many of the problems in our case studies concern the design phase. In addition, ineffective use of information technology, specifically the lack of interoperability, can lead to inappropriate and non-timely information transfer between design team members. When information technology is used effectively by the design team members, it can improve information flow and communication, decision-making, and design coordination, and it can be used to monitor changes in projects.

4.3 3rd Article: The Possibilities and Limitations of ICTs in Public Construction Projects

This article is included in the book titled ‘Rakennusprojektin onnistumisen eväitä’ (Instructions for the success of a public construction project) that has been published in the Vaasa University’s Publication Series in 2006. It is a summary of two earlier articles, and the viewpoint to the subject matter is quite practical. The target groups for the book are project managers, project personnel, and those who make the decisions in public construction projects, such as officers and other employees that represent city or municipal administration.

4.3.1 Computer Aided Design (CAD)

Construction industry is an old-fashioned industry based on traditions and many new developments face resistance. But it is obvious that even construction industry accepts the renewals if the benefits are clear enough. CAD applications are little by little taken into use, but the most intelligent IT solutions and tools developed by research and development initiatives still remain unused. CAD applications have evolved since 1990s when the first solutions appeared on the market. There are still several designers using the first technologies of CAD applications which produce lines and 2D drawings. The different methods of CAD design are presented in **Table 4**.

4.3.2 Product Model

The main achievements of this article that relate to the possibilities of ICT are the found benefits in the use of product models (later Building Information Model, BIM). Like Kuhne and Leistner (2002) state, there is substantial potential for optimising management processes in the construction industry when using a product model. According to Kuhne and Leistner (2002), the technical-constructive planning forms the basis for many processes in the context of execution of construction projects. This kind of planning includes data regarding geometry, location, and the quality of building parts. This data is used not only for fabrication but also for the planning and management processes, such as cost estimation, scheduling, invitation to bid, and billing. In this context, the construction plans not only form the basis for ascertaining the quantities of materials, but they also serve the spatial orientation and visualisation. With intelligent objects instead of simple points or lines, many tasks can be fundamentally better supported (**Figure 3**).

Table 4: Concepts related CAD-design.

Method	***Explanation***	***Benefit***
2D-CAD	Computer aided drawing system that produces vector components and two-dimensional drawings. The applications include building symbol libraries.	Easy and simple method to produce building drawings.
3D-CAD	Building elements can be illustrated as real three-dimensional objects and not merely as lines and vectors. From the virtual building one can take out different projections, plan drawings, cross-sections, facades, 3D-visualisations and lists of objects. Every drawing does not have to be drawn separately because the needed information comes directly from the 3D model.	The scenes, virtual visualisations and other real views can be taken from the model. The views are very illustrative and visual and they show how the future building will look like.
4D-system	Linking 3D plans and schedules together in order to visualise the progress of the construction project.	Helps in logistic and planning and optimising the installations on site.
Product model	Product model/Building Information Model (BIM) is a 3D model of a building. The BIM includes more intelligent properties more than traditional 3D model. Every component (e.g. door, window, and slab) includes information about its place, dimensions, properties, installation date etc. The product model helps in managing the construction phases from pre-design to facility management. The common data exchange format IFC ensures that the information can be transferred between the different CAD applications of several designers.	Project management becomes more effective when all the building information is integrated into the same system. This reduces double copies of information and information stays up-to-date.
Process model	Process model is a specification of processes in building design, construction and maintenance from the information management point of view.	Process model contributes to the design and management of the building and improves the continual development of the process.
IFC and IAI	IFC (Industry Foundation Classes) is an international standard for information exchange in construction and facility management. IAI (International Alliance for Interoperability) is an open international consortium that strives at developing and implementing IFC.	Information formats are combatible with each other. This enables information exchange between different solutions.
Virtual reality	A real sense of sight where the user feels being immersed in virtual reality. There the user is able to act interactively and handle big and complex information. The virtual reality works in computer display or in special virtual reality laboratory by using data glasses or data helmet.	Virtual reality enables simulations and virtual practicing.

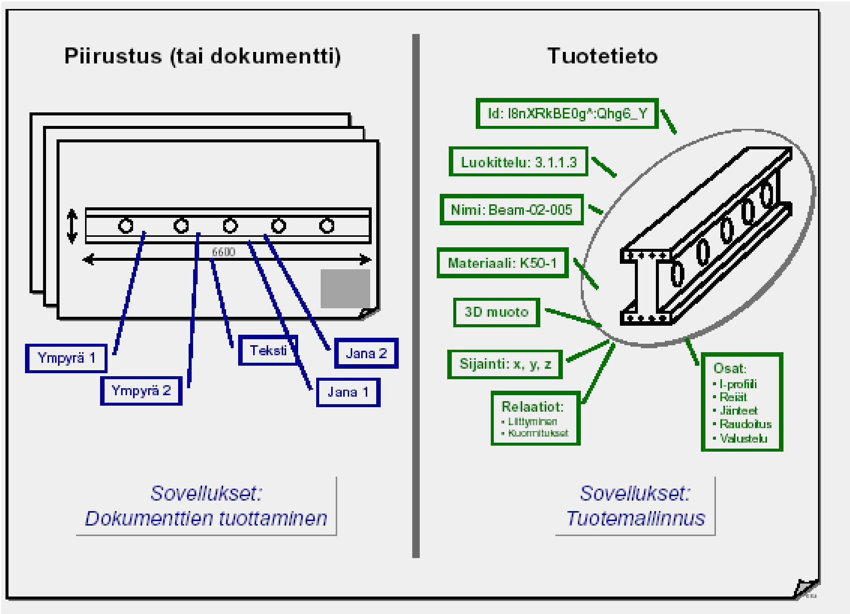

Figure 3: The difference between drawing and intelligent object (Karstila 2002).

4.3.3 Motives to utilise ICT

There are many factors affecting ICT usage at individual, organisation and network level (**Figure 4**). Every level has the same adoption barriers (Engsbo 2003): human, economical, technical and informational. The construction projects realise at an organisation network level but individual contribution is important as well.

4.3.4 Results

We suggested developing face-to-face and computer-aided communication in construction projects. Even if knowledge is mostly tacit and based on personal experiences, it can be better transmitted if people constantly communicate and co-operate. The ICT possibilities for communication are voluminous. The benefits of BIM are obvious: quantity surveying is trustful and accurate when the quantities can be obtained directly from the model, the design plans are more visual, the checking and control of plans is easier, and e-procurement, clash-detection, 4D design etc. are possible. The implementation of BIM is going on. In autumn 2007, BIM technologies are a prerequisite in Finland for the construction projects managed by Senate Properties (government-owned enterprise managing company).

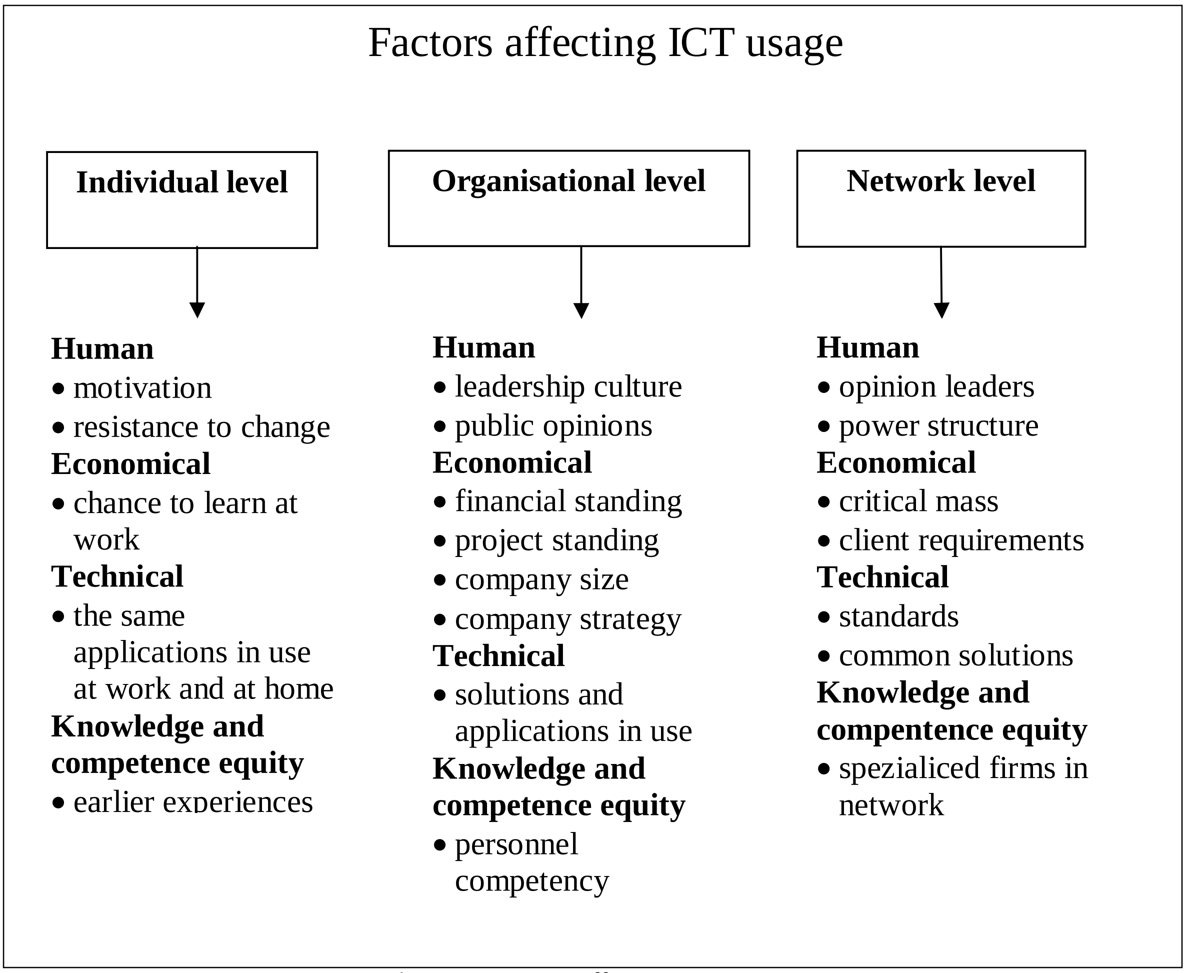

Figure 4: Factors affecting ICT usage.

The new technology brings about excellent opportunities but we have to remember that competence in practical work, management and leadership are still the prerequisites of success in construction. The usage of ICT does not guarantee the success in information management but it gives good possibilities for information sharing and communication in a construction process. The visualisations, simulations, and evaluations between different alternatives, calculations, estimations, and others facilitate the involvement of different parties to a construction project. The involvement of an end-user improves the quality of the result; the building may be more serviceable and useful. At its best, information that originates from the design phase of a construction project can serve the construction phase and the whole life cycle of the building in an intelligent and useful format.

4.4 4th Article: Learning Support of ICTs in a Construction Project

The aim of this article is to study what kind of learning is required in public construction projects and how ICTs (Information and Communication Technologies) currently and in an ideal case could support learning. Actually, the design process of a new building is a learning process where the parties learn from each other. For example, the architects learn from the user representatives how the building shall be used, and the users learn from the professionals of the construction industry how the building can support their operations. The site personnel learn how the designers plan the building should be built. The site personnel and the designers have realised the benefits of recognising the best practices and lessons learnt of the previous projects. The teams could avoid continuously dealing with similar problems by using knowledge from the past projects.

4.4.1 Learning and knowledge management

Haapalainen (2007) refers to Earl (1997) in suggesting the concept of knowledge management: "*knowledge management in an organization consists of at least four components; knowledge systems, networks, knowledge workers, and learning organizations*". Knowledge systems refer to databases and information systems that can capture information and help decision making. Networks that can be local, corporate or external are important for knowledge capture, knowledge building, and dissemination. Knowledge workers are the core asset for an organisation, people with crucial skills for knowledge processing. And finally, the organisation must be developed into a learning organisation, because "*knowledge is only maximized if the organization can learn*". (Haapalainen 2007.)

4.4.2 Learning needs

The many problems in construction projects seemed to result from misunderstandings when people from different backgrounds did not understand each other. Project stakeholders have to learn about the others' viewpoints and opinions. Other learning needs come from the learning of technical issues, learning of new regulations and standards, and learning of project work in general etc.

4.4.3 Learning issues

A central aspect of collaborative knowledge building is to create shared knowledge objects, such as ideas, building designs of functional plans, and to engage an intensive synchronous and asynchronous interaction among the participants for further developing and building on them as well as to re-use the emerging knowledge later on for solving new problems or reflecting on the process. The dissemination of information is very important in a construction project. It is important to understand the importance of rewarding in the time of delivery and the work overload of people. We should also pay attention to how easy it is to deliver the relevant information to every party.

4.4.4 Learning means utilising ICT

- Document management: In terms of knowledge management, the documents produced by organisations represent their explicit documented knowledge. Common needs in construction projects are related to identifying the latest version of the plans. Most artefacts guiding a project and being developed during a project can be represented as documents and enable the transfer of knowledge from experts to novices. It should also be clear that it is not enough to simply create more and more data on computer systems. This data needs to be accessed and evaluated, critiqued and used. Organisations are identifiable by the way people develop their own skilful practices in sharing data and information resources (Lindvall et al. 2002).
- Organisational memory: According to Ozorhon et al. (2005), organisational memories are used to improve strategic decisions and after the actions are taken, new experiences are added to the organisational memory. This is a cyclic process rather than a sequential process as newly acquired knowledge from the given decisions should be used to revise organisational memory. How this cycle operates in each company depends on company characteristics and the height of organisational learning barriers.
- Sharing knowledge: Dixon (1992) has considered distribution of information occurring in what she termed “intentionally” and “unintentionally”. Distribution may occur intentionally through individual written communication, such as the use of memos, reports, letters or training; as well as through formal courses, on the job training, internal conferences, seminars, briefing or internal publications. She cites that

distribution of information may occur unintentionally through job rotation, task forces, informal networks, stories and myths.

- Collaboration services: According Lindvall et al. (2002), delivering the right information at the right time is one of the major objectives of knowledge management. To achieve this, employees need to collaborate and communicate, especially when people work in an environment that is distributed in time and space. A common practice is to use a tool to share a document in real-time so that two or more geographically distributed groups can see and hear the same presentation. In construction projects the role of knowledge management and communication is particularly important since the participants come from many companies and have quite diverse backgrounds. The basic functionality of tools in this category is to connect employees by providing a computer-based communication channel. This communication can be synchronous or asynchronous. Collaboration in terms of chatting or white-boarding using a chat tool or a messenger tool would be an example of the synchronous communication and, e-mail, bulletin boards, and newsgroups would be examples of the asynchronous communication. (Lindvall et al. 2002.)
- Knowledge portals: Through portals, knowledge can be distributed to different users and applications, such as e-learning, competence management, intellectual property management, and customer relationship management. The ultimate portal provides an environment to manage organisational knowledge – true data aggregation and information integration coupled with knowledge worker collaboration (Roberts-Witt 1999). These information sources need to be integrated and accessed through a common and personalised interface. Portals create a customised single gateway to a wide and heterogeneous collection of data, information and knowledge (Lindvall et al. 2002).
- E-learning: Knowledge management aims to help people acquire new knowledge, as well as package and deliver existing knowledge through conscious learning. E-learning includes computer-based and on-line training tools. E-learning systems often include collaboration tools and support for different types of content, i.e., video, audio, documents etc. Knowledge could be delivered through a variety of presentation devices including web browsers, PDAs and cell phones. This enables the project person to

receive the knowledge when it is needed, regardless of where they are and what they are doing. E-learning will be delivered as small, focused learning objects to fit the format of the presentation devices (Woelk & Agarwal 2002.)

4.4.5 Results

E-learning offers a lot of advantages for learning that are different from other ways of learning. A wave of empirical research has revealed a long list of the promises and reported benefits of computer networks for collaboration (Hakkarainen et al. 2001). One self-evident benefit is that computer networks break down the time and space constraints. In addition, the delay of asynchronous communication allows time for reflection in interaction. Making thinking visible by writing should help learners to reflect on their own and others' ideas and share their expertise. Shared discourse spaces and distributed interaction can offer many perspectives. Further, the database can function as a collective memory for a learning community, storing the history of knowledge construction processes for revisions and future use.

ICT is a good technical means when sharing knowledge in organisation, but without trust, support of the top management, and active interaction between members even good techniques are useless. ICT supports the production of high-quality artefacts. When these artefacts are linked to the success of the project, the better-quality artefacts improve the project success.

4.5 5th Article: Developing Project Management System to support Active Learning and Communication in a Construction Project

In the fifth article the aim was to develop the current electronic document management (EDM) systems to support communication and active learning in projects. It is impossible for each participant of the project to know everything, thus, knowledge sharing has a great importance in construction projects. It should be reassured that the right people know the right things at the right time and that they are at least able to find the needed information. In addition, this information should be up-to-date.

4.5.1 Communication

A design team's communication environment is a holistic environment where the key information carriers for the team members to communicate with are sketches, schemes, images, drawings, and written descriptions together with explanatory stories. In the external environment are the clients, contractors, end-users and other project participants. It is of paramount importance that all the information is coordinated and communicated effectively.

4.5.2 Learning in projects

The learning of the construction project stakeholders can be supported, for example, by an e-learning platform that aids studying and understanding the construction operation in advance, before of during construction execution (Lin et al. 2005). Conditions change so quickly that employers are hard pressed to keep up with the changing knowledge (Burnside 2001). On-line tools for learning can be roughly divided into tools for delivering learning content and for tools for communication. Learning content is, of course, always communicative. In the digital on-line environment the learning content can be continuously reviewed and improved. Wikipedia is probably the most well known example of this. Saved on-line communication may also become learning material (Põldoja et al. 2006). These kinds of Internet tools enable people to self-organise information or knowledge.

Off-site training formats are low-cost alternatives for on-the-job training and give a novice an opportunity to experience real working conditions (Wang and Dunston 2006). One simple version of an off-site training system is on-line video sharing sites, which allow anyone connected to the internet to upload digital video recordings. This kind of system supports efficient dissemination of project-related videos and virtual visits to sites (Kumaraswamy 2004), best practices, and technical operations on site, e.g. exceptional installations.

4.5.3 Project management system

There are several new technologies for the development of web-based project management systems. Our project management system consists of personalisation and four main components comprising active process support, teamwork, e-learning and document management (**Figure 5**).

Personalisation			
Customising	Personal Inbox	Scheduling	Personal favorites
Search tools	Personal directory	RSS	Hotlist
User Manager	Replication	History	Action reports
Active process support	**Teamwork**	**E-learning**	**Document Management**
Administrative information	Net meeting	Wikis	Linked to BIM server
Project management - costs and scheduling	Discussion groups	Blogs	Subscribe to contents
Workflow	E-mail	Videos	Versions control
Checklist	Find experts	Multimedia	Access control
To-do list	Message boards	Document annotation	Append/ modify/ delete
Site diary	Chat rooms		Document sharing
Customers	Meeting planner		Office integration
Employees	FAQs		Content rating
Supliers - e-procurement	COPs		

Figure 5: The functions of project management system (modified from Chong et al. 2007).

4.5.4 Requirements engineering (RE)

The viewpoint of RE seemed to be important in order to develop the solutions in a construction project. According to Arayici et al. (2006), the developments of IT systems for the construction supply chain have not reached their ultimate effectiveness. This is mainly due to the lack of communication between the system developers and the industrialists. Arayici et al. (2006) still claim that requirements engineering can be a major factor in determining the success of an entire system development. People of the industry have stressed that construction IT researchers should align with the practitioners when developing and proposing IT solutions to the industry (Arayici 2006).

The user requirements are important because if a system does not satisfy its users' requirements, it is useless, and in the worst case, the system is not taken into use at all. The most successful systems exceed users' expectations. One of the most difficult problems with improving the use of IT in construction is overcoming the implementation problem, which requires a strategy definition. One factor that needs to be considered is (Betts 1999) that new innovative systems should be process-led not IT-led. However, many construction IT-system developments have not been process-led. RE is a means of developing implementation in a more process-led way.

4.5.5 Barriers to using RE

Regardless of its several benefits, RE cannot be utilised automatically. Even if many references prove RE to help in implementing more efficient and qualified applications, its use is not self-evident. There may be something problematic in the system. Gabb (1999) listed some excuses for not using RE:

- Customer is not interested in RE. He has once stated his needs and expects the application to fulfil their needs and not to be asked unnecessary questions.
- Customer does not know what he wants. Producer thinks that the customer does not understand what is possible to execute and gives a completed application to the customer.
- Customer wants to fulfil even his unrealistic needs without bothering with the technical and other limitations.
- Customer only wants one certain application and does not want to co-operate with others.

- Due to the lack of time and resources, the requirements definitions are insufficient but there is a fear that the project will be delayed or earlier mistakes will be revealed.
- RE is too difficult for customer and it is too high-priced even to try to elicitate the user's requirements.
- Lack of experience in RE and prejudices towards it; "We don't know where to start and we are not convinced of its importance."
- No users yet. They do not believe that it is possible to elicitate requirements for a new application that has no users yet.
- The requirements will change after a certain time anyway. Even though it is typical that in the projects where RE is used the changes are smaller.
- Agreements where the schedules and cost have already been defined. The changes are often considered as dangers and not as a chance to acquire a better application.

4.5.6 Results

In order to improve their process, construction organisations must integrate learning with day-to-day work processes in such a way that they not only share knowledge but also provide access to knowledge at any level, operating efficiently in response to their changing environment. The most sophisticated systems do not guarantee the success of their utilisation. In addition, there is a need for a knowledge manager maintaining the e-learning environment and offering on-line courses and learning objects about project-related things. The environment should be up-to-date and provide learning about new technologies and devices and to respond to learning needs during a project. The knowledge-portal systems that include BIM operations and perceive user and business requirements are one way to innovative project management system. In literature we found solutions to strengthen the commitment to use new applications by involving the users in requirements elicitation. Continual discussion between customer and the application provider is necessary for the best results.

5 Discussion and conclusions

This thesis consists of five published articles that are based on Prolab project interviews in five public construction projects in Finland, and in addition, on some interviews conducted in Sweden. Included is also a literature review for each published article to explore the issues which are essential in that article. Each article represents a viewpoint of its own which is defined based on the literature (**Table 5**).

Table 5: Viewpoints of the articles.

Article	Viewpoint
1. Article: Knowledge management tools – possibilities and obstacles	Classification Possibilities Obstacles
2. Article: Information System (IS) tools for knowledge management in public construction projects	Needed knowledge Wanted knowledge Offered knowledge Challenges
3. Article: The possibilities and limitation of ICT's in public construction projects	CAD-design Product model Motives to utilise ICT
4. Article: Learning support of ICTs in construction projects	Learning and knowledge management Learning needs Learning means utilising ICT
5. Article: Developing project management system to support active learning and communication in a construction project	Web-based project management system E-learning possibilities

The objectives for the research were to find the bottlenecks and problems occurring in construction projects as well as achieving a deeper understanding for the reasons behind them. The ultimate goal was to study the current situation in construction industry and find possibilities to solve the problems by means of ICTs. The main problems and challenges are represented in this paper as well as in each article. The results and conclusions include some possible solutions for the existing problems.

The research questions were:

- What kind of problems related to information flow in a construction project do the project stakeholders highlight?
- What kind of solutions is being suggested?
- How could ICT be used to foster collective knowledge building and learning in construction projects?

- How could ICT tools be developed based on such understanding?
- What are the obstacles to efficiently administrating information and how can these obstacles be removed?

5.1 Discussion

5.1.1 Main contributions

In the first, second, and third articles the contribution is in ICT tools which could improve knowledge sharing and knowledge management in construction project. The knowledge processing tools are in use but not as centralized and intelligent as they could be. The technical problems seemed be that the solutions are not interoperable, and there is a need to measure the quantities of materials, calculate and feed all the information many times. The information is separated in different computers and there might be duplicated information stored in many different places. In addition, found problems related to inefficient information flow, lack of communication and that the project participants are not ready to utilize the modern technologies.

One solution is e.g. the use of the Building Information Model (BIM). BIM is a data rich digital representation cataloguing the physical and functional characteristics of design and construction. Its purpose is to make the design information explicit, so that the design intent and program can be immediately understood and automatically evaluated. BIM-based approach supports ‘on-demand’ generation of documents from the model, like drawings, lists, tables and 3D renderings. These documents present views of the current BIM.

In fourth and fifth articles the weight is in learning, e-learning and web-based project management system. The main recommendations relate to the usage of this kind of systems. In order to improve the process, construction organisations should integrate learning within day to day work processes, in such a way that they not only share knowledge but also provide access to knowledge and information at any level and operate efficiently in response to their changing environment. The most sophisticated systems don’t guarantee the success of the utilization. In addition there is a need for knowledge managers maintaining the e-learning environment and offering online courses and learning objects about project related things. The environment should be up-to-date and provide learning for new technologies and devices and to respond for learning needs during project.

By utilizing web-based project management systems firms have ability to share information, collaborate and transact across various technical platforms and information systems. The system links all the documents to a centralized platform and is able to share all the latest documents between all parties who involved. The role of the intranet varies between the passive publishing of up to date company information among its employees to dynamic exploitation of its capabilities to integrate with social networks (Ingirige and Sexton 2006). Through its facilitatory role of locating, transferring and more efficiently using information and expertise, intranets are positioned as effective and efficient tools in organisational knowledge sharing and learning (Offsey 1997). But the investment alone will not popularise intranet use in construction projects. The organisation strategy should take into account an appropriate culture change to alter the mindset of the people that task relevance of the intranet content is dependent on their usage and population (Ingirige and Sexton 2006).

It is easy to find applications to different tasks but the lack of the centralized knowledge management strategy brings about new problems. New ways of organizing the work are resisted and the people very soon become cynical and unintended consequences of techno change failure prevent the success of the new change efforts. Many times the interviewees talked about the obsolete computers and the limits of their knowledge on ICT possibilities. At the same time they had doubts on the possible benefits of a system and unwillingness to start to utilise the new system especially if the last ICT project had failed for some reason.

5.1.2 Validity and reliability of the research

The problem of validity is different in qualitative research compared to quantitative research. In fact, authors like Creswell (1998) would like to use the word 'verification' instead of 'validation' in qualitative research. The term validity is deeply rooted in quantitative research and it is questionable whether it can be applied to qualitative studies. The aim of qualitative research is to understand, not to prove something. The credibility of a study is important, and that is why terms like trustworthiness and authenticity should be applied (Creswell 1998). Yin (2003) suggests four commonly used tests: those of construct validity, internal validity, external validity, and reliability.

Construct validity: Construct validity is a question about establishing the correct operational measures for the concept being studied (Yin 2003). There are multiple sources of evidence that have been used; material has been gathered from four different case projects, and in addition, six interviews of project managers in Sweden have been analysed. The problems related to information flow and communication in construction projects seemed to be similar in each case project. In addition, the interviews were conducted using three different methods but still the results are quite similar. I have tried to establish a chain of evidence so that the reader could understand how the certain conclusions have emerged (Yin 2003). The gathering of the material and an example of analysis is described in this summary and in the three articles. In addition, there are many citations from the interviews.

External validity

External validity means establishing the domain compared to which a study's findings can be generalised. Generalisation in qualitative studies does not rely on statistical methods but on analytical issues: the researcher is trying to generalise a particular set of results to some broader theory (Yin 2003). Even though the main objective of this research was not to conclude generalised results, five different cases suggest that the findings from this research may be true also in other similar cases. Critics of case studies typically state that a few cases offer a poor basis for generalising (Yin 2003). However, case studies rely on analytical generalisation while surveys rely on statistical generalisation. The idea of this study was to generalise the common knowledge management problems in construction projects and their possible solutions.

Reliability

The idea of the reliability test is to make sure that if another investigator studied the same cases with the same methods and same procedures she would end up with the same conclusions (Yin 2003). Eskola and Suoranta (1999) say that because of the amount of interpretation in qualitative research, it may not be possible to ensure the reliability this way, but that one can and should always try. The most important part of the material are the interviews. It would be impossible to repeat the interviews, because so much time has passed. The second part on the study database is the report of the researcher (Yin 2003). This thesis represents my report. It presents the background issues of the research, theoretical part and conclusions. However, all the interviews are on tape and they have been transcribed. Chapter 3 includes detailed descriptions of the field procedures and interview questions. To maintain the anonymity of the informants, no names or actual places are mentioned.

5.1.3 Conclusions

If we seek an answer to the question *"To which challenges the ICTs do not offer solutions for?"* – First of all, face-to-face meetings are the best way to communicate. Secondly, an information system can be a helping tool or medium but thinking must be done by humans. Even projects utilising the most sophisticated information systems have succeeded or failed based on human actions. However, the new medium can help in several areas of communication, co-operation, information storage and rationalisation of the project work.

Grillitsch et al. (2006) state the importance of project experience. Construction company jumps from project to project without questioning relevant criteria for success or failure of specific project steps. If anything is questioned than just who are the ones responsible for the failure: a play of accusing and justification instead of learning from failures and improving systems, procedures or processes in the organisation, Learning from each other and learning by doing as well as learning from experiences is very effective. In many cases when problems have to be solved or “new avenues to fast track thinking and innovation” have to be explored, bringing different people together helps.

According to Walsham and Barret (2005), new technologies offer new opportunities, but whether they are taken up and used to change processes of knowing, depends on human agency. E-mail does not deliver better lateral communication if the authority is not there to legitimise this form interaction. Websites, for example, can be valuable ways of supporting external interaction, but only if the power structures and related resources of the organisation enable appropriate content to be created and updated. ICTs are important for globally-dispersed organisations, but they are not solutions in themselves for inflexible bureaucracies, inappropriate resource allocation, or poor attitudes towards knowledge sharing. ICTs can, however, be a crucial part of a balanced approach to change in all of these areas (Walsham and Barret 2005).

Davenport and Prusak (1998):

> *"What is most important in a knowledge technology strategy is to get a few toes into the water. You may not even know how willing people are to share knowledge through systems until you buy a system and see how the organisation responds. It will be difficult to determine which types of applications provide the best fit with an organisation until you experiment. There is no right technology for knowledge management. We're all finding our way, and as long as technology isn't the only aspect of your knowledge management effort, the most essential thing is just to get started with something."*

5.1.4 Recommendations for further research

Future research can be suggested for further analysing the communication and learning process during a construction project. Combining an e-learning application to the project web and testing the introduced system is another interesting point for further research.

References

Al-Hawamdeh, S., (2002). Knowledge management: re-thinking information management and facing the challenge of managing tacit knowledge. Information Research, Vol. 8 No. 1, October 2002.

Andersson, J. (1980). Cognitive Psychology and Its Implications. San Francisco: Freeman and Company.

Anumba, C.J., Bloomfield, D., Faraj, I. and Jarvis, P., (2000). Managing and exploiting your knowledge assets: knowledge based decision support techniques for the construction industry , BR382, Construction Research Communications Ltd., UK.

Argyris, C. & Schon, D. (1978). Organizational learning: A theory of action perspective. Reading, Mass.: Addison Wesley.

Argyris, C. (1999). On Organizational Learning. 2nd edition. Oxford etc.: Blackwell Publishers.

Arayici, Y., Ahmed, V., Aoud, G. (2006). A requirement engineering framework for the integrated system development for the construction industry. ITcon, 3, p. 35.

Awad, E.M. and Ghaziri, H.M. (2003). Knowledge Management. Prentice Hall.

Barrett, P. (1995). Facilities management towards best practise. Blackwell Science Ltd.

Bernard, R. (1996). The Corporate Intranet, John Wiley & Sons. New York.

Betts, M. (1999). Strategic management of IT, ISBN 0 632 04026 2, Blackwell Science.

Bhatt, G.D. (2001). KM in organisations: Examining the Interaction between Technologies, Techniques, and People. Journal of Knowledge Management 5(1), pp. 68-75.

Björk, B.-C. (1995). Requirements and information structures for building product data models. VTT, Espoo. VTT Publications : 245. http://www.vtt.fi/inf/pdf/publications/2003/P245.pdf, (date accessed 03.07.2007).

Bobrow, D. (1999) Eureka: sharing best practices in field service. San Jose, CA: Benchmarking Institute.

Boud, D., & Garrick, J.(1999). Understandings of workplace learning. In: Boud, D. & Garrick, J. (Eds.) Understanding Learning at Work. London: Routledge.

Bowden, S., Dorr, A., Thorpe, T., Anumba, C. (2006). Mobile ICT support for construction process improvement. Automation in construction (2006), Vol. 15, no5, pp. 664-676.

Braf, E., & Goldkuhl, G. (2002) The Significance of Organizational Capability: The Interplay of Knowledge, Communication and Technology. Paper presented at the 3rd European Conference on Knowledge Management (3ECKM), Dublin, Ireland.

Brelade, S., Harman, C. (2001). How Human Resources can influence knowledge management. Strategic HR Review 1:1. 30-33.

Burnside, R., M. E-Learning for Adults: Who Has the Goods? The Technology Source, July/August 2001. Available online at http://technologysource.org/article/elearning_for_adults/. (date accessed 30.5.2007)

Chong, N. B., Uden, L., Naaranoja, M. (2007). Knowledge management system for construction projects in Finland. International Journal of Knowledge Management Studies. Volume 1, Number 3-4 / 2007.

Cong, X., Pandya, K.V. (2003), "Issues of Knowledge Management in the Public Sector", in Electronic Journal of Knowledge Management, 1(2),pp. 25-33.

Creswell, J. W. (1998) Qualitative Inquiry and Research Design: Choosing among five traditions. Thousand Oaks: Sage.

Cunningham, J.B. (1997). Case study principles for different types of cases, Quality and Quantity 31.

Davenport, T., (1997). Process innovation: reengineering work through information technology. Harvard Business School Press Boston, MA, USA

Davenport, T., H., and Prusak, L., (1997). Information Ecology. Mastering the Information and Knowledge Environment. New York : Oxford University Press, 1997. :ISBN 0195111680

Davenport, T., H, and Prusak, L. (1998). Working Knowledge: how organizations manage what they know. Boston, Massachusetts: Harvard Business School Press.

Dixon, N. M. (1992). Organizational learning: A review of the literature with implication for HRD professionals. Human Resource Development Quarterly, 3(1), 29-48

Drucker, P. (2000). Need to Know: Integrating e-Learning with High Velocity Value Chains. A Delphi Group White Paper, http://www.delphigroup.com/pubs/whitepapers/20001213-e-learning-wp.pdf . (date accessed 14.10.2007).

Earl, M.J. (1997). Knowledge as strategy: Reflections on Skandia International and Shorko Films. In: Knowledge in Organizations, 1-15. Ed. Prusak L. Boston etc.: Butterworth –Heinemann.

Easterby-Smith, M., Lyles, M. (2003). editors. The blackboard handbook of organizational learning and knowledge management. Oxford: Blackwell Published; 2003.

Egan, J., (1998). Rethinking construction: report of the construction task force on the scope for improving the quality and efficiency of UK construction, DETR, London.

Egbu, C., Sturgesand, J. and Bates, B. (1999). 'Learning From Knowledge Management and Trans-organisational Innovations in Project Management Environments'. In W.P. Hughes (ed.), Proceedings of the 15th annual conference of the Association of Researchers in Construction Management (ARCOM), John Moore's University, Liverpool, UK, 15-17 September, pp 95-103.

Egbu, C.O., (2000). The role of information technology in strategic knowledge management and its potential in the construction industry. In: Proceedings of UK National Conference on 'Objects and Integration for Architecture, Engineering and Construction', March 2000, BRE.

Egbu, C.O., Botterill, K. (2002). Information technologies for knowledge management: Their usage and effectiveness. ITCon, Vol. 7. Special Issue ICT for Knowledge Management in Construction, pg. 125-137, Accessed 19th April 2005, at http://www.itcon.org/2002/8. (date accessed 03.07.2007).

Eliufoo, Harriet K. (2005). Knowledge creation and transfer in construction organisations in Tanzania, Stockholm : Building and Real Estate Economics, Royal Institute of Technology.

Ellström, P.-E. (1999). Understanding the Use of Knowledge in Practical Action. Paper presented at HSS - 99, March 16-18 1999, Falun. CMTO Research Papers.

Engsbo, M. (2003). Barriers to adopting Internet-enabled collaboration and business in the building construction industry - Towards a three-level framework, in Hannula Mika, Järvelin Anne-Mari & Seppä Marko (editors) FeBR 2003 - Frontiers of e-Business Research 2003.

Ertmer, P. A. & Newby, T. J. (1993). Behaviorism, cognitivism, constructivism: comparing critical features from an instructional design perspective. Performance Improvement Quarterly, 6(4) 50-72.

Ericsson, F (2003) Information Technology for Learning and Acquiring of Work Knowledge among Production Workers. Department of Computer and Information Science Linköpings universitet. SE-581 83 Linköping, Sweden.

Eskola, J. & J. Suoranta (1999). Johdatus laadulliseen tutkimukseen (Introduction to

qualitative research). Jyväskylä: Gummerus Kirjapaino Oy.

Fairclough, J., (2002), "Rethinking construction innovation and research, a review of government R&D policies and practices", Department of Trade and Industry, London.

Gabb, A., (1999). Requirements Denial – Examining the Excuses. Conference Proceedings of SETE99 1999. http://www1.tpgi.com.au/users/agabb/ (date accessed 30.5.2007).

Grillitsch, W., Müller-Stingl, A., Neumann, R. (2006). Enabling Cross-Project Knowledge Creation through “Knowledge Oriented Project Supervision”. Real-Life Knowledge Management: Lessons from the Field. Kazi, A.S & Wolf, P.(eds.), 63 – 79.

Grudin, J. (1995). Why Groupware Applications Fail: Problems in Design and Evaluation, in R. Baecker, et. al. (eds.), Readings in Human-Computer Interaction: Toward the Year 2000, Morgan Kauffman.

Haapalainen, P., (2007). Learning within Projects. A Qualitative Study of How Learning Contributes to Knowledge Management in Inter-organisational Construction Projects. Acta Wasaensia. No. 179.Industrial Management 14. Vaasan yliopisto.

Hakkarainen, K. & Lipponen, L. Muukkonen, H., & Seitamaa-Hakkarainen, P. (2001) Teknologian tukemien oppimisympäristöjen kognitiivinen tutkimus. Teoksessa P. Saariluoma, M. Kamppinen, & A. Hautamäki, (toim.) Moderni kognitiotiede (152–172). Gaudeamus;

Hannus, M., et al. (2003). ROADCON Construction ICT Roadmap. http://cic.vtt.fi/projects/roadcon/public.html. (date accessed 03.07.2007).

Harris, K., Fleming, M., Hunter, R., Rosser, B., Cushman, A. (1998). The Knowledge Management Scenario: Trends and Directions for 1998-2003. Technical Report, Gartner Group.

Huber, G.P. (1999). Organizational learning: the contributing processes and the literatures, Organization Science 1999.

Ingirige B. and Sexton M. (2007) Intranets in large construction organisations: exploring advancements, capabilities and barriers , ITcon Vol. 12, pg. 409-427, http://www.itcon.org/2007/27. (date accessed 14.10.2007).

Järvinen, A., & Poikela, E. (2001). Modeling Reflective and Contextual Learning at Work. Journal of Workplace Learning, 13(7/8), 282-289.

Järvinen, P. (1999). On research methods. Opinpaja, Tampere.

Karstila, K., IFC:n tilanne ja tuotetiedon elinkaaren hallinnan prosessi, ProIT Kick-off seminaari 23.9.2002. Viitattu 12.8.2005. http://www.vtt.fi/rte/cmp/projects/proit/seminaari020923dipoli/proit_seminaari020923esitys_eurostep.pdf.

Kasvi, J.J.J. (2003). Knowledge Support in Learning Operative Organisations. HUT Industrial Management and Work and Organisational Psychology Dissertation Series No 2.

Kazi, A.S., Puttonen, J., Sulkusalmi, M., Välikangas, P., and Hannus, M. (2001). Knowledge Creation and Management: the Case of Fortum Engineering Ltd. Knowledge Management in Sociotechnical World: the Graffiti continues, Springer-Verlag, pp.153-169.

Kazi, A.S., and Charoenngam, C. (2003). Facilitating inter-enterprise information exchange in one-of-a-kind settings, ITCON, Vol. 8, pp. 319-340.

Kazi, A.S., Koivuniemi, A. (2006). .Sharing through Social Interaction: The Case of YIT Construction Ltd. Real-Life Knowledge Management: Lessons from the Field. Kazi, A.S & Wolf, P.(eds.), 63 – 79.

Kazi, A.S. (2006) Learning from Experience: New Challenges, Theories and Practices in Construction. VTT-Publications.

King, W.R. (2005). Communications and information processing as a critical success factor in the effective knowledge organization.International Journal of Business Information Systems 2005.

King, W.R. (2006a). Knowledge sharing. The Encyclopedia of Knowledge Management. Schwartz DG, editor. Idea Group Publishing; 2006.

King, W.R. (2006b). Knowledge transfer. The Encyclopedia of Knowledge Management. Schwartz DG, editor. Idea Group Publishing; 2006.

King, W.R., Ko, D.-G. (2001). Evaluating knowledge management and the learning organization: an information/knowledge value chain approach (with D. Ko) Communications of the Association for Information Systems, May, 2001.

Kiviniemi, A. (2004). 3D Modeling in Architectural Design. CS 378 Phenomenological Foundations of Cognition, Language and Computation. Term Paper, 07.06.04, Stanford, USA. Unpublished Work.

Koponen, E. (2007). Exploring the higher education e-learning. (unfinished). Seinäjoki Polytechnic. School of Information and Communication Technology.

Kuhne, C., and Leistner, C. (2002). Benefits of using product and process model data in project management. The conference proceedings of 2002 ECPPM conference, eWork and eBusiness in AEC, Portorož, Slovenia, Sept. 9-11, 2002.

Koski, H., (1995), Production planning and management of a construction project. Rakennustieto Oy. Helsinki.

Kumaraswamy, M. (2004). Accelerating learning via virtual site visits. International Journal of IT in Architecture, Engineering and Construction. Volume 2 / Issue 1 / February 2004.

Latham, M., (1994). Constructing the team, HMSO, London.

Laudon and Laudon (1998), Management Information Systems, 5th ed.: New Approaches to Organization and Technology, Prentice Hall.

Lin, Y., Chang, C., Chiou, L.B., Jan Shu-Hui, Tserng, H. Ping (2005). Towards Web-based learning system for engineers integrated with problem-based learning (PBL) approach in construction. ICT in Construction and Facilities Management. VTT publications.

Lindvall, M., L. Rus and S. S. Sinha (2002). "Software systems support for knowledge management." Journal of Knowledge Management 7(5): 137–150.

Love, P.E.D., Smith, J., and Li, H., (1999). The propagation of rework benchmark metrics for construction. Int. J. Qual. Rel. Manage., vol. 16, no. 7, pp. 638-658.

Love, P.E.D. and Irani, Z.(2004). A Rework Reduction Model for Construction Projects. IEEE Transactions on Engineering Management, Vol. 51, No. 4, November 2004.

Lundequist, J. (1992). Projekteringsmetodikens teoretiska bakgrund, KTH Reprocentral, Stockholm.

Malhotra, Y. (2000). Knowledge Management and Virtual Organizations. Idea Group Publishing, Hershey, PA.

Malhotra, Y. (2001). Knowledge Management and Business Model Innovation. Idea Group Publishing, Hershey, PA.

Marquardt, M.J. (1996). Building the Learning Organization – A Systems Approach to Quantum Improvement. New York: McGraw-Hill.

Menon, T., Pfeffer, J. (2003). Valuing internal vs. external knowledge; explaining the preference for outsiders, Management Science 2003.

Moum, A. (2006). A framework for exploring the ICT impact on the architectural design process , ITcon Vol. 11, Special Issue The Effects of CAD on Building Form and Design Quality , pg. 409-425, http://www.itcon.org/2006/30.

Naaranoja, M., Haapalainen, P., Lonka, H. (2005), Challenges of knowledge management in public construction projects , Published at the conference CIB 2005, COMBINING FORCES - Advancing Facilities Management and Construction through Innovation, June 13-16, 2005, Helsinki.

Nonaka, I. and Takeuchi, H. (1995). The knowledge creating company: how Japanese companies create the dynasties of innovation. Oxford: Oxford University Press.

Offsey, S. (1997). Knowledge management: linking people to knowledge for bottom line results. Journal of Knowledge Management. Vol.1. No.2.

Omega Editorial. Knowledge Management and Organizational Learning. (2006). Editorial International Journal of Management Science (2007) / Omega 36 (2007).

Orange, G., Cushman, M. and Burke, A. (1999). "COLA: A Cross Organisational Learning Approach within UK Industry". in 4th International Conference on Networking Entities (Neties'99), Donau-Universität, Krems, Austria, 18-19 March 1999.

Ozorhon, B., Dikmen, I., Birgonul, M.T. (2005). A case-based Reasoning Model as an Organizational Learning Tool. Learning from Experience: New Challenge, Theories and Practices in Construction. Edited by Dr. Abdul Samad Kazi. VTT – Technical Research Centre of Finland.

Patel, M.B., McCarthy, T.J., Morris, P.W.G., Elhag, T.M.S. (2000). "The role of IT in capturing and managing knowledge for organisational learning on construction projects", Proceedings of CIT 2000, Reykjavik, Iceland, 28-30 June, pp.674-85.

Pathirage, C., Amaratunga, D., Haigh, R., (2005). Are we Catering to the Construction Industry KM Requirements?: A Literature Syntehesis. Learning from Experience: New Challenges, Theories and Practices in Construction. VTT publications.

Petursson, H. (1991). Construction information transfer in an object-oriented environment. Research report (26), Department of Building Economics and Construction Management Chalmers University of Technology, Gothenburg, Sweden.

Põldoja, H., Leinonen, T., Väljataga, T., Ellonen, A., Priha, M. (2006). Progressive Inquiry Learning Object Templates (PILOT). International Journal on E-Learning. 5 (1), 103-111. Chesapeake, VA: AACE.

Rezgui, Y. (2001), Review of Information and Knowledge Management Practices State of the Art in the Construction Industry, The Knowledge Engineering Review Journal, Issue 16(2).

Roberts-Witt, S. L. (1999). Making Sense of Portal Pandemonium. Knowledge Management, July 1999.

Rosenberg, M. (2001). E-Learning: Strategies for Delivering Knowledge in the Digital Age, The McGraw Hill Companies, Inc, P.O. Box 182604, Columbus, OH 43272, USA.

Salminen, J. (2005). Measuring performance and determining success factors of of construction sites. Helsinki University of Technology Construction Economics and Management. A Research reports 3. Doctoral dissertation. Espoo 2005.

Sarshar, M., Betts, M., Aouad, A. (2000). A vision for construction IT 2005– 2010, RICS Foundation Research Paper Series 3 (17).

Schwägerl, K. (2004). CAD - eine Bestandsaufnahme. Teil 1: Konzeptionen und Zeitersparnis, Deutsche Bauzeitung, No. 8, 80-81.

Senge, P. (1990). The Fifth Discipline. New York: Doubleday.

Shelbourn, M. A., Bouchlaghem, D. M., Anumba, C. J., Carillo, P. M., Khalfan, M. M. K. and Glass, J. (2006). Managing Knowledge in the context of sustainable construction. ITcon Vol. 11, pg. 57-71, http://www.itcon.org/2006/4.

Stewart, T. A. (1997). Intellectual Capital: The New Wealth of Organisations, New York, Doubleday.

Sveiby, K-E. (2001). What is knowledge management? Brisbane: Sveiby Knowledge Associates. Available at: http://www.sveiby.com.au/knowledgeManagement.html. (date accessed 24.9.2002).

Szulanski, G. (2003). Sticky knowledge – barriers to knowing in the firm. Satge publications ltd.

Tas, E., Irlayici, F. P. (2007). A survey of the use of IT ın buıldıng product ınformatıon acquısıtıon ın Turkey, ITcon Vol. 12, pg. 323-335, http://www.itcon.org/2007/22.

Tversky, A. and Kahneman, D. (1974).: Judgment under Uncertainty: Heuristics and Biases. Science (September 1974) 185: 1124-1131.

Uden, L., Naaranoja, M. (2007). The development of online trust among construction teams in Finland, ITcon Vol. 12, pg. 305-321, http://www.itcon.org/2007/21.

Ugwu, O.O., Kumaraswamy, M.M., (2006). Information & Communications Technology (ICT) Applications in Construction, Report of Surveys on ICT Applications, Benchmarks, Benefits, Costs, Barriers & Enablers, and Research & Development Issues in the HKSAR Construction Industry, CICID HKU, ISBN 962-86246-4-4.

Ugwu, O.O., Kumaraswamy, M.M. (2007). Critical success factors for construction ICT projects – some empirical evidence and lessons for emerging economies, ITcon Vol. 12, Special Issue Construction information technology in emerging economies , pg. 231-249, http://www.itcon.org/2007/16.

Walsham, G., Barret, M. (2005). ICTs and Changing Process of Knowing in a Global Development Agency. Judge Institute of Management, University of Cambridge; Research Papers in Management Studies.

Wang, X., and Dunston., P.S. (2007). Design, strategies, and issues towards an augmented reality-based construction training platform. ITcon Vol. 12, pg. 363-380, http://www.itcon.org/2007/25 (date accessed 14.10.2007).

Wetherill, M., Rezgui, Y., Lima, C. & Zarli, A. (2002). Knowledge management for the construction industry: the e-Cognos project. In Bo-Christer Björk (ed.), Electronic Journal of Information Technology in Construction; Special Issue ICT for Knowledge Management in Construction, v. 7: 183-196.

Wikforss Ö. (2003). Tillämpninger i praktiken. Utformning och projektering, in Byggandets informationsteknologi - så används och utvecklas IT i byggandet (Wikforss Ö. ed), Svensk byggtjänst, Stockholm, 89-105.

Wikipedia (2007).http://en.wikipedia.org/wiki/E-learning#Advantades_and_Disadvantages. (date accessed 14.10.2007).

Woelk, D., Agarwal, S. (2002). Integration of E-Learning and Knowledge Management. Association for the Advancement of Computing in Education (AACE), http://www.aace.org/DL/.

Wohlfahrt, L., Frielingsdorf, D. (2006). prodela: On-Demand Training for public Administrations. Real-Life Knowledge Management: Lessons from the Field. Knowledge Board in collaboration with VTT-Technical Research Centre of Finland.

Wyssusek, B., Schwartz, M., & Kremberg, B. (2002). Knowledge Management –A Sociopragmatic Approach. In D. Remenyi (Ed.), Second European Conference on Knowledge Management (pp. 767-776). Bled, Slovenia: Bled School of Management.

Visio 2010 (2005). Kiinteistö ja rakennusklusterin visio 2010, Raportti 4, Vision strategiapäivitys, http://www.visio2010.fi/attachements/2005-11-22T11-44-5340.pdf.

Yin, R.K. (1994). Case study research: Design and methods, 2nd edn. Thousands Oaks, California: SAGE Publications.

APPENDIX

List of publications

1. Naaranoja Marja, Jäväjä Päivi, Haapalainen Päivi, Lonka Heikki (2005). Knowledge Management Tools – Possibilities and Obstacles. “CIB W102 – 2005, International Conference on Information and Knowledge Management in a Global Economy: Challenges and Opportunities for Construction Organisations”. F.L. Ribeiro, P.D.E. Love, C.H. Davidson, C.O. Egbu and B. Dimitrijevic, Lisbon, Portugal. CIB Publication.

2. Jäväjä Päivi, Naaranoja Marja (2005). IS Tools for KM in public Construction Projects. "CIB-W78 22nd Conference on Information Technology in Construction". Editors Raimar Scherer, Peter Katranuschkov & Sven-Eric Schapke. Published by: Institute for Construction Informatics, Technische Universität Dresden, Germany. CIB Publication No.:304.

3. Jäväjä Päivi, Naaranoja Marja (2006). Tietotekniikan mahdollisuudet ja rajoitukset. Vaasan yliopiston julkaisusarja: Rakennusprojektin onnistumisen eväitä. Toim. Marja Naaranoja. Selvityksiä ja raportteja 137.

4. Jäväjä Päivi, Naaranoja Marja (2006). Learning support of ICTs in construction projects – Case study approach. Proceedings of KMO 2006, International Conference on Knowledge Management in Organizations. UM FERI; editors: M. Hericko, A. ZivKovic. ISBN: 86-435-0780-6. Maribor, Slovenia, June 13–14, 2006.

5. Jäväjä Päivi, Naaranoja Marja (2007). Developing project management system to support active learning and communication in a construction project. To be presented in CIB W102 Conference, Information and Knowledge Management - Helping the practioners in planning and building: Meeting on October 16 – 18, 2007. Stuttgart, Germany.

KNOWLEDGE MANAGEMENT TOOLS – POSSIBILITIES AND OBSTACLES

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ABSTRACT

This article discusses how a developer or a client organisation could utilize knowledge management tools in construction projects. The article is based on the findings of the PROLAB-project. The project seeks to find solutions for how the information can effectively be used in project management, specially in construction projects, what kind of procedures help the management of the knowledge and how the obstacles for efficient ways of administrating the information can be removed. These obstacles can be either related to use of new technology or to organization culture.

The viewpoint for the research is socially and physically distributed cognition. The paper is based on theme interviews made in three public construction projects in Finland. The study focuses on finding

- the possibilities of knowledge management tools to solve the major problems of knowledge management,
- the major obstacles of utilizing such tools.

The paper contributes to a move towards a wider use of knowledge management tools in order to provide suitable solutions to small and medium size enterprises in the construction industry.

Keywords: Data, information, Knowledge, construction, information systems, utilization.

1. INTRODUCTION

The human brain is able to handle huge amounts of information. Therefore if only people with the right education and right properties are selected for projects then they should, one would expect, succeed. However, this is not the truth. Projects with top experts have failed. Human thinking is very defective and deduction mistakes are common (Tversky and Kahneman 1974). We have difficulties to deal with situation with multiple variables. Stress, depression, and circumstances can affect our thinking (Kobasa et al. 1982). We may succeed in a good day but there are not many of them. Researching individual cognition is not enough if we want to develop project work.

But if we can' t rely on an individdal, surely we can trust a group of people, a team? If a well-trained team has enough time for problem solving, it would end up with a good solution, wouldn’ t it? Decision making related literature is, however, filled with opposite examples (Parkin, 1996). Tension between team members may destroy the teamwork but also too much consensus may be bad and lead to ” groupthink”-situations (Janis and Mann 1977, Fink et al. 1971). Thinking of a team is as problematic as the thinking of an individual: we don’ t examine all the possibilities but take the first solution not asking enough questions first (Busby 1999).

Naaranoja (et al 2004) described that the main knowledge management challenges in construction projects concern trust, cultural differences and decision making(Figure 1). That paper also presented some ideas how to manage the knowledge better: making it visible who makes the decisions; familiarizing the project members with each other; awareness of the importance of trust and consciously improve the trust between the parties; and the improvement of the shared understanding of the goal of the project. In this paper we further develop the solutions by discussing to which degree the Information technology or project planning methods are solutions for these challenges and what kind of obstacles there exist in the utilization of these methods.

Trust
o Protracted decision making o Perceptions, stereotypes o The personality differences in the group o Misunderstanding
Culture and language
o Misunderstanding o Professional jargon o Cultural differences
Decision making
o Leadership skills are not good enough o Own position is seen more important o Actions are not even o Changing needs o Not clear responsibilities o Complicated matrix organisations o Lack of co-ordination o Poor estimating and control of design o Knowledge based errors

Figure 1. Main challenges of Knowledge management in construction (Naaranoja et al 2004)

2. DATA, INFORMATION, KNOWLEDGE, AND KNOWLDEGE MANAGEMENT(KM)

If we want to improve the quality of the project industry, we should focus on information and the way it is handled in routine and non-routine situations. There are many different approaches to the concept of information. “ Data” and “ information” are often used as synonyms of “ knowledge” . However, these words have different meanings (Cong & Pandya 2003, Nonaka & Takeuchi 1995). *Data* are raw facts. To become *information* data has to be processed. Decisions can only be made based on information. *Knowledge*, on the other hand, is meaningful information. Knowledge is derived from information. It depends on interpretation whether we are talking about data, information, or knowledge. What makes difference between data and information is their *organisation* and what makes difference between information and knowledge is their *interpretation* (Bhatt 2001). Knowledge is understanding one gains through experience, reasoning, intuition, and learning. We expand our knowledge when others share their knowledge. New knowledge is born when we combine our knowledge with the knowledge of others. Wisdom and insight can be included to the definition of knowledge. *Wisdom* is the utilization of accumulated knowledge. (Cong & Pandya 2003)

Our culturally adapted life is based on shared meanings and shared modes for negotiating differences in meaning and interpretations (Bruner 1990). Bruner describes how this negotiation takes place by means of *narratives*. Narratives are not needed if things proceed in ordinary fashion. We have theories of mind called “ folk psychology” or “ common sense” : normative descriptions of what makes human beings “ tick” , what one can expect situations to be like, what our minds and those of others are like, what are possible modes of life and so on. We believe (or “ know”) that world is organized in a certain way, that we want certain things, that people hold believes about past and future. We believe in coherence of all these believes, that people should not want “ irrational” things. We have very strong opinions about how things *should be* and how one *should behave.*

There seem to be no agreement on definitions for “ data” , “ information” , “ knowledge” , or “ wisdom” . However, there are some aspects all of the authors share. Whether information or knowledge are seen as separate concepts or not, the transformation of data to knowledge or information happens when meaning is given to them. This happens in a shared action, where meaning is negotiated or constructed together with other actors. If we want to improve the non-routine processes of project management we should concentrate on the concept of meaning.

Knowledge management (KM) is according to Brelade and Harman (2001) obtaining and using resources to create an environment in which individuals have an access to information and in which individuals obtain, share and use these information to raise the level of their knowledge. In addition to this individuals are encouraged and enabled to obtain new information for organization.

3. KNOWLEDGE MANAGEMENT TOOLS

3.1 General principles of knowledge management

It is recognised that good knowledge management does not result from the implementation of information systems alone (Grudin 1995; Davenport 1997; Stewart 1997). However, the role of IT as a key enabler remains undiminished (Carillo et al 2000; Egbu 2000). IT should be understood less in its capacity to store explicit information and more in its potential to aid collaboration and co-operation between people (Egbu and Botterill, 2002). Dougherty (1999) argues that IT should be seen as a tool to assist the process of KM in organisations. Such a process relies more on the face-to-face interaction of people than on static reports and databases (Davenport and Prusak, 1998). Some organisations have developed software to encourage social interaction in organisations in the hope that a unique forum for tacit knowledge exchange will be established.

Alavi and Leidner (1999) asked managers about their key concems about knowledge management. The managers expressed concern primarily over the cultural, managerial and informational issues (Figure 2). In terms of the culture, the managers were concerned over the implications for change management, the ability to convince people to volunteer their knowledge, and the ability to convince business units to share their knowledge with other units. Concern was also expressed over how to implement knowledge management system effectively (Alavi and Leider 1999). These concerns are all relevant for construction project especially because the project environment always bring together people not only from various units but from various organizations.

Information	Building vast amounts of data into usable form
	Avoiding overloading users with unnecessary data
	Eliminating wrong/old data
	Ensuring customer confidentiality
	Keeping the information current
Management	Change management implications
	Getting individuals to volunteer knowledge
	Getting business units to share knowledge
	Demonstrating business value
	Bringing together the many people from various units
	Determining responsibility for managing the knowledge
Technology	Determining infrastructure requirements
	Keeping up with new technologies
	Security of data on Internet

Figure 2. Key concerns related to knowledge management (Alavi and Leidner 1999)

Hansen (et al 1999) found two very different knowledge management strategies in place. In companies that sell relatively standardized products that fill common needs, knowledge is carefully codified and stored in databases, where it can be accessed and used - over and over again - by anyone in the organization. That is called the codification strategy. In companies that provide highly customized solutions to unique problems, knowledge is shared mainly through person-to-person contacts; the chief purpose of computers is to help people communicate. This is called the personalization strategy. Hansen (et al 1999) emphasize that the benefits are greatest - to both the company and its customers - when the company actively choose one of the approaches as a primary strategy.

The construction industry provide customized solutions for their clients. That is the reason why the knowledge management solutions between clients and construction professionals should focus in sharing knowledge through person-to-person contacts and the ICT enabled communication. The co-operation between the professionals is more standardized and the codified strategy might be useful in some parts of their work. In this paper we focus on improving knowledge management in construction project by either planning the projects better or utilizing information systems. We are conscious that there are also other tools, for instance, pre evaluation meeting of the project plan where experts give their view for the project in advance.

3.2 Writing a project management plan in construction projects

Planning is one of the most crucial activities in every project, no matter if it’s a new product development project, a research project or a construction project. Everybody can remember problems in projects that exist because of inadequate plans: sometimes walls already built must have been torn down, sometimes workers have to wait for a machine or tool that is missing, sometimes weather conditions bring surprises. This list could be continued for several pages.

One effective tool for project planning is writing a project management plan that contains the most critical factors for project success. However, for some reason project management plans used in construction projects in Finland are usually very insufficient, they consist only of timetable, budget and some sort of quality plan. Naturally, some exceptions exist. But there hasn’t been a proper project management plan in any of the construction projects that we’ve been researching. Not even in those managed by a construction company.

According to ISO 10006 standard project management plan is a “document specifying what is necessary to meet the objective(s) of the project”. Project management plan can roughly be divided into 8 following sections: definitions, organization, timetable, budget, chance management, risk management, communication and information management, and quality management. Every project is naturally different from others but this content of the project management plan can be modified according to each project. It is also important to realize that project management plan should be reviewed regularly and updated if needed. (Pelin, 2002; Kettunen, 2003)

The main benefit of the project management plan is that the a structured way of making the important plans helps the planner to remember everything that is needed, for example:

- the human recourses of the client organization. Project managers may have several projects to run at the same time and nobody is checking if they really have time for a new project. Writing the project plan reminds also to plan the recourses while making the timetable. This is specially important in multi project environment.

- risk management. Project managers seem to feel that since they have lots of experience of the projects they don’ t need to think about the risk management. Obviously this is not true. Since all the projects are different there may be different risks related to each project. And even tough the risks were the same the plan how to deal with the risks is needed.
- information sharing. The informing plan defines which information is handed over to which parties via which channels and how it is checked that crtical information is understood. In addition, project management plan can be used in giving the new project participants a brief introduction to the project.

Construction industry is an old industry with old, traditional ways of doing things. In Finland there is a habit of writing a project definition plan after programming phase of the project that is meant for guiding the actual planning phase of the project. This plan includes some of the information that should also be also in project management plan. I believe that it is felt as doing the same thing twice if both project definition and project management plan must be written. However, these plans are not the same and not for the same purposes, so both of them should be made.

3.3 INFORMATION SYSTEMS (IS) IN KNOWLEDGE MANAGEMENT

Information system (IS) combine organisational, human and information technology based resources to generate the effective and efficient collection, retrieval, communication and use of information. Information technology (IT) serves IS by supporting business operations and enabling new ways of carrying out organisational activities (Barrett 1995, p. 153 and 154).

Laudon and Laudon (1998) classify IS for knowledge management into four main categories:

1. those for creating knowledge (knowledge work systems): these support the activities of highly skilled knowledge workers and professionals as they create new knowledge; CAD systems, Analysis systems, Estimating systems. Increasingly, these systems are being integrated both within and across disciplines, thereby facilitating the flow of information.

2. those for processing knowledge (office automation systems): these help disseminate and co-ordinate the flow of information in an organisation; Word Processing, Spreadsheets, Imaging and Web Publishing, Electronic Calendars, Desktop Databases. These systems are now routinely used within construction organisations to ensure the smooth running of businesses.

3. those for sharing knowledge (group collaboration systems): these support the creation and sharing of knowledge among people working in groups; Groupware, Intranets, Video-conferencing, Document management systems, Bulletin Boards, Shared Databases, Electronic mail systems. The use of these systems is growing in the construction industry but the emphasis has been more on supporting intra-organisation

groups rather than virtual project teams that have members drawn from several organisations.

4. those for capturing and codifying knowledge (artificial intelligence system): these provide organisations and managers with codified knowledge that can be reused by others in the organisation; Expert Systems, Neural Nets, Fuzzy Logic, Genetic Algorithms, Intelligent Agents. They enable the setting up and maintenance of knowledge bases that preserve knowledge/expertise that might otherwise be lost when a key member of staff is no longer available.

Construction organisations need to view IT as an enabler, which should be part of an integral multi-faceted KM strategy; develop and implement an IT infrastructure for KM which is tailored to suit the needs of the organisation and implement an appropriate training programme that educates the organisations employees on the benefits of KM, and in the use of any supporting IT systems (Carrillo et al., 2000).

Knowledge work systems
Product modelling is a mean of creating new knowledge with the aid developed CAD-systems. Product models make construction plans more effective and competent during construction project and the whole life cycle of the building.

Kuhne and Leistner (2002) conclude that there is a substantial potential for optimizing management processes in the construction industry when using a product model. The various potential have been arranged into three areas: collaboration, data processing and controlling.

Collaboration
- the use of product model for defining a common project language illustrates a basis for well working communication between the project participants.
- quick availability of data; in order to avoid delays and incorrect deliveries with regards to location, quantity or type, a quick availability of data is urgently necessary

Data processing
- estimating time and cost expense
- productivity; heat flow calculation, bearing capacity
- view of project’s life cycle; facility management information
- data quality; poor quality of critical data can have substantial influences on decision making

Project controlling
- monitoring an overview of the total project from a cost and time viewpoint
- analyses and evaluation; project-wide usage of product model data simplifies the tasks of the project controller
- visualization; at the time the technical-constructive planning is based on alphanumeric data, it is an abstract nature and possess no direct graphical representation, but geometrical and spatial representation is becoming more and more significant for humans for trying to understand and control large projects with complex structures

- workflow; in order to improve the flow on information between sub-processes, workflow systems are increasingly employed today

Office automation systems

Word processing, spreadsheet and other office automation system are wide used systems. There are numbers of document models and sheets for reports prepared. Also timing is often made by project planning systems. Regulations and documents are often stored in intranets. But the use of electronic calendars and intranet use as publishing and discussing tool is not quite common.

Group collaboration systems

Collaboration is a fundamental aspect of project-based work and it is therefore, recommended that organisations pay attention to the different types of collaborative technologies that exist. According Egbu and Botterill (2002) there are good experiences about virtual teamwork stations included desktop video-conferencing equipment, multimedia e-mail, shared chalkboards, a document scanner, and tools to record video clips, group-ware and web-browser. Although it is arguable whether these technologies capture or distribute structured knowledge, many would contend that they are useful at enabling people to transfer tacit knowledge. Perhaps the potential benefits of using such technologies are not fully understood and organisations are more incremental in their implementation of IT.

Artificial intelligence systems

Neural networks have been described as a statistically oriented tool that excels at using data to classify cases into one category or another. Other data mining tools include artificial intelligence tools as well as conventional statistical analysis. Strong proponents of these tools advance the view that the pattern identification and matching capabilities of software can eliminate human intervention. It could be argued, however, that an intelligent human is required to structure the data in the first place, interpret data and understand identified patterns; and of course make a decision based on the knowledge generated (Egbu, Botterill 2002).

The obstacles of ICT use

The obstacles can be divided into three main categories:

- technical: Continual demand for upgrading hardware and software is the greatest obstacles according to Samuelson 2002.
- human: The construction professionals assessed that the “Greater know-how is required from staff” and overabundance of information are among the main obstacles of ICT use (Samuelson 2002, 17). Cynicism and defeatism are unintended consequences of technochange failure preventing the success of the new change efforts (Markus 2003).
- economical: Strategic objectives are not clear (Love 2004). Investment costs are too high (Samuelson 2002). Network effects on the utilization of ICT (Bansler and Havn 2004, p 271, 272). The key challenge is to obtain a “critical mass” of users. Many new technologies fail to obtain critical mass and simply flop. The problem is the “chicken and the egg” paradox: many users are not interested in adopting the

technology because the installed base is too small, and an insufficiently small number of users have adopted the technology (Bansler and Havn 2004, p 271, 272).

The above findings are supported with our case studies. Many times the interviewees talked about the obsolete computers and the limits of their knowledge on ICT possibilities. At the same time they had doubts on the possible benefits of a system and unwillingness to start to utilise the new system especially if the last ICT project had failed for some reasons.

5. Discussion

Key finding of our paper is that it is easy to find solutions to the challenges of construction problems but when you come to the realisation of the solution we seem to be fighting against the culture. Construction industry is an old industry with old, traditional ways of doing things**.** New ways of organizing the work are resisted and the people very soon become cynical and unintended consequences of technochange failure prevent the success of the new change efforts. It is important to be aware of this and the change efforts should be implemented in the project work by letting the practitioners effect on the change and select the way of working.

We also found out that often ICT have positive effects on the challenges but that often there is the critical mass problem the benefits are not yet gained if there are not enough many users.

REFERENCES

Alavi M, Leidner D E, 1999, Knowledge management systems: Issues, challenges, and benefits, in *Communications of AIS* Volume 1, February 1999

Anumba, C.J., Bloomfield, D., Faraj, I. and Jarvis P. (2000). Managing Your Knowledge Assets: Knowledge Based Decision Support Techniques for the Construction Industry, BR 382, Construction Research Communications Ltd.

Bansler J P and Havn E C (2004), Exploring the role of network effects in IT implementation: The case of knowledge repositories. In: *Information, Technology and People,* Vol. 17(3): 268-285, accessed 110th December 2004 at http://www.cti.dtu.dk/~havn/IT&P.pdf

Barrett P. (1995) (ed.), Facilities management towards best practise. Blackwell Science Ltd.

Bruner, J. (1990), Acts of Meaning, Cambridge, Harvard University Press.

Brelade S, Harman C (2001). How Human Resources can influence knowledge management. Strategic HR Review 1:1. 30–33.

Busby J. S. (1999), An assessment of post-project reviews. Project Management Journal (1999) No 3: 23-29

Carrillo P M, Anumba C J, Kamara J M (2000), Knowledge management strategy for construction: key I.T. and contextual issues, in construction informatics digital library, accessed 12th November 2000 at http://itc.scix.net/data/works/att/w78-2000-155.content.pdf

Cong, X., Pandya, K.V. (2003), " Issues of Knowledge Management in the Public Sector" , in *Electronic Journal of Knowledge Management*, 1(2),pp. 25-33.

Davenport, T. (1997). "Secrets of Successful Knowlegde Management", *Knowledge Inc.* 2, February.
Davenport, Thomas H. & Laurence Prusak (1998). Working Knowledge: how organizations manage what they know. Boston, Massachusetts: Harvard Business School Press.
Dougherty, V. (1999); Knowledge is about people, not databases, Industrial and Commercial Training, Vol. 31, No. 7, 1999, p262-266.
Egbu, C O, Botterill, K (2002), Information Technologies for knowledge management: Their usage and effectiveness, (Abdul Samad Kazi ed) *ITCon* Accessed 10th November 2004, *http*://www.itcon.org/2002/8.
Fink S L, Beak J and Taddeo K (1971), Organizational Crisis and Change. Applied Behavioral Science (1971) No 1: 15-37.
Grundin, J. (1995). Why Groupware Applications Fail: Problems in Design and Evaluation., in R. Baecker, et. al. (eds.), *Readings in Human-Computer Interaction: Toward the Year 2000*, Morgan Kauffman.
Hansen, M T, Nohria N, Tierney T (1999), What's your strategy for managing knowledge? In *Harvard Business Review* 1999 Mar-Apr; Vol 77, No. 2, pp 106-16, 187
Janis I L, Mann L (1977), Decision making. New York, Free Press.
Kettunen S (2003), Onnistu projektissa, Helsinki, WSOY
Kobasa S C., Maddi S R., and Kahn S (1982): Hardiness and Health: A Prospective Study. Journal of Personality and Social Psychology (1982) No 1: 168-177.
Kuhne C and Leistner C (2002) Benefits of using product and process model data in project management in the conference proceedings of 2002 ECPPM conference, *eWork and eBusiness in AEC*, Portorož , Slovenia, Sept. 9-11, 2002.
Laudon and Laudon (1998), Management Information Systems, 5th ed.: New Approaches to Organization and Technology, Prentice Hall
Love, P.E.D. and Irani, Z. (2004). An Exploratory Study of Information Technology Evaluation and Benefits Management of SMEs in Construction. Information and Management 42(1), pp. 227-242.
Markus, M. Lynne. "Technochange Management: Using IT to Drive Organizational Change," *Journal of Information Technology*, vol. 19, 4-20, 2004.
Naaranoja M, Haapalainen P, Lonka H (2004), The construction team and the challenge of knowledge management in Katsanis, Dimitrijevic, Davidson (eds), *Proceedings of annual meeting of CIB W102 Information and knowledge management in Building*. Toronto 29-30 April 2003, pp. 40-48.
Nonaka, I., & Takeuchi, H. (1995), The Knowledge-creating Company, New York, Oxford University Press
Parkin, James (1996): Organizatonal decision making and the project manager. International Journal of Project Management (1996) No 5: 257-263
Pelin R. (2002), Projektihallinnan käsikirja, Oy Risto Pelin.
Samuelson O (2002), IT barometer. The use of IT in the Nordic Construction in (Björk B-C ed) *ITCon*. Accessed 10th Novemeber 2004, at http://www.itcon.org/2002/1/
Stewart, T. A. (1997). Intellectual Capital: The New Wealth of Organisations, New York, Doubleday.
Tversky A and Kahneman D (1974): Judgment under Uncertainty: Heuristics and Biases. Science (September 1974) 185: 1124-1131.

IS tools for knowledge management in public construction projects

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ABSTRACT: This paper focuses on the possible tools of knowledge management by exploring offered, needed and wanted knowledge. We study knowledge management by exploring how the tools are utilized currently in case projects in Finland and how new tools could improve the processes. We also aim to study what kind of obstacles there are for IS tools utilization. New ways of organizing work are resisted and people very soon become cynical and unintended consequences of techno change failure hinder the success of the new change efforts. It is important to be aware of this and change efforts should be implemented in project work by letting the practitioners effect the change and select the way of working. We also found that often ICT have positive effects on the challenges but that often there is a critical mass problem, where the benefits are not yet gained if there are not sufficient users.

Keywords: knowledge management, IS, project, construction

1 INTRODUCTION

The article is based on the findings of the PROLAB-project. The project seeks to find solutions for how information can effectively be used in project management, especially in construction projects, what kind of procedures help the management of knowledge and how the obstacles to efficient ways of administrating the information can be removed. This paper is based on four case studies.

The paper focuses on the possible tools of knowledge management by exploring offered, needed and wanted knowledge. We study knowledge management (KM) by exploring how the tools are utilized currently in case projects in Finland and how new tools could improve the processes. We also aim to study what kind of obstacles there are for information system (IS) tools utilization. We aim at exploring what kind of tools can improve success in projects. The research is qualitative, aiming at exploring the IS tools of knowledge management in construction projects. The paper is based on four case studies in public construction projects in Finland.

Knowledge management (KM) is according to Brelade and Harman (2001) obtaining and using resources to create an environment in which individuals have access to information and in which individuals obtain, share and use this information to raise the level of their knowledge. In addition to this individuals are encouraged and enabled to obtain new information for organization. Egbu (2001, p.126) argues that KM should be understood to mean the processes by which knowledge is created, acquired, communicated, shared, applied and effectively utilized and managed, in order to meet existing and emerging needs and to identify and exploit existing and acquired knowledge assets.

Since the 1960s, information technology (IT) has become an all-pervasive force in the business world, superseding more conventional tools for data storage and communication. It has been argued that IT has the potential to “redefine the management and control of global basis through the removal of barriers such as time and distance” (Egbu 2000, p.109).

Naaranoja et al. (2005) have studied how difficult it is to know what kind of knowledge you need in a project and how people filter the information they don’t want to learn. This filtering may also include issues that they should learn. People do not utilize all the available knowledge resources. These resources might be people or tools that give new knowledge, e.g. on the state of the building they are renovating. The offered knowledge may not be trustworthy, or you don’ t need the knowledge at that moment. They also tried to find out how knowledge resources are critical and why they are accessed or, even more importantly, why they might not be accessed and how managers can know what offered knowledge they should take seriously in the project environment. Their conclusion is that a more relevant question is how the manager facilitates the learning in the team and makes people to learn from each other. The project manager is not able to select what knowledge is reliable, but he should be able to know how the project is organised and who knows what and therefore who is able to select what offered knowledge should be taken seriously.

Love et al. (2004) argue that rework is an endemic problem in building construction projects in Australia. Research has shown that rework is the primary cause of time and schedule overruns and quality deviations in projects. Delays and cost overruns are seemingly the rule rather than the exception in the construction industry. Design changes are frequent, generating costly ripple effects that create delay and disruption. Projects often appear to be going smoothly until near the end when errors made earlier are discovered, necessitating costly rework. Various industry development initiatives have focused on addressing the symptoms rather the causes of the industry’ s problems.

2 METHOD

The paper is based on literature review and four case studies in public construction projects in Finland, in three municipalities. The number of inhabitants in these towns or municipalities varies between 23 000 to 57 000. The four construction projects that are researched here are:

- Renovation and partly new construction of a school that had mould problems, total area 3000 m^2 and budget 2 7 000 000 euros. Project started 1998 and ended 2005.

- Hospital for senior sitizens, the renovation of the nursing home, total area 7 000 m^2 and budget 5 700 000 euros. Project started 1996 and is still going on.

- University project, 24 000 m^2. Alteration of an old factory into a university and partly new construction. The project started 1997 and was finished February 2004. There were 10 interviews in the construction company, one designer, one end user and the project manager.

- Renovation / partly new construction of a nursing home, total area 3500 m^2. Construction stage started March 2003 and ended February 2004. The case study is based on interviews of 7 construction company employees.

We used theme interviews as a means of collecting information, but we have also collected artifacts of the projects such as drawings, memos, and observed the meetings in two projects. In addition, action research is going on in two towns – the aim of this action research is to find out new ways of organizing knowledge management in the construction projects. In the PROLAB project we studied also other case studies than the four that were selected in order to focus on both the pre-construction and construction stages.

The interview material was scanned by marking not only what the interviewees talked about IS but also the challenges that might be solved by IS. The used classification of the challenges is design changes, construction changes, client, design team, site management, subcontractor, project scope, contract documentation, project communication, procurement strategy and design management. The classification was made according to Love (2004) who aimed at building a holistic rework reduction model. It provides a platform in the context of the challenges of project management, reducing rework in construction projects. From the data we perceived how the IS-tools are utilized currently in case projects in Finland and what kind of tools can improve success in projects and how new tools could improve the processes. We also aim to study what kind of obstacles there are for IS-tools utilization.

3 GENERAL PRINCIPLES OF KNOWLEDGE MANAGEMENT

Knowledge is often defined to be meaningful information. Knowledge is derived from information. What makes the difference between data and information is their organisation and the difference between information and knowledge is their interpretation (Bhatt 2001). Knowledge is the understanding one gains through experience, reasoning, intuition, and learning. We expand our knowledge when others share their knowledge. New knowledge is created when we combine our knowledge with the knowledge of others. Wisdom and insight can be included in the definition of knowledge. Wisdom is the utilization of accumulated knowledge (Cong and Pandya 2003).

Quinn et al.(1996) divided the knowledge of an organization onto four levels: (1) knowing what: cognitive knowledge; (2) knowing how: the ability to translate bookish (knowing what) knowledge into real world results; (3) knowing why: the ability to take know how into unknown interactions; and (4) caring why: self-motivated creativity, this level of knowledge exists in a organisation's culture.

It is recognised that good knowledge management does not result from the implementation of information systems alone (Grudin 1995; Davenport 1997; Stewart 1997). However, the role of IT as a key enabler remains undiminished (Anumba et al 2000; Egbu 2000). IT should be understood less in its capacity to store explicit information and more in its potential to aid collaboration and co-operation between people (Egbu and Botterill 2002). Dougherty (1999) argues that IT should be seen as a tool to assist the process of KM in organisations. Such a process relies more on the face-to-face interaction of people than on static reports and databases (Davenport and Prusak 1998). Some organisations have developed software to encourage social interaction in organisations in the hope that a unique forum for tacit knowledge exchange will be established.

Alavi and Leidner (1999) asked managers about their key concerns about knowledge management. The managers expressed concern primarily over the cultural, managerial and informational issues (Figure 1). In terms of the culture, the managers were concerned over the implications for change management, the ability to convince people to volunteer their knowledge, and the ability to convince business units to share their knowledge with other units. Concern was also expressed over how to implement the knowledge management system effectively (Alavi and Leidner 1999). These concerns are all relevant for construction projects, especially because the project environment always bring together people not only from various units but from various companies.

The construction industry provides customized solutions for clients. That is the reason why the knowledge management solutions between clients and construction professionals should focus on sharing knowledge through person-to-person contacts and ICT enabled communication. The co-operation between professionals is more standardized and the codified strategy might be useful in some parts of their work. In this paper we focus on improving knowledge management in construction project by utilizing information systems.

INFORMATION

- § Building vast amounts of data into usable form
- § Avoiding overloading users with unnecessary data
- § Eliminating wrong/old data
- § Ensuring customer confidentiality
- § Keeping the information current

MANAGEMENT

- § Change management implications
- § Getting individuals to volunteer knowledge
- § Getting business units to share knowledge
- § Demonstrating business value
- § Bringing together the many people from various units
- § Determining responsibility for managing the knowledge

TECHNOLOGY

- § Determining infrastructure requirements
- § Keeping up with new technologies
- § Security of data on Internet

Figure 1 Key concerns related to knowledge management (Alavi and Leidner 1999)

4 IS TOOLS FOR KNOWLEDGE MANAGEMENT

Information system (IS) combine organisational, human and information technology based resources to generate the effective and efficient collection, retrieval, communication and use of information. Information technology (IT) serves IS by supporting business operations and enabling new ways of carrying out organisational activities (Barrett 1995).

Laudon and Laudon (1998) classify IS for knowledge management into four main categories:

1. those for creating knowledge (knowledge work systems): these support the activities of highly skilled knowledge workers and professionals as they create new knowledge; CAD systems, analysis systems, estimating systems. Increasingly, these systems are being integrated both within and across disciplines, thereby facilitating the flow of information

2. those for processing knowledge (office automation systems): these help disseminate and co-ordinate the flow of information in an organisation - word processing, spreadsheets, imaging and web publishing, electronic calendars, desktop databases. These systems are now routinely used within construction organisations to ensure the smooth running of businesses

3. those for sharing knowledge (group collaboration systems): these support the creation and sharing of knowledge among people working in groups -

groupware, intranets, video-conferencing, document management systems, bulletin boards, shared databases, electronic mail systems. The use of these systems is growing in the construction industry, but the emphasis has been more on supporting intra-organisation groups rather than virtual project teams that have members drawn from several organisations

4. those for capturing and codifying knowledge (artificial intelligence systems): these provide organisations and managers with codified knowledge that can be reused by others in the organisation - expert systems, neural nets, fuzzy logic, genetic algorithms, intelligent agents. They enable the setting up and maintenance of knowledge bases that preserve knowledge/expertise that might otherwise be lost when a key member of staff is no longer available.

Construction organisations need to view IT as an enabler, which should be part of an integral multi-faceted KM strategy; develop and implement an IT infrastructure for KM which is tailored to suit the needs of the organisation and implement an appropriate training programme that educates the organisation’ s employees on the benefits of KM, and in the use of any supporting IT systems (Carrillo et al., 2000).

Knowledge work systems

Product modelling is a mean of creating new knowledge with the aid developed CAD-systems. Product models make construction plans more effective and competent during construction project and the whole life cycle of the building. Kuhne and Leistner (2002) conclude that there is substantial potential for optimizing management processes in the construction industry when using a product model. The various potentials have been arranged into three areas: collaboration, data processing and controlling.

Office automation systems

Word processing, spreadsheets and other office automation systems are widely used systems. There are numbers of document models and sheets for reports prepared. Also timing is often made by project planning systems. Regulations and documents are often stored in intranets. But the use of electronic calendars and intranet use as publishing and discussing tools is not very common.

Group collaboration systems

Collaboration is a fundamental aspect of project-based work and it is therefore recommended that organisations pay attention to the different types of collaborative technologies that exist.

According Egbu and Botterill (2002) there are good experiences about virtual teamwork stations included desktop video-conferencing equipment, multimedia e-mail, shared chalkboards, a document scanner, and tools to record video clips, group-ware and web-browser. Although it is arguable whether these technologies capture or distribute structured knowledge, many would contend that they are useful at enabling people to transfer tacit knowledge. Perhaps the potential benefits of using such technologies are not fully understood and organisations are more incremental in their implementation of IT.

Artificial intelligence systems

Neural networks have been described as a statistically oriented tool that excels at using data to classify cases into one category or another. Other data mining tools include artificial intelligence tools as well as conventional statistical analysis. Strong proponents of these tools advance the view that the pattern identification and matching capabilities of software can eliminate human intervention. It could be argued, however, that an intelligent human is required to structure the data in the first place, interpret data and understand identified patterns; and of course make a decision based on the knowledge generated (Egbu, Botterill 2002).

5 OBSTACLES

The construction industry does not understand as a whole the need for computable information - the industry’ smindset needs to be shifted from pictures to information models. This is a shift that all industries experience. Once the value of a modelling is recognized – and the models of buildings are created – new forms of value can be unleashed.

The obstacles can be categorized into three different levels: 1) individual level (e.g. project team member, procurement manager), 2) organisational level and 3) network level. The levels of the adoption decisions have been discussed within the innovation diffusion theory literature in the form of optional, collective and authority adoption-decisions (Rogers 1983; Engsbo 2003). The projects are realised at the network level.

The obstacles can be divided into four main categories:

1. technical: continual demand for upgrading hardware and software is the greatest obstacle according to Samuelson (2002). There is a lack of supporting infrastructure for security or privacy. Legacy systems and/or standards are needed to be able to develop the systems

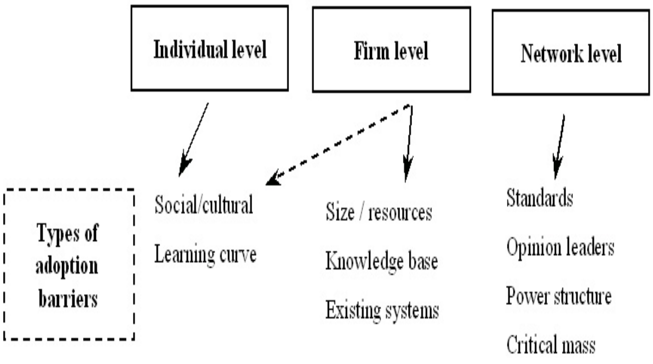

Figure 2 Links between levels and adoption barriers. (Engsbo 2003)

2. human: lack of knowledge of the possibilities and overabundance of information are among the main obstacles to ICT use (Samuelson 2002: 17). Cynicism and defeatism are unintended consequences of techno change failure, preventing the success of the new change efforts (Markus 2003). In addition, there are obstacles such as the lack of project-centric or senior executive commitment; loss of personal benefits from contacts with pre-existing business network; inconsistency with existing strategies, and cultural or internal resistance.

3. economic: the strategic objectives are not clear (Love 2004). Investment costs are too high (Samuelson 2002). The network affects the utilization of ICT (Bansler and Havn 2004, p 271, 272). The key challenge is to obtain a "critical mass" of users. Many new technologies fail to obtain critical mass and simply flop. The problem is the "chicken and the egg" paradox: many users are not interested in adopting the technology because the installed base is too small, and an insufficiently small number of users have adopted the technology (Bansler and Havn 2004, p 271, 272). Other economic obstacles are investment costs justification, unclear benefits, time or resource constraints, uncertainty or risk aversion; and perceived no-win situations for the individual firm.

4. information or knowledge resources: There is not enough information or knowledge available about certain issues such as how to accept electrically a delivery or also that the security issues are even more important than before since a virus may attack even if there is a firewall.

6 THE CHALLENGE OF REDUCING REWORK IN CONSTRUCTION PROJECTS

The end users of the case construction projects had often experienced communication problems. They did not understand, for example, the drawing symbols of the electric conduits and they experienced confusion when every special designer introduced their design papers. The users pointed out that real size mock ups helped them to understand what was going on. Also the end users had difficulties in expressing their current and future needs.

The designers said that they had to wait too long for the final plans of the main designer. They longed for a controlled timetable for design. Also competition on price was found to be a reason for poor design quality. The designers also talked about the reasons for changes:

- special designers don't always understand the needs of the end user.
- end users change their minds
- designers don't always understand each other
- solutions are not introduced properly for end users.

The designers often talked about commitment and the need to deliver information to every party that might need that information.

The project managers frequently talked about losing the goal of the design and how they did not manage the design process well enough. Also they could tell that document management was not done as well as it could be. The checking of the solutions should be made properly – the designers couldn´t see their own mistakes. The design contracting was also discussed. The best design group has also worked together previously. Maybe it would be best to make a design agreement with the group of designers and not with every designer separately. The project managers also told about the difficulties they had in producing working drawings since the changes were realised at the very last moment in the requirements. Design schedules were seen as challenging: how to give end users enough time to comment on the solutions and the professionals to double check the solutions.

The contractors found out that the design quality was not good enough – when the work starts there are a lot of details lacking. The site managers wanted a better relationship with the designers. At the moment the designers communicate with the site in site meetings, by phone and by fax. The information doesn't flow. On site the personal contacts effect the information flow. The work is not often planned at a reasonable level. The contractors explained that if they could be involved during the design process there would be less mess during construction. Quality systems require bureaucracy that is partly very good and partly the benefits are not visible from the process point of view. According to the contractors most of the extra costs incurred are due to poor design. However, they could recognise some points in how they could improve their own work: change the management, detailed scheduling their own work, documenting difficult situations, and information flows inside the company.

Analyses from the needed, wanted and offered knowledge points of view pinpoint that collaboration systems are the main tool in offering knowledge, but it does not ensure that the knowledge is in the kind of format that it is learned in order to get the wanted or needed knowledge. In addition the needed information might not exist in the collaboration systems. The needed knowledge could be in the artificial systems so that a party would get it whether he wants it or not. The main challenge is how to motivate the designer to utilize the knowledge of the end-user, though it is time consuming and requires a lot of co-operation. We did not find any specific tools that support this motivation.

The collaboration between the site and designers could also be improved by videoconferencing technology in the future. The project intranets could be developed to support the learning of each party, not only the learning of the end user, but also the construction professionals.

The companies are at the moment also starting to create environments where best practice stories are gathered. In the interviews this was seen as a good opportunity by not only giving the template and example documents to the other parties, but also information on possible difficulties and how to avoid them.

Quite many of the problems in our case studies concern the design phase. Product modelling is one way, but not yet a common way, to enhance the construction planning system. Some pilot projects test product modelling, and the use of IFC specification is under development. Product modelling does not separate the plans of the different designers but it adds to the coordination and communication between designers who usually come from many firms. The use of product models helps the customer orientation as well. 3D visualization decreases the jargon problems between the client and construction professionals. By means of product modelling it is possible to check the constructability and interoperability of plans by model-checker software. 4D-design helps to optimize the schedule. So the product model could be the answer to many designers´, clients´ and contractors´ problems.

Kuhne and Leistner (2002) conclude that there is substantial potential for optimizing management processes in the construction industry when using a product model. The various potentials have been arranged into three areas: collaboration, data processing and controlling. The use of product models for defining a common project language illustrates a basis for well-functioning communication between the project participants and quick availability of data in order to avoid delays and incorrect deliveries. Product models give the chance to estimate time and cost expenses, productivity in e.g. heat flow calculations and bearing capacity, giving a view of a project' s life cycle and facility management information. Monitoring and overview of the total project from a cost and time viewpoint, analyses and evaluation, and project-wide usage of product model data simplify the tasks of the project controller, and visualization; at the present time the technical-constructive planning is based on alphanumeric data, it is of an abstract nature and possesses no direct graphical representation, but geometrical and spatial representation is becoming more and more significant for humans in trying to understand and control large projects with complex structures.

7 CONCLUSION

The four case studies showed that the main challenges of knowledge management in construction projects are the requirements of management and constructability analysis of the design and communication during the construction. For example, the professionals do not always want to spend time with the real problems of a customer, though it is obvious they would need this knowledge. We did not find any tools for this motivation purpose. Currently the offered knowledge during the design stage is not in the kind of format that the client would get the knowledge he/she wants or is able to understand that he/she needs. The ICT solutions are able to support in this process by giving visualisation tools and giving advice on what kind of questions need to be answered in each stage of the construction process.

We studied what kind of obstacles there are for information system (IS) tools utilization. The obstacles can be categorized into three different levels: 1) individual level, 2) organisational level and 3) network level. The case construction projects happened in the inter-organisational network. The obstacles can be divided into four dimensions: technical, human, economic and information or knowledge resources. Due to the resistance to change and the past failures of techno change the project people very soon become cynical and the success of the new change efforts are not realised. We also found that often ICT have positive effects on the challenges, but that often there is a critical mass problem, where the benefits are not yet gained if there are insufficient users.

In the introduction we promised to discuss what kind of tools can improve success in projects. According to our studies this can be obtained by enabling the learning in the team and making people learn from each other. Nobody is able on their own to select what knowledge is needed, and the project team should be able to know how the project is organised, who knows what and thus who is able to select what offered knowledge should be taken seriously and what knowledge is trustworthy and what kind of extra knowledge is still needed.

The used ICT systems of the case projects were moderate. The benefits of the most modern tools could not be tested. However, this research shows what kind of challenges there are in all projects – the challenges that could or are being partly solved by ICT. Most of the challenges can be found also in projects where there are better ICT solutions in use. It would be interesting to study the practises in projects that have a proper databank in use and study the benefits of such tools. Part of the interviewees had utilised such tools and, in addition, we have made interviews in other case projects in which there has been a project intranet in use. According to our research they had failed to gain all the benefits we have proposed in this paper. How the benefits are really gained and how the change efforts should be made is a subject of future studies.

REFERENCES

Alavi M, Leidner D E, 1999, Knowledge management systems: Issues, challenges, and benefits, in *Communications of AIS* Volume 1, February 1999

Anumba, C.J., Bloomfield, D., Faraj, I. and Jarvis, P., 2000, Managing and exploiting your knowledge assets: knowledge based decision support techniques for the construction industry , BR382, Construction Research Communications Ltd., UK .

Carrillo, P.M., Anumba, C.J. and Kamara, J.M., 2000, "Knowledge management strategy for construction: key IT and contextual issues" , *Proceedings International Conference on Construction Information Technology*, Gudnason, G. (Ed) , Icelandic Building Research Institute, Reykjavik.

Bansler J.and Havn E., 2004, Technology-Use Mediation: Making Sense of Electronic Communication in an Organizational Context. *Scandinavian Journal of Information Systems*, Vol. 16(1): 57-84

Barrett P. (1995) (ed.), Facilities management towards best practice. Blackwell Science Ltd.

Bhatt, G.D. 2001. KM in organisations: Examining the Interaction between Technologies, Techniques, and People. Journal of Knowledge Management 5(1), pp. 68-75.

Brelade S, Harman C. (2001). How Human Resources can influence knowledge management. *Strategic HR Review* 1:1. 30-33.

Cong, X. & Pandya, K.V. 2003. Issues of Knowledge Management in the Public Sector. Electronic Journal of Knowledge Management 1(2) pp. 25-33.

Egbu, C. O. (2000) The Role of IT in Strategic Knowledge Management and its Potential in the Construction Industry. *UK National Conference on Objects and Integration for Architecture, Engineering, and Construction. 13 to 14th March 2000, BRE, Watford, UK*

Engsbo M (2003), Barriers to adopting Internet-enabled collaboration and business in the building construction industry - Towards a three-level framework, in Hannula Mika, Järvelin Anne-Mari & Seppä Marko (editors*) FeBR 2003 - Frontiers of e-Business Research 2003.*

Davenport T., 1997, Process innovation: reengineering work through information technology. Harvard Business School Press Boston, MA, USA

Davenport, TH, Prusak, L. (1998). Working Knowledge: how organizations manage what they know. *Boston, Massachusetts: Harvard Business School Press.*

Dougherty, V. (1999); Knowledge is about people, not databases, *Industrial and Commercial Training,* Vol. 31, No. 7, 1999, p262-266.

Egbu CO, Botterill K. (2002). Information technologies for knowledge management: Their usage and effectiveness. *ITCon, Vol. 7. Special Issue ICT for Knowledge Management in Construction*, pg. 125-137, Accessed 19th April 2005, at http://www.itcon.org/2002/8

Egbu CO, (2000). The role of information technology in strategic knowledge management and its potential in the construction industry. In: *Proceedings of UK National Conference on 'Objects and Integration for Architecture, Engineering and Construction',* March 2000, BRE

Grundin, J. (1995). Why Groupware Applications Fail: Problems in Design and Evaluation, in R. Baecker, et. al. (eds.), *Readings in Human-Computer Interaction: Toward the Year 2000*, Morgan Kauffman.

Kuhne, C. and Leistner C.,2002, Benefits of using product and process model data in project management, *in Turk Z., ShererR(eds). ECCPM 2002, eWork, eBusiness in Architecture, Engineering and Construction,*

Laudon, J and Laudon, K. (1998), Management Information Systems, 5th ed.: *New Approaches to Organization and Technology*, Prentice Hall

Love, P.E.D. and Irani, Z.(2004). A Rework Reduction Model for Construction Projects. *IEEE Transactions on Engineering Management*, Vol. 51, No. 4, November 2004.

Markus, M. Lynne. "Techno change Management: Using IT to Drive Organizational Change," *Journal of Information Technology*, vol. 19, 4-20, 2004.

Naaranoja Marja, Päivi Haapalainen, Heikki Lonka (2005), Challenges of knowledge management in public construction projects , Accepted to be published at the conference CIB 2005, COMBINING FORCES - Advancing Facilities Management and Construction through Innovation, June 13-16, 2005, Helsinki

Quinn, J., Anderson, P., and Finkelstein, S. 1996. Managing Professional Intellect: Making the Most of the Best. *Harvard Business Review* (March-April): 71-80.

Rogers, E. M. 1983. Diffusion of innovation, 3rd edition. *Free Press*, New York.

Samuelson, O. 2002. IT-barometern 2000. IT Bygg och fastighet 2002. Available online at http://www.itbof.com/documents/skrifter/ITBAROMETER2000.pdf

Stewart, T. A. (1997). Intellectual Capital: *The New Wealth of Organisations*, New York, Doubleday.

LUKU 9

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Tietotekniikan mahdollisuudet ja rajoitukset eli mihin haasteisiin tietotekniikka on vastaus?

Päivi Jäväjä, Marja Naaranoja

9.1 Johdanto

Rakennusalan haasteita - aikatauluylityksiä, laatuongelmia ja kustannuksia nostavia muutostarpeita - voidaan analysoida kahdesta näkökulmasta (Kashiwagi et al. 2005:172). Ensimmäinen näkökulma on yksittäisen projektin näkökulma, joka olettaa, että ongelmat johtuvat kunkin hankkeen ainutkertaisuudesta. Tämä näkökulma johtaa tarpeeseen kouluttaa parempia työmiehiä, standardointiin, projektin johtamisen menetelmien kehittämiseen ja tarkastuksiin. Toinen näkökulma keskittyy prosessien kehittämiseen. Prosessinäkökulma keskittyy siihen, kuinka asiakkaan tarpeet saadaan tehokkaan toiminnan avulla tyydytettyä. Tämä artikkeli pohtii prosessien kehittämistä tietotekniikan näkökulmasta.

Tietotekniikka on työkalu, joka taitavasti käytettynä parantaa tuottavuutta ja tarjoaa rakennushankkeiden johtamiselle ja organisoinnille uusia mahdollisuuksia. Uusien tietoteknisten järjestelmien käyttämisellä on mahdollista tehostaa rakentamisprosessin informaation hallintaa ja osapuolten välistä viestintää. Tärkeäksi muodostuvat tietotekniikan sovitut, yhteiset pelisäännöt, laitteistojen ja ohjelmistojen yhteensopivuus ja verkossa tapahtuva tiedonvaihto. Internetin käyttöalueen laajentuminen tarjoaa nopeasti kehittyviä menetelmiä ja vaatii jatkuvaa seurantaa. Yritysten on huomioitava sähköisen kaupan mahdollisuudet sekä sidosryhmien sisällöltään laajemmat ja nopeammat tietovaatimukset. (RAKLI 1998.) Uusi tekniikka tuo mukanaan hienoja mahdollisuuksia, mutta siitä huolimatta rakentamisen ammattitaito on välttämätön edellytys onnistumiselle tietotekniikan hyödyntämisessä. Tietotekniikka on vain apuväline, joka ei sinänsä synnytä menestystä, kuten kirves ei rakenna taloa ilman kirvesmiehen kädentaitoa ja kokemusta.

Tietotekniikan käyttämisellä ei automaattisesti aikaansaada hyvää tiedonhallintaa (Davenport 1997), mutta se tarjoaa mahdollisuuden tehokkaaseen tiedon jakamiseen rakentamisprosessin aikana. Tietotekniset sovellusohjelmat tarjoavat ratkaisuja kommunikoinnin parantamiseen eri osapuolten välillä visuaalisten mallien avulla. Erilaiset suunnitelmavaihtoehdot ovat tarkasteltavissa ja arvioitavissa tietokoneruudulla etukäteen havainnollisessa kolmiulotteisessa muodossa. Rakennuksen tuotemalli auttaa yhteisen kielen löytymistä rakennuksen tulevien käyttäjien ja rakennusalan ammattilaisten välille, tämä luo suunnittelukokouksissa käytävälle keskustelulle yhteisen pohjan. Tilaajan osallistumismahdollisuuksien parantumisen myötä lopputulos eli käyttöön otettava rakennus vastaa todennäköisesti paremmin toiveita ja odotuksia. (Sulankivi et al. 2002.) Tuotemallin ja prosessimallin hyödyntäminen muuttavat toimintatapoja älykkään tiedon tallentamiseen ja siirtämiseen nykyisen dokumenttien tallennuksen sijaan. Elinkaariajattelun omaksuminen korostaa kaikkien osapuolten yhteistyön tärkeyttä, kun alkuvaiheesta lähtien huomioidaan kokonaisuus suunnittelusta ja toteutuksesta valmistukseen, käyttöön, huoltoon, korjauksiin ja lopulta purkuun asti.

Tehokkainta tiedonvaihto rakennusprojektissa on silloin, kun projektin kaikki osapuolet kommunikoivat keskenään yhtenäisen järjestelmän avulla. Työryhmän yhteistyömahdollisuudet paranevat merkittävästi, jos suunnittelijat voivat yhteistyössä tuottaa rakennuksen tuotemallin eli virtuaalirakennuksen sen sijaan, että eri suunnittelijoilla on omat irralliset suunnitelmansa. Muiden suunnittelijoiden työn edistymisen seuraaminen oman työn ohella on luontevampaa, kun eri suunnittelualojen suunnittelutieto on integroitu yhteiskäyttöiseen tuotemalliin eikä tiedon etsimiseen tarvita erillisiä toimenpiteitä (Sulankivi et al. 2002).

Suunnitelmien havainnollisuus ja tehokas analysointi, kuten asennusjärjestyksen tai rakennettavuuden tutkiminen etukäteen tietokoneruudulta, voi myös helpottaa urakoitsijaa tunnistamaan tuotannon kannalta epäedullisia tai riskejä sisältäviä ratkaisuja. Tuotevalmistajien objektien mukana suunnitelmaan voidaan liittää asennuksen ja käytön kannalta tärkeää tietoa, kuten valmistusaineet, takuuajat ja hoito-ohjeet. Aikataulun seuranta ja optimointi sekä asennusjärjestyksen ja työmaan logistiikan suunnittelu on mahdollista mallin 4D-ominaisuuksien avulla (4D tarkoittaa aikatauluun yhdistettyä 3D-mallinnusta), ja lisäksi määrätiedot ovat saatavissa suunnitelmista automaattisesti ja virheettömästi.

Kuva 1. 3D-visualisointi

9.2 Tietotekniikka rakennusalalla

Konservatiivisena pidetty rakennusala on vastahakoinen muutoksille, mutta väitetään, että rakentajatkin hyväksyvät uudistukset, jos edut ovat riittävän selvästi nähtävissä. Rakennusalan tietokoneavusteiset suunnittelujärjestelmät eli CAD-järjestelmät (Computer Aided Design) ovat vähitellen vakiintuneet käyttöön, mutta useat tehokkaat informaatioteknologiset (IT) järjestelmät ja alan tutkijoiden kehittämät työkalut ongelmien ratkaisemiseksi ovat edelleen jääneet vaille laajempaa käyttöä rakennusteollisuudessa. Tietojen yhteensopimattomuus ja muut tiedonhallinnan ongelmat aiheuttavat huomattavia kustannuksia sekä rakennusvaiheessa että myöhemmin kiinteistöjen omistajille ja ylläpitäjille. Tiedonhallinnan ja kommunikoinnin merkitys korostuu rakennusalalla erityisesti, koska projektissa on useita osapuolia, jotka tulevat useasta eri yrityksestä. Tiedonvaihto yritysten välillä on puutteellista ja jopa yrityksen sisällä voi syntyä tiedonkulun katkoksia. Suunnitelmien tietosisällön kasvaessa virhemahdollisuudet lisääntyvät.

Rakennushankkeen eri vaiheissa syntyvä tieto ei palvele pelkästään rakennusvaihetta eikä rakennustyö tuota vain rakennusta, vaan suunnittelu- ja rakentamisvaiheessa syntyy koko rakennusta koskeva tietomalli. Tämän tietokannan hyödyntäminen rakennuksen elinkaarta palvelevana tietovarastona vaatii paljon kehitystyötä. Standardimuotoinen suunnitelmatieto ja valmistajien digitaalinen tuotetieto (valmistusaineet, takuuajat, hoito-ohjeet) voidaan liittää osaksi rakennuksen tuotemallia, ja tiedon tulee liittyä tuotemalliin osana rakennustarvikekauppaa. Digitaalisella tilatiedolla on useita käyttökohteita rakennuksen elinkaaren aikana. Tilatietoon pohjautuen rakennuksen omistaja ja käyttäjä voivat tehdä tilojensa käyttösuunnitelmat, kuten tilankäytön tehokkuuden ja kalustettavuuden arvioinnit, käyttökustannuslaskelmat, siivouksen ja huollon tarpeet ja toimenpiteet, palvelut yms. Kiinteistönhallinnan sovelluksien tehokkaalla hyötykäytöllä voidaan omistajien kiinteistövarallisuutta tarkastella reaaliaikaisesti ja saada käsitys sen kunnosta ja käyttöasteesta. (RAKLI 1998.)

9.3 Tietojohtamisen IT-työkaluja

Laudon ja Laudon (1998) luokittelevat tietojohtamisen tietojärjestelmät neljään luokkaan.

1. *Tietoa luovat järjestelmät (tietotyön tukijärjestelmät)*
   Erikoisasiantuntijat luovat uutta tietoa näiden järjestelmien avulla. Esimerkkinä voidaan mainita rakennusalan CAD-järjestelmät (ks. taulukko 1), rakenteiden suunnittelu- ja mitoitusohjelmat, mallinnus-, laskenta- ja analysointityökalut. Nämä järjestelmät ovat yleensä eri ammattialojen sisäisessä käytössä, mutta parhaimmillaan ne ovat yhteensopivia eri osapuolten järjestelmien kanssa.

2. *Tietoa käsittelevät ja varastoivat järjestelmät (toimistoautomaatiojärjestelmät)*
   Toimistoautomaatiojärjestelmien avulla voidaan hoitaa rutiininomaisia tehtäviä kuten tekstinkäsittelyä ja taulukkolaskentaa. Sähköisillä kalentereilla voidaan hallita useiden ihmisten aikatauluja samanaikaisesti. Aikataulu- ja resurssisuunnitteluun käytettävät projektinhallintaohjelmistot kuuluvat myös tähän ryhmään. Dokumentit ja yrityksen sisäiset ohjeistukset tallennetaan intranet-järjestelmiin. Toimistoautomaatiojärjestelmät liittyvät informaation käsittelyyn, hallintaan ja varastointiin.

3. *Tietoa jakavat järjestelmät (kommunikointi)*
   Näiden järjestelmien avulla mahdollistetaan tiedon jakaminen työryhmän sisällä ja työryhmien välillä. Esimerkkeinä voidaan mainita erilaiset ryhmätyökalut, intranet-järjestelmät, sähköiset ilmoitustaulut, jaetut tietokannat, videoneuvotteluyhteydet ja sähköpostijärjestelmät.

4. *Tietoa kiteyttävät järjestelmät (älykkäät tietojärjestelmät)*

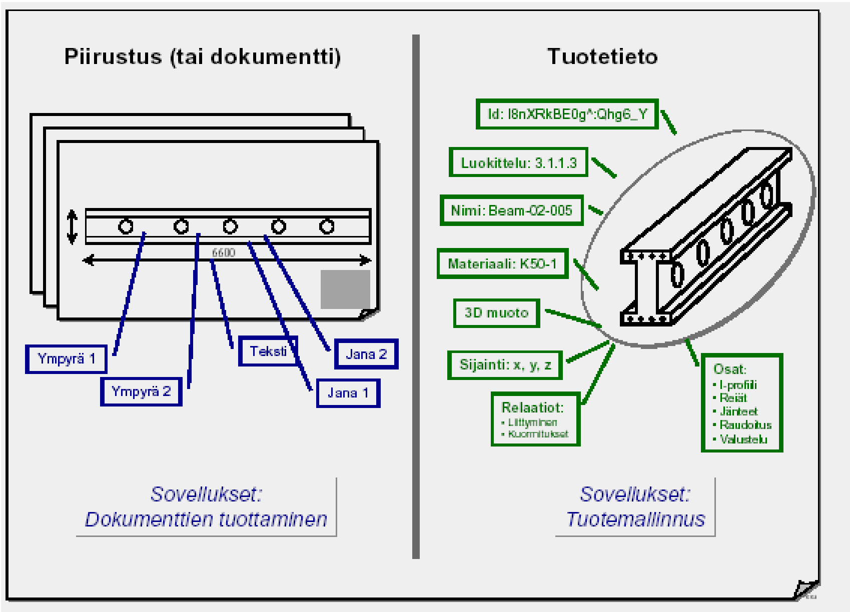
   Nämä järjestelmät lajittelevat ja priorisoivat tietovarastoihin tallennettua tietoa ja toimivat päätöksenteon, analysoinnin ja tiedonhaun välineenä yrityksen sisällä. Esimerkkejä näistä järjestelmistä ovat asiantuntijajärjestelmät, neuroverkot, sumeat logiikat, geneettiset algoritmit ja älykkäät agentit.

Tietoa luovat järjestelmät (tietotyön tukijärjestelmät)

Taulukko 1. CAD-suunnitteluun liittyviä käsitteitä

Menetelmä	*Selitys*	*Hyödyt*
2D-CAD	Piirustukset luodaan tietokoneavusteisesti piirtämällä vektoriviivatyökaluilla kaksiulotteisia tasokuvia. 2D-järjestelmä voi sisältää valmiita symboleja esimerkiksi rakennuspiirustuksissa käytettäväksi.	Helppo ja yksinkertainen menetelmä perinteisten rakennussuunnitelmien esittämiseen.
3D-CAD	Oliopohjaiset järjestelmät mahdollistavat rakennuselementtien käsittelyn todellisina kolmiulotteisina kappaleina eikä pelkästään viivoina ja symboleina. Virtuaalinen rakennus sisältää eri projektiot - pohjat, leikkaukset, julkisivut, näkymät, 3D-visualisoinnit ja määräluettelot. Jokaista piirustusta ei tarvitse konstruoida erikseen, vaan tarvittava tieto on virtuaalisessa rakennuksessa.	Näkymäkuvat, animaatiot ja liikuteltavat virtuaalimaisemat on helppo tuottaa ja neuvottelutilanteissa ne kertovat asiakkaalle ja tilaajalle selkeästi, mitä ollaan tekemässä
4D-järjestelmät	3D-suunnitelman ja aikataulun linkittäminen yhteen. Aikataulua havainnollistetaan 4D-mallin avulla.	Voidaan käyttää tarkasteltaessa projektin eri vaiheiden vaikutusta toisiinsa esimerkiksi asennusjärjestyksen ja logistiikan kuvaamisessa.
Tuotemallit	Tuotemalli (Building Information Model, BIM) on rakennuksen kolmiulotteinen tietokonemalli, jonka jokaiselle komponentille, esimerkiksi ovelle tai seinälle, on määritelty sisältö, mitta ja sijainti, jopa asennuspäivämäärä. Tuotemallin avulla voidaan hallita rakennusprosessin kaikkia vaiheita hankesuunnittelusta ylläpitoon. Yhteinen tiedonsiirtostandardi (IFC) takaa, että tietoa voidaan siirtää malliin eri osapuolien ohjelmistoista. Tuotemallissa rakennusosaan liittyy siis materiaali-, määrä-, kustannus-, sijainti- ja ajoitustieto sekä visualisointi (ks. kuva 2).	Projektinhallinta tehostuu kaikkien tietojen yhdentyessä samaan järjestelmään. Enää ei tuoteta päällekkäistä tietoa, vaan täydennetään jatkuvasti samaa tietokantaa projektin osapuolten suunnitelmilla.
Prosessimallit	Prosessimalli on prosessikuvaus rakennushankkeen ja rakennuksen elinkaaren aikaisista prosesseista, erityisesti tiedonhallinnan näkökulmasta. Prosessimallin tarkoituksena on tarjota systemaattinen kuvaus tuotemallipoh-	Prosessimalli auttaa rakennusprojektin suunnittelua ja hallintaa ja mahdollistaa prosessin jatkuvan parantami-

	jaisista rakennuksen suunnittelun, toteutuksen ja ylläpidon prosesseista, niiden toiminnoista ja toimintojen välisistä tietovirroista (ks. kuva 3).	sen.
IFC ja IAI	IFC (Industry Foundation Classes) on kansainvälinen tiedonsiirtostandardi rakentamisen ja kiinteistönpidon tuotetietojen tiedonsiirtoon ja yhteiskäyttöön. IAI (International Alliance for Interoperability) on avoin kansainvälinen yhteenliittymä IFC-tiedonsiirtostandardin kehittämiseksi ja sen käyttöönoton edistämiseksi.	Tietojen esitysmuoto on yhteensopiva ja projektin osapuolet voivat jakaa ja muokata mallin tietoja omilla tietojärjestelmillään.
Virtuaalitodellisuus	Todentuntuinen näköaistimus, jossa käyttäjä tuntee olevansa sisällä ja läsnä tietokoneen luomassa todentuntuisessa ympäristössä, kykenevänsä toimimaan siellä vuorovaikutteisesti ja käsittelemään suurta ja monimutkaista tietomäärää. Käytetään esimerkiksi tietokoneruudulla tai erityisessä virtuaalitodellisuuslaboratoriossa datalasien tai datakypärän avulla.	Virtuaalitodellisuudessa voidaan mallintaa ja kokeilla valmisteilla olevia asioita ja simuloida eli harjoitella todellisia tilanteita.



Kuva 2. Piirustuksen ja tuotemallin ero (Karstila 2002)

Prosessimalli

ProIT-prosessimalli kuvaa tuotemallipohjaisen rakennusprosessin erityisesti tiedonhallinnan ja tiedon yhteiskäytön näkökulmasta. Siten ProIT-prosessimallin tärkeimmät elementit ovat rakennusprosessin toiminnot, toimintojen väliset tietovirrat, toimijoiden roolit ja prosessissa käytettävät tietotekniset sovellukset. Prosessin materiaalivirtoja on käsitelty vain rajoitetusti. IDEF0-prosessimalli selkiyttää ja havainnollistaa rakentamisprosessia, sen tieto- ja materiaalivirtoja, osapuolia ja toimintoja. Laaditaan prosessimalli, joka käsittää seuraavat osaprosessit (ks. kuva 3):

§ hankkeen johtaminen

§ asiakaspäätösprosessi, sekä asiakas- ja viranomaisvaatimusten hallinta

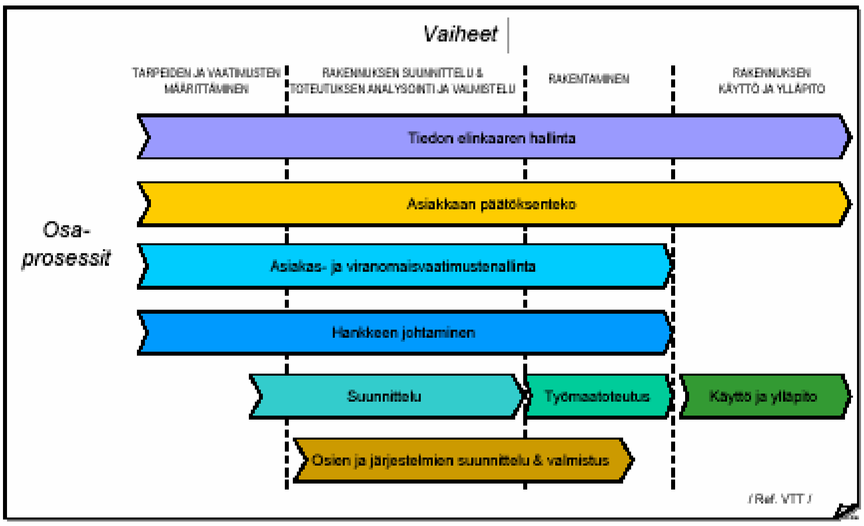
§ rakennuksen suunnittelu, sekä työmaatoteutuksen valmistelu

§ tuoteosien ja järjestelmien suunnittelu ja valmistus

§ työmaatoteutus ja rakennuksen luovutus

§ rakennuksen käyttöönotto, käyttö ja ylläpito

§ tiedonhallinta.



Kuva 3. Prosessimallin lähtökohtana olleen prosessikartan karkea osittelu (ProIT-prosessimalli)

ProIT-prosessimallissa on käytetty IDEF0-prosessin mallintamisjärjestelmää. IDEF0-mallien peruskäsitteet ovat seuraavat (ks. kuva 4):

§ *Toiminto* muuntaa syötteen tulokseksi. Toiminnon toteutusta määrää ohjaus, ja toiminnon suorittaa mekanismi. Toiminto kuvataan laatikkona.

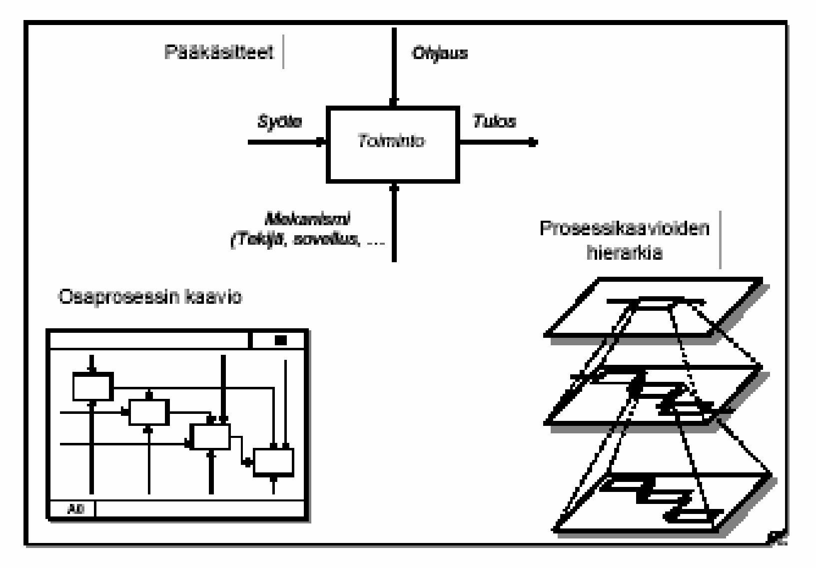
§ *Syöte* voi olla esimerkiksi materiaalia, tietoa tms., jota toiminto muuttaa tulokseksi. Syöte kuvataan toimintolaatikkoon vasemmalta tulevana nuolena.

§ *Tulos* voi olla esimerkiksi materiaalia, tietoa tms., jota toiminto tuottaa syötteestä. Tulos kuvataan toimintolaatikosta oikealle menevänä nuolena.

§ *Ohjaus* ohjaa toiminnon suorittamista muuttumatta itse osaksi tulosta. Ohjaus voi olla esimerkiksi suunnitelma, ohje tms. Ohjaus kuvataan toimintolaatikkoon ylhäältä tulevana nuolena.

§ *Mekanismi* on toiminnon tekijä, esimerkiksi organisaatio tai henkilö, tai se voi olla väline, jota käytetään toiminnon suorittamiseen, esimerkiksi kone tai tietokoneohjelma. Mekanismi kuvataan toimintolaatikkoon alhaalta tulevana nuolena.

Toimintomalli voidaan jakaa hierarkkisesti eri tasoille siten, että koostumuksen seuraavalla alemmalla tasolla kukin toiminto voidaan jakaa edelleen osatoimintoihin. Jakoa voidaan jatkaa alaspäin halutulle detaljitasolle (ks. kuva 4). Koko mallin juuri on yksi toiminto sekä sen syötteet, tulokset, ohjaukset ja mekanismit, joilla kuvataan koko mallin ympäristö.



Kuva 4. Prosessimallin perusosat (ProIT-prosessimalli)

Tietoa käsittelevät ja varastoivat järjestelmät (toimistoautomaatiojärjestelmät)

Toimistoautomaatiolla hoidetaan kaikki tulostettavat asiakirjat, kuten arkistoitavat paperit, materiaalit, muistiot ja pöytäkirjat. Näitä tuotetaan pääsääntöisesti sähköisessä muodossa. Tekstinkäsittelyn, taulukkolaskennan ja kustannuslaskennan työkalut ovat yleisessä käytössä. Uudet ohjelmaversiot ovat entistä monipuolisempia ja helppokäyttöisempiä tehoonsa ja ominaisuuksiinsa nähden. Internet-liittymät ovat tulleet osaksi em. ohjelmia. Ohjelmiin on tullut mukaan myös tärkeitä dokumenttien hallinta-, arkistointi- ja ryhmätyöominaisuuksia.

Projektinhallintaohjelmat luetaan kuuluvaksi tietoa käsitteleviin järjestelmiin. Projektinhallintajärjestelmät auttavat aikataulun suunnittelussa ja siinä pysymisessä. Projektien suunnittelun avulla tehostetaan resurssien käyttöä ja projektin ohjausta sekä voidaan vähentää riskejä. Riskianalyysin avulla järjestelmä näyttää etukäteen graafisesti ne paikat, jossa ohjausta tullaan tarvitsemaan. Hälytykset ohjaavat käyttäjää tekemään ohjaustoimenpiteitä ennen ongelmien syntymistä.

Mitä enemmän kaikki se työ, jonka tulee hoitua säännönmukaisesti, voidaan siirtää koneitten ja ohjelmistojen hoitoon, sitä enemmän ihmisillä vapautuu voimavaroja vaativampiin tehtäviin (Ståhle ja Grönroos 1999). Organisaation pitäisi pyrkiä varastoimaan tietoa tehokkaasti eri keinoin, sillä usein organisaation kriittisin tieto kävelee ulos työpäivän päätteeksi (Benbya et al. 2004).

Tietoa jakavat järjestelmät (kommunikointi)

Ståhlen (1999) mukaan tietotekniikka voi edistää verkostoitumista, koska se toimii henkilökohtaisen tiedonhallinnan välineenä. Mitä enemmän kontakteja ihmisellä on, sitä voimakkaammassa tiedon virrassa hän elää. Silloin hänellä on välttämättä oltava sellaisia välineitä, jotka eivät ainoastaan etsi hänelle tarvittavaa tietoa, vaan myös priorisoivat ja lajittelevat sitä hänen puolestaan.

Yhteistyö on merkittävä aspekti projektityöskentelyssä, ja on erityisen tärkeää kiinnittää huomiota erilaisiin tietoa jakaviin ja välittäviin järjestelmiin. Egbun ja Botterillin (2002) mukaan virtuaalisista tiimityöasemista on saatu hyviä kokemuksia. Työasemiin on liitetty videoneuvotteluvarustus, multimediaviestien lähetys- ja vastaanottomahdollisuus, jaetut piirtotaulut, dokumenttien skannausmahdollisuus, videoiden nauhoitusmahdollisuus, ryhmätyökalut ja web-selain. Nämä sovellukset ovat nykyisin jokaisen tietokoneen käyttäjän ulottuvilla esimerkiksi ilmaisen Messenger-ohjelman avulla. Kehittyneempiä versioita keskustelualustoista edustavat esimerkiksi useat verkko-oppimisalustat. Vaikka on ilmeistä, että nämä välineet toimivat eksplisiittisen eli koodatun ja kirjoitettavissa olevan tiedon välittäjänä, voidaan myös olettaa niiden lisäävän hiljaisen eli kokemuksesta syntyneen tiedon siirtymistä tarjoamalla keskustelualustan projektiryhmän jäsenille. Nämä tekniikat ovat yleistymässä, mutta toistaiseksi niiden käyttäminen rajoittuu enimmäkseen yrityksen sisälle eikä vielä eri yrityksistä tulevien projektiryhmän jäsenten välille.

Sähköposti on yleinen tiedonvaihdon ja dokumenttien välityksen väline. Useat suunnitelmat ja asiakirjat siirretään sähköpostiliitteenä yksityisesti tai ryhmäjakeluna. Etuja ovat työrauha ja automaattinen dokumenttien hallinta ja edullisuus. Sähköposti toimii myös lähiarkistona. Ongelmina tällä hetkellä ovat liiallinen sähköpostitulva, saantikuittausten puutteellisuus, tietosuoja, tietokonevirukset ja roskaposti.

Projektitietopankki on tavallaan sähköpostin seuraava vaihe: varasto, johon jokainen voi viedä ne tiedot, joita muut projektissa tarvitsevat ja josta voi hakea muiden tuottamia tietoja ajankohdasta riippumatta. Merkittäviä etuja verrattuna perinteiseen kopioiden lähettämiseen ovat nopeus, riippumattomuus kellonajasta tai viikonpäivästä sekä halvat kustannukset.

Elektroninen tiedonsiirto vähentää paperiin perustuvan tiedonsiirron tarvetta ja pienentää kopiointikustannuksia. Rakennuttajalla on mahdollisuus saada hankkeen kuluessa ajan tasalla olevaa tietoa suoraan omalta työpöydältään, esimerkiksi työmaapäiväkirjasta (mikä on työmaan tilanne juuri nyt), työmaakokousmuistioista ja katselmuksista (arkistossa viimeisin ja kaikki edelliset muistiot), hankinnoista (mitä valintoja urakoitsijat ovat tehneet). Kokouksiin perustuvaa tiedonvaihtoa tarvitaan vähemmän ja suunnitteluprosessi on nopeampi. Käyttäjille ja tilaajille projektin www-sivut tuovat tietoa hankkeen etenemisestä.

Tietoa kiteyttävät järjestelmät (älykkäät tietojärjestelmät)

Laudon ja Laudon (1996) luokittelevat tähän ryhmään kuuluvaksi johdon tietojärjestelmät ja tukijärjestelmät. Nämä ovat tietokoneperusteisia järjestelmiä, jotka tukevat johdon suorittamaa valvontaa ja päätöksentekoa tarjoamalla yhteenveto- ja poikkeamaraportteja. Korkeamman luokan järjestelmiin kuuluvat tukijärjestelmät ovat strategista tasoa tukevia järjestelmiä, jotka on suunniteltu tukemaan päätöksentekoa hyödyntämällä kehittynyttä grafiikkaa ja viestintäteknologiaa.

9.4 Tietotekniikan hyödyntämisen tekijät

Tietotekniikan hyödyntämiseen vaikuttavat yksilö-, organisaatio- ja yritysverkkotason tekijät. Rakennushankkeissa joka tasolla on suuri merkitys, sillä hankkeet toteutetaan lähes poikkeuksetta yritysverkossa. Tietotekniikan käytön esteitä on kirjallisuudessa luokiteltu seuraavasti:

1. Inhimilliset esteet: Rakennusalan ammattilaisten tietotekninen osaaminen ei ole riittävän hyvällä tasolla, lisäksi informaatiotulva estää tietotekniikan käyttämisen tahtoa (Samuelson 2002). Aikaisemmat epäonnistumiset aiheuttavat kyynistä ja epäilevää suhtautumista teknologiseen muutokseen (Markus 2003). Lisäksi tarvitaan johdon sitoutuminen sekä projekti- että yritystasoilla ICT-kehityshankkeisiin – ilman tätä sitoutumista harva ICT-hanke voi menestyä. Voidaan myös nähdä, että tietotekniikka saattaa vaikuttaa negatiivisesti työntekijöiden työnkuvaan – tai työntekijät ajattelevat sen vaikuttavan negatiivisesti (Engsbo 2003).
   Rakennusalan perinteisyyden ja vanhanaikaisuuden vuoksi monet uudistukset toteutuvat rakennusalalla hitaammin kuin muilla aloilla. Esimerkiksi tutkimustiedon leviäminen käytännön sovellutuksiin on erittäin hidasta, vähäinen loppukäyttäjien huomioonottaminen ja vähäiset IT-investoinnit ovat rakennusalalla arkipäivää (Anumba 1998).

2. Taloudelliset esteet: Strategiset tavoitteet eivät ole selvillä (Love 2004). Investointikustannukset ovat liian korkeat (Samuelson 2002), Verkottumisvaikutus ICT:n hyödyntämisessä ts. käyttäjät eivät ole kiinnostuneita tietotekniikan käytöstä, koska kaikki osapuolet eivät käytä järjestelmiä (Bansler ja Havn 2004, s 271, 272). Powellin (1992) mukaan IT-investointien kannattavuuden arvioinnin tekee vaikeaksi se seikka, että investoinnin hyötyjä on vaikea määritellä laskennallisesti niiden aineettoman luonteen vuoksi. Lisäksi tietotekniikan kehityksen nopeatempoisuuden vuoksi suurten investointien tekeminen on hankalaa. Tse et al. (2005) havaitsivat, että suurin syy olla käyttämättä uutta tekniikkaa oli arkkitehtitoimistoissa se, etteivät asiakkaat sitä vaatineet.

3. Tekniset esteet: Jatkuva laitteistojen ja ohjelmistojen päivitysten tarve on merkittävä este tietotekniikan käyttämiselle (Samuelson 2002). Lisäksi tietotekninen virallinen dokumentin hyväksyntä allekirjoituksen avulla ei ole vielä yleisesti käytössä. Toisaalta turvallisuus- ja yksityisyyssuojissa saattaa olla vielä aukkoja

4. Tieto- ja osaamisresurssit: Projektiverkossa ei ole tietoa, kuinka asiat voitaisiin järjestää. Tämän tiedon saaminen vaikuttaa liian hankalalta ja kalliilta, joten vaikka tietoa ehkä jossakin päin Suomea tai maailmaa olisi, ei sitä ole sen projektin käytössä.

Kuva 5. Tietotekniikan hyödyntämiseen vaikuttavat tekijät

Kuvaan 5 on kerätty tekijöitä, jotka vaikuttavat tietotekniikan hyödyntämiseen joko estävästi tai parantaen. Kuvassa on jaoteltu hyödyntämisen tekijät yksilö-, organisaatio- ja verkostotasoon. Kussakin tasossa vaikuttavat edellä kuvatut inhimilliset, taloudelliset, tekniset sekä tieto- ja osaamispääomatekijät. Yksilötasolla inhimilliset tekijät määrittävät motivaation ja muutosvastarinnan voimakkuuden- organisaatiotasolla vaikuttavat johtamiskulttuuri ja yhteiset asenteet uusiin asioihin – verkostotasolla vaikuttavat alan mielipidejohtajat ja valtarakenteet. Vain muutamassa yrityksessä kyetään yhteisten ponnistusten avulla toimimaan vahvojen mielipidevaikuttajien ajatusten vastaisesti ja siten uudistamaan eri tavalla toimintaa.

9.5 Haasteita

Peter Loven (2004) tutkimuksen mukaan työsuoritusten uusimisen tarve on yleinen ongelma Australian rakennusprojekteissa. Love on tutkimuksessaan todennut, että töiden parantelu ja uudestaan tekeminen aiheuttavat aikataulun ja kustannusten ylittymistä sekä perinteisissä urakkakohteissa että suunnittelun sisältäneissä urakkakohteissa. Hän mainitsee lukuisia esimerkkejä raporteista, jotka kertovat rakennusalan hajanaisuudesta, koordinoinnin ja kommunikoinnin puutteesta, asiakaslähtöisyyden unohtamisesta, pelkkiin hintoihin perustuvien valintojen tekemisestä ja puutteellisesta teknologian hyödyntämisestä. Suunnitelmien muuttuminen toteutuksen aikana on enemmän sääntö kuin poikkeus. Hän on luokitellut rakennusprojektin haasteet seuraavasti: suunnitelmien muutokset, rakentamisen muutokset, asiakas, suunnittelutiimi, työmaan johtaminen, alaurakoitsijat, projektin keskittyminen, sopimusasiakirjat, projektin kommunikaatio, hankintastrategia ja suunnittelun johtaminen.

Prolab-haastatteluissa esille tulleita haasteita

Käyttäjä

Käyttäjien edustajat pitivät suunnitteluvaihetta vaikeana prosessina. Nykyisiä ja tulevia tarpeita on hankala määritellä ja suunnitelmien ymmärtäminen on vaikeaa. Esimerkiksi käyttäjälle voidaan antaa eteen sähköpiirustukset, joiden tekninen esitystapa on maallikolle vieras. Ensin pitää selvittää ja opetella, mitä mikäkin merkintä tarkoittaa. Käyttäjä hämmentyy entistä enemmän, kun useat eri suunnittelijat esittelevät hänelle suunnitelmiaan ja pyytävät niistä kommentteja. Mallihuoneen todettiin helpottavan ymmärtämistä ja näyttävän konkreettisesti mistä on kysymys.

Suunnittelija

Useat suunnittelijat mainitsivat suunnitteluvaiheen puutteellisen aikatauluttamisen ongelmana. Suunnittelijat odottivat aikataulua, jota seurataan yhtä huolellisesti kuin rakennusvaiheen aikataulua. Usein jouduttiin pääsuunnittelijan piirustuksia odottamaan liian kauan, joten erikoissuunnitteluun käytettävissä oleva aika lyheni entisestään. Suunnittelun laadun katsottiin kärsivän, kun suunnittelijoita kilpailutetaan hinnalla. Hinta ei saisi olla suunnittelijan ainut valintaperuste. Kun suunnitteluvaiheessa tingitään, siitä seuraa ongelmia rakennusvaiheeseen. Isot muutokset rakentamisen loppuvaiheessa aiheuttavat paljon lisäsuunnittelun tarvetta erikoissuunnittelijoille. Ongelmana pidettiin sitoutumisen puutetta ja ymmärrystä suunnittelun luonteen muuttumisesta, joka edellyttää tiedon avointa jakamista kaikkien osapuolten välillä.

Rakennuttaja

Rakennuttajat arvostelivat suunnittelun huonoa laatua, minkä katsottiin aiheutuvan tarkistusvaiheen puuttumisesta. Rakennuttajalla ei ole aikaa paneutua riittävästi kaikkeen. Ennen suunnitelmat tarkistettiin suunnittelutoimistossa ennen niiden lähettämistä työmaalle. Suunnitelman tulisi olla niin paljon tietoa sisältävä, että myös asiaa tuntematon henkilö pystyy suunnitelmia tulkitsemaan. Hyvänä vaihtoehtona mainittiin yhteistyöhön tottuneen suunnittelijaryhmän käyttämistä. Toteutussuunnittelun johtamista pidettiin vaikeana ja haasteellisena tehtävänä.

Urakoitsija

Myös urakoitsijoiden kommenteissa mainittiin suunnittelun hinnan kilpailuttaminen, mikä johtaa suunnittelijoiden puutteellisiin resursseihin tehdä huolellisia suunnitelmia. Yleensä joudutaan tekemään mahdollisimman vähän piirustuksia. CAD-suunnitelmien katsottiin entisestään huonontuneen, vaikka menetelmän odotettiin parantavan suunnitelmien laatua. Suunnitelmia ei ole yhteensovitettu eri suunnittelijoiden kesken mitenkään. Suunnittelijoiden ja työmaan välisen kommunikoinnin puutteita myös mainittiin. Yhteydenpidon kerrottiin olevan puhelimen ja faxin varassa. Muutoksista aiheutuu paljon työtä ja päänvaivaa, jolloin kireä aikataulu aiheuttaa päällekkäisiä työvaiheita ja loppuvaiheessa työmaalla voi vallita täysi sekasorto. Laatujärjestelmän katsottiin aiheuttaneen hyvää ja huonoa, kuten lisääntynyttä paperityön määrää. Kunnollisen tiedonvaihdon vaatimuksina pidettiin ihmisten kohtaamista, tiedonvaihdosta jäävää dokumenttia ja havainnollisuutta. Kohteissa, joissa rakennusliike on osallistunut suunnitteluun ja siihen käytettiin riittävästi aikaa, ei ole ollut toteutusaikana ongelmia.

Mihin haasteisiin tietotekniikka on vastaus

Rakennusprosessin kehittämisen haasteisiin voidaan vastata tietotekniikan avulla:

- § Suunnitelmien muutokset
  - o suunnitteluprosessia kehittämällä. Suunnittelijat suunnittelevat rakennuksen tuotemallin yhteistyössä. Suunnittelun koordinointi paranee.
- § Urakoitsijan tekemät muutokset
  - o rakennettavuusanalyyseilla. 4D-suunnittelu mahdollistaa tuotantovaiheen simuloinnin suunnittelijan ja urakoitsijan yhteistyönä.
- § Asiakkaasta johtuvat muutokset
  - o asiakaslähtöisyyden lisäämisellä. Tuotemallin käyttäminen visualisointeineen helpottaa asiakastarpeiden määrittelemistä, tuotemalli mahdollistaa myös rakennuksen elinkaarikustannusten optimoinnin.
- § Suunnittelijoiden ja työmaan välinen yhteistyö

- o kommunikaatiota lisäämällä. Videoneuvottelutekniikoiden käyttäminen suunnittelu- ja rakentamisvaiheessa mahdollistaa nopean tietojenvaihdon, mikä vaatisi usean osapuolen matkustamista kokoukseen.

§ Alaurakoitsijat ja työmaan johto

- o projektin reaaliaikaisuutta lisäämällä. Projektipankin käyttö, kaikilla osapuolilla on kaikki ajan tasalla olevat dokumentit saatavilla mihin vuorokauden aikaan tahansa. Tiedon lukemisesta jää jälki.

§ Hankintatoimi

- o sähköisellä hankintatoimella. Määräluettelot saadaan tuotemallista automaattisesti ja virheettömästi, tuoteluettelot ja nimikkeet löytyvät internetistä, hankintajärjestelmissä ovat valmiit toimittajatiedot ja tiedot aikaisemmista hankinnoista hintoineen.

§ Kokemuspankki

- o ohjausjärjestelmiä kehittämällä. Voidaan tallentaa hyviä käytäntöjä, työohjeistusta, työturvallisuutta edistäviä ” läheltäpiti”- tarinoita, projektien loppukeskustelut ja muita kokemuksia. Edellyttää avoimuutta ja halua kertoa omista kokemuksista. Sisäinen kilpailu voi estää, koska halutaan olla yritykselle ” korvaamattomia” .

§ Rakentamisen maine

- o julkisen rakentamisen esimerkillisyyttä parantamalla. Kun ammattirakennuttajat pätevöityvät näiden menetelmien käytössä, pienet ja kertarakennuttajat seuraavat esimerkkiä.

9.5 Loppupäätelmät

Kehittämismentelmiä

Tietotekniset välineet
Kaikki tietotekniset välineet, jotka tukevat ja helpottavat ihmisten välistä vuorovaikutusta, on syytä ottaa käyttöön. Vaikka orgaanisen toimintaympäristön tieto on pääasiallisesti piilevää ja kokemuksellista, se välittyy helpoimmin puhumalla ja toimimalla yhdessä. Tietotekniikka voi kuitenkin helpottaa kommunikaation ylläpitoa ja sujuvuutta (Ståhle & Grönroos 1999).

Tuotemallit (BIM)
Tuotemallin saavutukset alkavat olla selvästi nähtävissä: tuotemalliin perustuva määrälaskenta on yleistynyt, suunnitelmista on saatu havainnollisempia ja niiden tarkastaminen on mutkattomampaa. Ennen kaikkea tuotemallintamisesta on tullut laajasti tunnettu toimintata-

pa, jonka tulevaisuutta harva enää kyseenalaistaa. Nyt ollaan vaiheessa, jossa työn tulokset ollaan ottamassa kattavasti käyttöön. Tätä helpottavat paitsi suunnitteluohjeet ja tuotekirjastot, myös erityisesti rakenne- ja taloteknisen suunnittelun nopeasti kehittyneet ohjelmistot. Nykyiset ohjelmistot tekevät mahdolliseksi esimerkiksi törmäystarkastelut, määräluetteloiden tulostamisen tuotemallista, aikataulusuunnittelun ja visualisoinnin.

Tavoitteena on luoda laaja eri materiaaliryhmien tavanomaisimmat rakenneratkaisut kattava kokonaisuus, joka on aina ajan tasalla ja helposti käytettävissä. Kirjastojen käyttöä tuetaan parantamalla myös mallintamisohjeita arkkitehti-, rakenne- ja taloteknisessä suunnittelussa. Pro IT -tuoterakenteita aletaan julkaista osana RT-kortistoa vuoden 2006 alkupuolella. (Pro IT 2005.)

Sähköinen liiketoiminta

Internet-kaupankäynti tapahtuu www-kauppapalvelinsovellusten avulla, joilla kustannukset ovat pienemmät kuin vanhaksi käyneissä EDI-järjestelmissä (Electronic Data Interchange). EDI on tapa välittää tietoa sähköisesti. Suomeksi EDI:stä käytetään nimeä OVT eli organisaatioiden välinen tiedonsiirto. Tuoteinfo-, linkitys- ja tukipalveluominaisuudet ovat myös kehittyneet ja maksuliikenne voidaan hoitaa reaaliaikaisesti. Internet tulee antamaan erinomaiset mahdollisuudet urakka- ja tarjouspyyntömenettelyille sekä tuoteosakaupalle. Internetin kautta voidaan järjestää myös tehokkaita kuljetusten logistisia järjestelmiä, jotka luovat tulevaisuudessa rakennustuotekaupallekin uudet ulottuvuudet. Maksuliikenteen turvallisuus Internetissä on jo pääosiltaan ratkaistu luottokorttiyhtiöiden Suomessakin hyväksymällä tavalla maailmanlaajuisesti.

Rakennusalan liiketoiminta

Liiketoiminnan mallit rakennuttamis- ja suunnitteluprosesseissa muuttuvat perusteellisesti Internetin toimiessa siltana rakennuttamisen, suunnittelun, urakoinnin ja käyttäjän välillä. Uusien kilpailuvalttien löytäminen ja "vaativan asiakkaan malli" niin Suomessa kuin kansainvälisestikin tulevat pakottamaan uuden tekniikan käyttöönottoon. Tietoturva esitetään usein kriittisenä tekijänä internetin käytössä. Voidaan kysyä myös, ovatko perinteiset kopiointi-, lähetys- ja arkistointitavat riskittömiä tai mitkä tiedot todellisuudessa ovat salauksen tarpeessa.

Yhteisten pelisääntöjen tarve (RAKLI, 1998)

Rakennusalan eri osapuolien ohjelmistot poikkeavat toisistaan ja tiedon standardoitu esittämistapa on vielä kehitystilassa. Standardien puuttuminen vaikeuttaa tiedon yhteiskäyttöisyyttä. Myös menettelytavat ovat vielä kehitystilassa. Jotta hankkeessa toimittaisiin kuitenkin alusta lähtien mahdollisimman yhtenäisesti ja rutiininomaisesti, tulisi hankkeessa noudatettavista toimintatavoista sopia jo ennen suunnittelutyön aloittamista. Näin saadaan suurin hyöty projektin tietokeskuksesta ja vältytään turhalta työltä ja muutoksilta yhteensopivuusongelmien vuoksi. Kaikkien hankkeessa mukana olevien osapuolien tulisi olla mukana sopimassa pelisääntöjä.

Tietotekniikan mukaantulo rakennushankkeen suunnitteluun, määrälaskentaan, kustannustenhallintaan, rakennuttamiseen ja myös työmaan hoitoon, antaa uusia mahdollisuuksia hallita rakennushanketta. Toisaalta se on myös uhka, mikäli osapuolet eivät hallitse käyttämiään ohjelmia, eikä projektin läpiviemisestä ei ole selkeitä ohjeita. Integroidun suunnittelun ja toteutuksen laatuohje on välttämättömyys rakennushankkeen ohjauksessa. Rakennuttaja tai muu rakennushanketta johtavan taho huolehtii, että suunnittelu ja myöhemmin rakentaminen etenevät sovitulla tavalla ja asetettujen laatu- ja aikatavoitteiden mukaisesti. Hankkeen johtajalla on käytettävissään seuraavat välineet ja keinot hankkeen menettelytapojen kirjaamiseen ja tietovirtojen ohjaamiseen:

- suunnitteluaikataulu
- IT-organisaatio
- CAD-integraatio-ohje
- projektin tietokeskusohje
- sovittu piirustusten tulostus- ja jakelukäytäntö
- sovittu muutoskäytäntö
- työmaan piirustustarveluettelo.

Tiedonhallintaa pitää kehittää koko rakentamisen ketjussa siten, että kerran tuotettu tieto on hyödynnettävissä koko prosessissa. Rakennuttamisen ja koko rakennushankkeen kannalta on erittäin tärkeää, että hankkeen kaikki osapuolet hallitsevat hyvin oman osansa prosessista. Tietoteknisessä toteutuksessa tämä on erittäin tärkeää, sillä jos yksikin lenkki tietovirran tuottamisessa on heikko, koko ketjun toiminta häiriintyy. Rakennushankkeelle olisi eduksi, mikäli osapuolet tuntisivat toistensa toimintatavat ja integroitu projektityöskentely olisi osapuolille tuttua.

Lähteet

Benbya, H., Passiante, G. & Belbaly, N. A. (2004). Corporate portal: a tool for knowledge management synchronisation. International Journal of Information Management.

Davenport, T.H. and Prusak, L. (1998) Working Knowledge. Boston, Harvard Business School Press

Egbu, C O, Botterill, K (2002), Information Technologies for knowledge management: Their usage and effectiveness, (Abdul Samad Kazi ed) ITCon. Viitattu 7.3.2005, http://www.itcon.org/2002/8 .

Kashiwagi D, Savicky J, Sullivan K, Kovel J, Greenwood D, Egbu C. (*2005)* Is Performance Based Procurement a Solution to Construction Performance? in Kazi S (ed.) *Systemic Innovation in the Management of Construction Projects and Processes.* VTT. Finland, pg. 172-183

Laudon, J and Laudon, K. (1998), Management Information Systems, 5th ed.: New Approaches to Organization and Technology, Prentice Hall

Love, P.E.D. and Irani, Z.(2004). A Rework Reduction Model for Construction Projects. IEEE Transactions on Engineering Management, Vol. 51, No. 4, November 2004.

Karstila, K., IFC:n tilanne ja tuotetiedon elinkaaren hallinnan prosessi, ProIT Kick-off seminaari 23.9.2002. Viitattu 12.8.2005. http://www.vtt.fi/rte/cmp/projects/proit/seminaari020923dipoli/proit_seminaari020923esitys_eurostep.pdf

Rakennusteollisuus RT ry:n Pro IT – kehityshanke. Viitattu 24.4.2005, http://www.vtt.fi/rte/cmp/projects/proit/

Sulankivi, K, Nykänen, V, Koskela L, Teriö, O. Rakentamisprosessin nykytila: Nykyinen suunnittelu-rakentamisprosessi – Lähtötilannekuvaus tuotemalliteknologiaa hyödyntävälle prosessille. VTT Rakennus- ja yhdyskuntatekniikka. Espoo 2002.

Ståhle, Pirjo, Grönroos Mauri (1999) Knowledge Management – tietopääoma yrityksen kilpailutekijänä, Helsinki, WSOY

Suomen toimitila- ja rakennuttajaliitto RAKLI ry (1998), Tilaajatoiminnan ohjeistus ja tiedonhallinnan menetelmäkehitys ATK:n hyötykäytön tehostamiseksi kiinteistöalalla, Viitattu 7.3.2005, http://www.rakli.fi/TDM/projekti.htm

Tse T K, Wong K A and Wong K F (2005), The utilisation of building information models in nD modelling: A study of data interfacing and adoption barriers, ITcon Vol. 10, Special Issue From 3D to nD modelling , pg. 85-110, http://www.itcon.org/2005/8

LEARNING SUPPORT OF ICTs IN CONSTRUCTION PROJECTS – CASE STUDY APPROACH

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ABSTRACT

All people working in construction business have been involved in such projects where costs have exceeded the budget enormously, where timetable has been drawn out causing disadvantages for the project, and where the end results proved to be useless or even unhealthy for people. The knowledge management in construction projects fails and there is no commitment to improve the process by giving the lessons learned available to be applied in future projects.

The aim of this paper is to study what kind of learning is required in public construction projects and how the Information and Communication Technologies (ICTs) currently support the learning. We study how the ICTs in optimum case could support the learning. Our paper is a qualitative research study looking into the issues of learning among existing construction team members. The work is based on four case studies in public construction projects in Finland in three different towns and on literature review. The cases revealed that though ICT is used in the processes it could be used more effectively in assisting the learning of the parties and in confirming that the required learning has occurred. Now the tools help to visualize and distribute the knowledge but there are no tools that check the reaction of the reader or obtain any feedback how well a person has learned and applied it to a business problem.

1. INTRODUCTION

Construction professionals are working in complex and heterogeneous networks that consist of humans and various artifacts. Actually, the design process of a new building is a learning process where the parties learn from each other. For example, the architects learn from the representatives of the users how the building shall be used, and the users learn from the professionals of the construction industry how the building can support their operations. The site personnel learn how the designers plan the building should be built. The site personnel and the designers have realized the benefits of recognizing the best practices and lessons learned of the previous projects. The teams could avoid working continuously on similar kinds of problems in the future by using the knowledge of the past projects.

Using the knowledge of past projects require changes in the organizational level. In the organizational level Nonaka and Takeuchi (1995) have investigated the relationship between tacit knowledge and explicit knowledge and have described four phases of knowledge conversion (1) externalization: from tacit to explicit, (2) combination: from explicit to explicit, (3) internalization: from explicit to tacit and (4) socialization: from tacit to tacit. Woelk and Agarwal (2002) suggest that there are the fifth and the sixth phase as well. The fifth is (5) cognition: applying tacit knowledge to a business problem. It means how people can be provided with performance support by getting just the training that they need at the time that they need it to complete a business task. The sixth is (6) feedback: concerning how well a person has learned and applied it to a business problem.

The evaluation of the cognition and the feedback concerning how well a person has learned and applied it to a business problem are quite complex tasks like the evaluation of knowledge and knowledge management. Davenport and Prusak (1998) addressed the evaluation of the knowledge by the decisions or actions to which it leads. Better knowledge can lead, for example, to more efficient product development and production. Knowledge is aware of what it doesn’ t know.Since what you don’ t know can hurt you, this awareness is important.

The second way of quantifying the economic returns of knowledge management according Davenport et al.(1997) have defined some indicators of success to evaluate the projects they have explored. In interviewing the managers of knowledge projects, they didn’ t ask if they felt their projects were successful. They did, however, ask about the indicators of success described below. The presence or absence of these indicators allowed them to differentiate clearly successful projects from those that were not successful, i.e., likely to fail or not *yet* showing signs of success. The indicators they used included:

- growth in the resources attached to the project
- growth in the volume of knowledge content and usage
- some evidence of financial return
- the likelihood that the project would survive without the support of a particular individual or two, I. e. the project is an organizational initiative, not an individual project

According Shelbourn et al. (2006) experiences have shown difficulties in capturing, storing, sharing and re-using all the information and knowledge relating to and arising from a construction project. There are no mechanisms or processes to foster the social interaction required to give any shape or form to it. Lindvall et al. (2002) discovered the situation in software organizations like the need of knowing 'who knows what', the need for distance collaboration, and the need for lessons learned and best practices. This has led to a growing call for knowledge management (KM). Knowledge sharing and organizational learning can happen ad-hoc. It is, however, more efficient if organized. The amount of information and knowledge and the dynamic evolution of information make the use of software tools not an option, but a necessity.

If wisely used ICTs may have an important role in answering these challenges. From the viewpoint of cognitive science, it is narrow-minded to understand learning as a process of delivering information and material to people by the means of ICTs or other ways. This assumption greatly oversimplifies and distorts both the concept of knowledge and concept of learning.

The aim of this paper is to study how the Information and Communication Technologies (ICTs) currently support the learning in public construction projects. We study what kind of learning is required and how ICT supports it and in optimum case could support the learning. The paper presents the used research method, how learning is supported by ICT in the cases and in theory. The cases revealed that though ICT is used in the processes it could be used more effectively in assisting learning of the parties and in confirming that the required learning has occurred.

2. METHOD

Our paper is a qualitative research study looking into the issues of learning among existing construction team members in order to identify the need to learn and how ICT is used to aid learning. The work is based four case studies in public construction projects in Finland in three different towns and on literature review. The inhabitants in these towns vary between 23 000 to 185 000. The four construction projects we have been studying were:

- Renovation of a school that had mould problems, total area 7000 m^2 and budget of 4 Million euros. Project started 1997 and ended 2002.
- Renovation and partly new construction of a school that had mould problems, total area 3000 m2 and budget 2.7 Million euros. Project started 1998 and ended 2005.
- Hospital for senior citizens, the renovation of the nursing home, total area 7 000 m2 and budget 5.7 Million euros. Project started 1996 and is still on-going.
- University project, 24 000 m². Alteration of an old factory into a university and partly new construction. The project started 1997 and finished at 2004.

We used theme interviews as a means to collect information but we have also collected artefacts of the projects like drawings, memos, and observed the meetings in two projects. We had action research in two towns – there we discussed new ways of organizing the knowledge management in the construction projects. This action research ended with the first town in 2005 and with the other town in 2006. This paper describes learning needs and ICT support on learning that we have identified among the four case studies.

3. EXPERIENCES AND CHALLENGES IN CASE PROJECTS

End user

The major challenge in the case project was that in the building projects there were people to whom the project is once in the lifetime project. These people had no background knowledge and they needed to learn what kind of information they need to deliver to the professionals also the professionals need to learn from them.

> *"End user 1: All the technical drawings were discussed in one meeting and I felt very confused because I didn't understand the technical conduits in their design papers. It was difficult to check if the plans are good enough and if the rooms and spaces will fulfil our future needs."*

Project manager

The project managers frequently talked about losing the goal of the design and how they did not manage the design process well enough. Also they could tell that document management was not done as well as it could be. The checking of the solutions should be made properly – the designers couldn't see their own mistakes. The project managers also told about the difficulties they had in producing working drawings since the changes were realised at the very last moment in the requirements.

> *"Project Manager 1: Though CAD-systems should improve the quality of the design it appears that the quality has became even poorer than before. There are too much things, dimensions and texts in the drawings so that they are not readable anymore. The CAD-systems influence also that only one person in design office makes the drawings and no others*

check if the drawings are understandable like it was before when they had a designer making the drafts and another person who made the final drawings. Design schedules are so challenging that it is impossible to give end users enough time to comment on the solutions and the professionals to double check the solutions."

Designer

The designers said that they had to wait too long for the final plans of the main designer. They longed for a controlled timetable for design. Also competition on price was found to be a reason for poor design quality. The designers also talked about the reasons for changes:

- special designers don't always understand the needs of the end user.
- end users change their minds
- designers don't always understand each other
- solutions are not introduced properly for end users.

"*Designer 1: The schedule was so tight that we had no chance to check the compatibility of the solutions of different designers."*

" Designer 2: They may make on last week big changes for example tubs and basins can be moved to another room and two rooms can be mirrored. The project consultants don't even understand the big amount of extra work it makes for designers."

Site personnel

The contractors found out that the design quality was not good enough – when the work starts there are a lot of details lacking. The site mangers wanted a better relationship with the designers. They explained if they could be involved during the design process there would be less mess during construction. It will also minimize the constructability problems. Quality systems require documents of many situations but many site managers think it is pure bureaucracy and partly the benefits are not visible from the process point of view.

" Site Manager 1: The men and the materials are waiting on site and there are no drawings how to construct. Often we need to decide on site how to solve problems for example to get big air-condition machines inside to an old building. It causes a catastrophe and a lot of extra costs if we open roofs and walls afterwards for machine installations. Such things should be planned by designers beforehand and not suddenly at site. And the schedule problems are the worst of all."

" Site Manager 2: There was nobody controlling the design phase, which is the simple reason for the problems. Nobody was skilled enough and nobody had time to control the design. The checking task is not easy; it means demanding the relevant plans on time and checking their constructability. Nowadays the plans are still under preparation though the building should be ready in a short time."

" Site Manager 3: We should never accept " a faxed plan" (a temporary drawing which is sent by fax). If we, however, accept them, the changes should be always added into the official drawings. Now we have even about five folders full of faxed plans. It is too difficult then to find the up-to-date information and to remember which drawings are changed by faxed plans."

What kind of ICT tools were used in Case projects?

In the case projects there were CAD-software, emails, project management systems, office automation systems like word processing and spreadsheets and in some projects project databank and web based procurement systems. The cost estimates were created by computer software and all the companies used computer based accounting systems, some of the contractors used web based invoicing system. In one renovation project there was a laser based measuring system. The biggest contractors have the Enterprise Resource Planning – systems (ERP). Video conferencing systems were used in one case project.

How they supported learning

The current computer systems are not yet utilized so effective that they support the learning as effectively as one would wish to. The ICTs support learning in visualizing the plans by 3D models or simulations but also they are presented in face to face discussions. The modelling and product modelling were not yet common tools in our case projects. The email system works well for communication and for archives files. The project databank improves the efficiency of the project because there are always the newest drawings on hand and as well as all the information of the designers and subcontractors and other people involved in the project. Only one of the case projects had a project databank in use. The project management system contains all the decisions made in the project and the history and the main things of the project can be used to another similar project. There can be descriptions of the tasks, best practices and even dangerous situations which can be used and avoided in future projects.

Video conferencing was used only in one of the projects we discovered. But however the wireless computers or phones could improve the efficiency of a field based workers such as the site personnel with access to information (audio, video or data) they require. They can have video conferences with office based experts or colleagues, to obtain advice or provide such advice.

Artefacts

Project based work uses both material and conceptual artefacts. Construction project workers use design documents, time-tables, cost estimates and other secondary artefacts to help the thinking and to carry the knowledge to other parties. All the design documents, even the 3D models, are secondary artefacts. There were also found tertiary artefacts: the model room, the space definition cards. These were created in order to help people to test the theories before realization. In the project there were several primary artefacts like phones, computers, etc. that make the working more efficient and effective.

Lonka (2005) found a correlation between the possible success of the project and the quality of artefacts in a project. The creation of artefacts is strongly related to the project success. The better quality of conceptual artefacts made the project a better project. One should look for the problems first and then look for the solutions, not vice versa. Processing at the level of theories is necessary condition for project success.

Challenges

- The end-users of the buildings need more visual presentations of the designed building. They have no experience to determine how many square-meters they need space for their activities. They need to learn everything what is needed in construction project. 3D-modeling of the future building is one possible solution to this problem.
- The site personnel are concerned about things they have not noticed and which are written only in someone' s private papers. Project Intranets and other document management systems could eliminate this problem. It would enable to immediate access to the tender documents, the latest version of the document like drawings and other design documents.
- Well-known are the jargon problems where people of different branch don' t understand each others but even two specialists speaking on the phone are not always able to understand others meaning if they don' t know each other personally. Communication during more visual device like desktop video conferencing and phones, web-cameras and video-cameras could help in those situations.
- The designers of the projects emphasize the commitment and trust between members in construction projects. Experienced designers are able to know what kind of information there is needed but sharing the information is not clear because of, for example, tight competition of prices when selecting designers for the project.
- The constructability problems are common in our interviews. By means of 3D-modelling and model-checker software it is possible to check the compatibility of different designs and by means of 4D-modelling to check and optimize the schedule of installations on site.

4. KNOWLEDGE AND LEARNING IN ORGANIZATIONS

A central aspect of collaborative knowledge building is to create shared knowledge objects, such as ideas, building designs or functional plans, engage an intensive synchronous and asynchronous interaction among the participants for further developing and building on them, and to re-use the emerging knowledge later on for solving new problems or reflecting on the process. An important issue is to know who knows what but according to Huber (1991) organization often do not know what they know. The dissemination of information or knowledge in an organization is prevented due to several reasons. Based on literature Huber (1991) presents following statements of dissemination of information in the organization:

A. The probability that organizational member or unit A will route information to member or unit B is:

1. positively related to A's view of the information's relevance to B,
2. positively related to B's power and status,
3. negatively related to A's view of A's costs of routing the information to B,
4. negatively related to A's workload,
5. positively related to the rewards and negatively related to penalties that A expects to result from the routing, and
6. positively related to the frequency with which A has previously routed information to B in the recent past.

B. The probability or extent of delay in the routing of information by A to B is:

1. positively related to A's workload,
2. positively related to the number of sequential links in the communication chain connecting A to B, and
3. negatively related to A's view of the timeliness of the information for B.

C. The probability or extent of information distortion by A when communicating to B is:

1. positively related to A's view of the consequent increase in A's goal attainment that will result from the distortion,
2. negatively related to the penalty that A expects to incur as a result of introducing the distortion,
3. positively related to the amount of discretion allowed in the presentation format,
4. positively related to the difference between the actual information and the desired or expected information,
5. positively related to A's work overload, and
6. positively related to the number of sequential links in the communication chain connecting A with B.

The dissemination of information is very important in a construction project. It is important to understand importance of rewarding in time delivery and the work overload of people. Also we should pay attention to how easy it is to deliver the relevant information to every party.

Knowledge creation does not happen only by working with pure knowledge but working with different types of artefacts. According to Wartofsky (1979), *primary artefacts* are tools and practices directly used in human labor and other activities (like knife or telephone).

Secondary artefacts are "symbolic externalizations" or "objectifications" of primary artefacts and used in transmission of the acquired skills and modes of action (e.g. drawing or other working documents). He distinguished, further, *tertiary artefacts* that are derived and abstracted from secondary artefacts and which are relatively independent of on-going praxis and provide a basis of creating visions and foreseeing changes and transformed future states of affairs (theories how things are in general). It is plausible to assume that these artefacts are transformed to each other in a sustained process of building knowledge.

Bateson's (1978) has defined that there are three levels in any communicative system. At the first level are straightforward 'fact' statements (verify to the primary artifacts). A discontinuous shift in context occurs at the second level. 'There is a gulf between context and message (or between metamessage and message) which is of the same nature as the gulf between a thing and the word or sign which stands for it, or between the members of a class and the name of the class.' At the third level, the gulf appears in evaluating the context itself Star and Ruhleder (1996) give the following examples of these levels: "Level one statements appear in their study: 'Unix may be used to run the software'. These statements are of a different character than a level two statement such as 'A system developer may say Unix can be used here, but they don't understand our support situation'. At the third level, the context widens to include theories of technical culture: 'Unix users are evil – we are Mac people'" Bateson (1978) found out that people often talk in different levels and then their talk may be misunderstood and the communicators do not meet each other. In our case studies the end-users prefer to talk about the facts and their theories of using the building and the construction professionals about the constructability issues often in the level two using the design drawings. The collaboration is so seldom very effective since the level of conversation is different.

Shared working supported by collaborative technology facilitates working with secondary and tertiary artefacts. 'Collaborative technology' refers to groupware and network environments as well as associated teamwork methods that allow the participants to produce knowledge to a shared working space. This kind of technology enables the users to rely on socially distributed intellectual resources embedded in the workplace community while conducting various kinds of projects (Hakkarainen et al. 2001). These kinds of environments are critically important because not only scientific communities but also modern knowledge-intensive construction companies are focused on systematic work for creating new knowledge. Huysman (2000) discusses the four learning biases within the organizational learning literature. These biases can be defined by the following questions related to learning: who, how, when and why. The individual learning bias (who) defines if the learning is done by an individual or by an organization. The active agency bias (how) explains if learning is voluntary or determined. Purposeful learning bias (when) handles the issue whether the learning is purposeful or accidental. Huysman states that the general view towards organizational learning is that learning is purposeful. The improvement bias (why) refers to the tendency to perceive learning as resulting in positively valued outcomes, treating other outcomes of the same process as less or even not relevant.

According to the questionnaire the participants of a construction project of a school claimed that they had learnt several things during the design of the school (Haapalainen & Naaranoja 2005). First, they had learned the importance of communication and understanding other parties in the project. Some participants felt that they had learnt about project work and project management in general and the third group of answers was related to learning about concrete issues related to construction and school work. It is likely that all the learning could be made more purposeful and the ICT tools could help in this. (Haapalainen & Naaranoja 2005)

It is the common experience of all construction industry professionals that problems are resolved in one project or a new solution developed, but that these lessons are not learned. Too often the same problem recurs in another project because nothing has been done to eliminate the cause of the problem and, because the team is different, the issue is again dealt with from scratch. A commitment to a continuous improvement process should mean, at best, that the problem does not occur more than once, but at least that the lessons learned from overcoming it the first time are available to be applied in future. Similarly it means that successes and innovations that are developed in one environment need to be available to be used on other projects. (Orange, Cushman & Burke 1999.)

5. ICT SUPPORT ON KNOWLEDGE MANAGEMENT

Figure 1 shows layered knowledge management system architecture based on Lawton, (Lindvall, Rus & Sinha 2003). It is made for a software organization but there are many similarities to apply it in construction project. KM services provide tools for data and knowledge discovery and collaboration services. Through portals, knowledge can be distributed to different users and applications, such as e-learning, competence management, intellectual property management, and customer relationship management.

Document Management

In terms of knowledge management, the documents produced by organizations represent their explicit documented knowledge. Common needs in construction project are related to identifying the latest version of the document like drawings and other design documents. Document management systems can aid learning

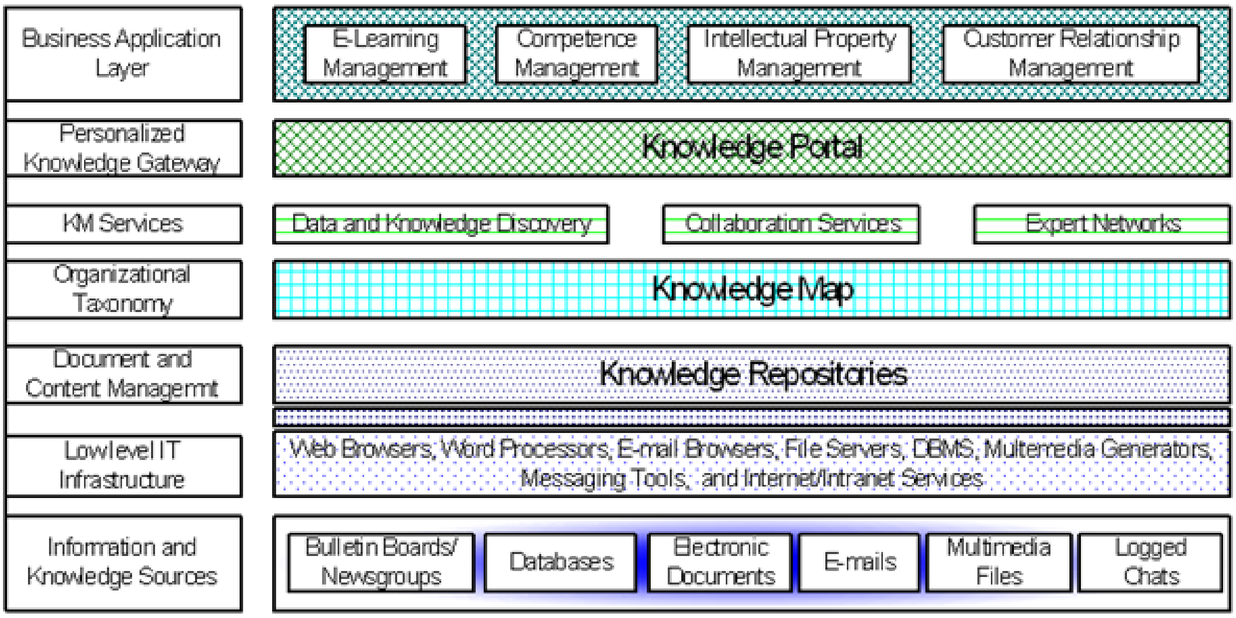

Figure1. *KM architecture model based on Lawton (Lindvall et al. 2002)*

organizations that need to capture and share process and product knowledge. Most artefacts guiding a project and being developed during a project can be represented as documents and are the main explicit assets of the organization and can enable transferring knowledge from experts to novices. It should also be clear that it is not enough to simply create more and more data on computer systems. This data needs to be accessed and evaluated, critiqued and used. Organizations are identifiable by the way people develop their own skilful practices drawing on and sharing data and information resources (Lindvall et al. 2002).

Collaboration Services

Delivering the right information at the right time is one of the major objectives of knowledge management. To achieve this, employees need to collaborate and communicate, especially when people work in an environment that is distributed in time and space. A common practice is to use a tool to share a document in real-time so that two or more geographically distributed groups can see and hear the same presentation. In construction projects the role of knowledge management and communication is particularly important since the participants come from many companies and have quite diverse backgrounds.

Current research on distributed knowledge processes suggests a critical conflict between knowledge processes in groups and the technologies built to support those (Kanfer et al. 2000). Authentic and efficient knowledge creation and sharing is deeply embedded in an interpersonal face to face context (Kanfer et al. 2000, Naaranoja et al. 2005), but ICT technologies to support distributed knowledge processes rely on the assumption that knowledge can be created mobile outside these specific contexts.

Knowledge Portals

Lindvall et al. (2002) found a study that people in software organizations like other organizations spent 40% of their time in searching for different types of information related to their projects. It can be assumed that the time is big enough even in construction organizations. For example designers and the project managers use many different computer-based information sources. These information sources need to be integrated and accessed through a common and personalized interface. Portals create a customized single gateway to a wide and heterogeneous collection of data, information, and knowledge. The items that are typically included in the portals consist of business intelligence, content and document management, enterprise resource planning systems, data warehouses, data-management applications, search and retrieval of information. A portal is the next evolutionary step in the use of web browsers (Uden & Naaranoja 2006).

E-learning

Knowledge management aims to help people acquire new knowledge, as well as package and deliver existing knowledge through conscious learning. E-learning is a relatively new area that includes computer-based and on-line training tools. E-learning systems often include collaboration tools and support for different types of content, i.e., video, audio, documents etc. Knowledge could be delivered through a variety of presentation devices including web browsers, PDA' s and cell phones. This enables the project person to receive the knowledge when it is needed regardless of where they are and what they are doing. E-learning will be delivered as small, focused learning objects to fit the format of the presentation devices (Woelk & Agarwal 2002.) This technology could aid the learning in construction projects also.

E-learning offers many kind of advantages for learning which are different from other ways of learning. A wave of empirical research has revealed a long list of the promises and reported benefits of computer networks for collaboration (Hakkarainen et al. 2001). One self-evident benefit is, that computer networks break down the time and space constraints. And the delay of asynchronous communication allows time for reflection in interaction. Making thinking visible by writing should help students to reflect on their own and others' ideas and share their expertise. Shared discourse spaces and distributed interaction can offer many perspectives. Further, the database can function as a collective memory for a learning community, storing the history of knowledge construction processes for revisions and future use.

It is important to build a culture of learning where learning is perceived and used as a natural piece of one' s job. An effective knowledge management system not only provides a vehicle to share information, but also builds a community of learners. The employee can use their computer to view company policies, access forms, distribute information among colleagues, share stories, access expertise of respected sages, trouble shoot, gain up-to-the-minute advice, teach, coach, and customize one' s training needs. A successful strategy involves developing a receptive culture toward e-learning and technology, getting key players on board, communicating its value, and leading through the change. (Rosenberg 2001.)

Knowledge Map

People with experience and expertise are vital information sources in organizations. The knowledge management services have to provide access to information about knowledgeable experts in the organization. Information about knowledgeable human sources has to be collected and updated in a systematic manner. One of the best methods of accomplishing this is for employees themselves to maintain their CVs online. Human resources and other functional departments in the organization may also be able to supply current information about training courses, conferences, assignments, and projects. (Choo 2000.)

6. CONCLUSIONS

The cases revealed that though ICT is used in the processes it could be used more effectively in assisting the learning of the parties and in confirming that the required learning has occurred. Now the tools help to visualize and distribute the knowledge but there are no tools that check the reaction of the reader or any questions to the reader. The evaluation of the knowledge and the knowledge management is difficult. Davenport and Prusak (1998) addressed the evaluation of the knowledge by the decisions or actions to which it leads. Better knowledge can lead, for example, to more efficient product development and production. Knowledge is aware of what it doesn' t know. Since what you don' t know can hurt you, this awareness is important.

ICT is good technical mean when sharing knowledge in organization but without trust, support of the top-management and active interaction between members even good techniques are useless. ICT supports the production of high quality artefacts. When the artefacts are linked to the success of the project the better quality artefacts improve the project success.

One of the future researches is to study how much the conscious learning support can improve the communication in the construction project, for example, how e-learning methods can be utilized.

REFERENCES

Bateson G. (1978), Steps to an ecology of mind, Ballantine Books, New York.

Choo, C., W., (2000) Working With Knowledge: How Information Professionals Help Organizations Manage What They Know. Article published in Library Management 2000 Vol. 21 No. 8.

Davenport, T H, Prusak L (1998) Working Knowledge – How Organizations Mange What They Know. Harvard Business School Press, 1998, 187 (199) pages

Haapalainen, P. & Naaranoja, M. (2005). Making an Inter-organizational Team more Effective – Case Public Construction

Hakkarainen, K. & Lipponen, L. Muukkonen, H., & Seitamaa-Hakkarainen, P. (2001) Teknologian tukemien oppimisympäristöjen kognitiivinen tutkimus. Teoksessa P. Saariluoma, M. Kamppinen, & A. Hautamäki, (toim.) Moderni kognitiotiede (152–172). Gaudeamus;

Seitamaa-Hakkarainen, P., Lahti, H., Muukkonen, H., & Hakkarainen, K. (2000) Facilitating Collaborative Designing Through A Networked Learning Environment. In S. Scrivener, L. Ball, & A. Woodrock (Eds.), Collaborative design (pp. 411-420). London: Springer.

Huber, G.P. (1991). Organizational learning: The contributing processes and the literatures, Organization Science 2, No 1, 88-115.

Huysman, M, H. (2000). Rethinking Organizational Learning: Analysing Learning Processes of IS Designers, Accounting Management and Information Technologies, 10, 81-99.

Kanfer A. G., Haythornthwaite C., Bruce B.C., Bowker G. C., Burbules N. C., Porac J. F., Wade J., (2000), Modelling Distributed Knowledge Processes in Next Generation Multidisciplinary Alliances* Information Systems Frontiers, Volume 2 Issue 3-4

Lindvall, M., L. Rus and S. S. Sinha (2003). "Software systems support for knowledge management." Journal of Knowledge Management 7(5): 137–150.

Lonka, H. (2005), Socially shared cognition and the management of a building project: Dynamic action in a network. Licentiate thesis. Helsinki University of Technology.

Naaranoja, M., Haapalainen, P., Lonka, H. (2005) Challenges of Knowledge Management in Public Construction Projects, Published at the Conference CIB 2005, COMBINING FORCES Advancing Facilities Management and Construction through Innovation, June 13-15, 2005, Helsinki

Nonaka, I. and H. Takeuchi. The Knowledge-Creating Company, Oxford Univ. Press, NY, 1995.

Orange, G., M. Cushman and A. Burke (1999) "COLA: A Cross Organisational Learning Approach within UK Industry". in 4th International Conference on Networking Entities (Neties'99), Donau-Universität, Krems, Austria, 18-19 March 1999.

Rosenberg, M. (2001) E-Learning: Strategies for Delivering Knowledge in the Digital Age, The McGraw Hill Companies, Inc, P.O. Box 182604, Columbus, OH 43272, USA, ISBN 0-07-136268-1, 344 pp

Shelbourn M A, Bouchlaghem D M, Anumba C J, Carillo P M, Khalfan M M K & Glass J (2006) Managing Knowledge in the context of sustainable construction, ITcon Vol. 11, pg. 57-71, http://www.itcon.org/2006/4

Star, S.L., Ruhleder, K. (1996), Steps toward an ecology of infrastructure: Design and access for large information spaces, Information Systems Research 7, No 1, 111-134.

Wartofsky, M. (1979). Models: Representation and the scientific understanding. Boston: Reidel.

Woelk, D., Agarwal, S. (2002) Integration of E-Learning and Knowledge Management. Association for the Advancement of Computing in Education (AACE), http://www.aace.org/DL/.

DEVELOPING PROJECT MANAGEMENT SYSTEM TO SUPPORT ACTIVE LEARNING AND COMMUNICATION IN A CONSTRUCTION PROJECT

Päivi Jäväjä[1], Marja Naaranoja[2]

ABSTRACT

Stakeholders of construction projects are numerous and multidisciplinary, and it is of paramount importance that all the information is coordinated and communicated effectively. Participation in knowledge-intensive work requires that individual professionals and their communities continuously transform their practices and create new knowledge. One effective means of ensuring the success of information flow between various partners is the use of an electronic project management system. The main target of this article is to study what kind of learning is needed in a construction project and how ICT tools could be developed based on such understanding. The material is based on project interviews and literature review on construction IT and Requirement Engineering (RE). RE plays a fundamental role within the systems development process by identifying stakeholders, applying elicitation techniques, validating and prioritizing requirements and managing changing requirements. This paper gives an analysis of the requirements for the system. Among the user's requirements were guidance for the novices, FAQ, possibilities to use Building Information Model (BIM) services, video sharing sites, instant messaging, text and voice chat, Wikis, blogs etc. All the tools leave a digital trace and permit conversations to be saved.

KEY WORDS

knowledge management, requirement engineering, learning, communication

INTRODUCTION

The terms used for construction project managements systems are numerous like project webs, project banks, project extranets, concurrent engineering software, electronic document management systems (EDM) (Hjelt and Björk 2006). This paper uses the term "project management system" which means a compilation of different solutions for construction project management. Currently the systems are used mainly for data storage but not to support active learning and communication between parties in construction projects. Active learning is purposeful learning instead of all the learning which happens ad hoc all the time.

The use of project management systems and other related technologies has been the subject of many research papers. Several researchers have studied the end-user's point of view; the required features (e.g. Hartvig 2001, Lakka et al 2001), properties which current website services provide to AEC industry (Leung 2002) and end users attitudes towards EDM-use (Hjelt 2006). Researchers and industrialists however, have attempted to utilise IT as an enabling technology to reduce the problems of communication and information sharing within the construction industry (Sarshar et al 2004). The user requirements capture and the richer forms of communication are still interesting research questions (verify Arayici 2006, Bowden et al 2006, East et al 2007, Wikforss and Löfgren 2007). East et al (2007) found out

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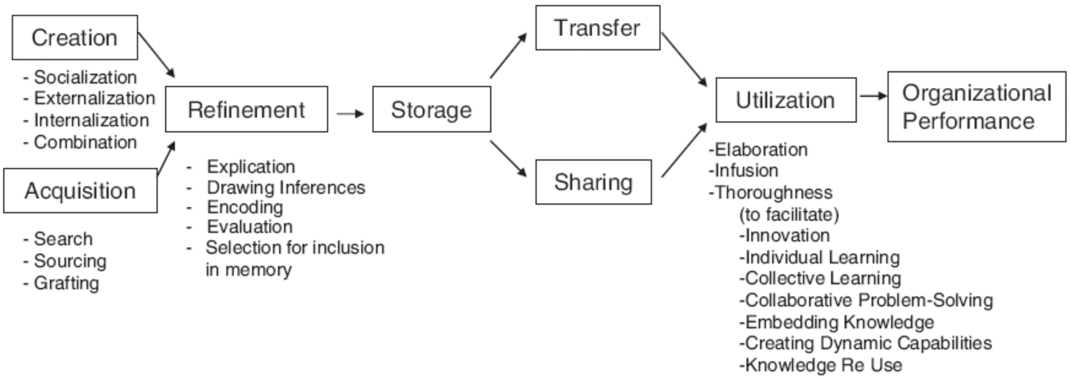
that the users of the developed communication tools needed surprisingly often assistance. According to Bowden et al. (2006) the extension of knowledge management systems could improve the communication between the participants so that the knowledge is gained ‘‘from the horse’s mouth’’ rather than a sanitized, second-hand version.

Figure 1. KM cycle model (Omega 2007)



Editors of Omega, International Journal of Management Science (2007) created a KM cycle model. The initiation of the KM cycle involves either the creation or the acquisition of knowledge by an organization. Nonaka’s (1998) four modes of knowledge creation—socialization (the conversion of tacit knowledge to new tacit knowledge through social interactions and shared experiences), combination (creating new explicit knowledge by merging, categorizing, and synthesizing existing explicit knowledge), externalization (converting tacit knowledge to new explicit knowledge) and internalization (the creation of new tacit knowledge from explicit knowledge). All these stages of KM are important in construction projects especially during the design when new knowledge needs to be created and all the parties create something new together.

This paper discusses what kind of learning is needed in a construction project during design and how ICT tools could be developed based on such understanding. We study this area first by exploring what kind of needs for learning appear in our interviews and how the requirements for learning can be defined based on requirement engineering literature. Based on our interviews we found that the need for learning appears among every stakeholder in the construction projects like learning about new materials, techniques, regulations, processes and business activities. Another need for learning is the wish to utilize ICT-tools. The applications used in the projects were quite many but the effective utilizing is incomplete. The hope of learning from past projects in order not to make same mistakes again came to light many times. They talked also about the need for quicker means to arrange meetings between project participants which have long distances to the site and about the need of model based design and construction process. The end users prefer more visual systems and models to understand how the future building will be.

The structure of the paper is as follows. The method of the research is given in section two. Communication and learning in projects are presented in the section three. ICT-support for communication and learning are given in fourth section. The basics of Requirement Engineering are given in the section five and the findings and analysis are presented in section six.

METHOD

The objective of the present study was to describe the role of ICT enabled learning in construction projects. The study adopted a systematic approach that builds on the refinement of existing theories, rather than attempting to invent new theories. The aim is to find what kind of learning is needed in a construction project and how ICT tools could be developed based on such understanding.

The empirical aspect of this research comes from the ProLab-project interviews of construction project stakeholders in Finland and Sweden. The number of theme interviews is over one hundred and they are made during years 2003-2005. The themes were: what kind of phases there has been in the project; what kind of successes and failures were experienced during the project; how the co-operation was arranged; what kind of co-operation tools has been used; and who were important persons in the project (in order to know who should be interviewed). In this paper we analyze what kind of learning needs there were and especially the theme question about the co-operation tools:

- Channels of information (meetings, phone calls, emails, drawings)
- Why are the information channels utilized?
- What kind of IT tools are used or not used and what kind of IT tools should be in use?
- What are the problems with IT tools and how the tools should be improved?

The findings were analysed through qualitative content analysis and compared with extant theory in the literature. Having defined the research focus, the empirical data were reanalysed, which allowed the conclusions to be drawn.

COMMUNICATION AND LEARNING IN PROJECTS

COMMUNICATION NEEDS

The design process can be characterized as a continuous process of change that has to be well documented and updated because many stakeholders are involved in the processes. A design team's communication environment is a holistic environment where the key information carriers for team members to communicate are sketches, schemes, images, drawings, and written descriptions together with explanatory stories. In the external environment are the clients, contractors, end-users and other project participants. It is of paramount importance that all the information is coordinated and communicated effectively.

Ineffective communication has been identified as a problem that can lead to conflict and subsequent litigation (Emmit and Gorce 2003). Knowledge and information in architecture and generally in design process has two characteristics (Paterson 1977):

- knowledge is infinitive (we can never get to absolute truth); and
- data is environment dependent, i.e. it will have different meanings when placed or taken from different environments.

Throughout the project life cycle information and knowledge is generated, stored, discarded and transmitted through a variety of communication media and communication channels. Human beings are good at handling information (in theory at least) but most of us are poor at holding a lot of information in our memory. Computers can now do the memory task for us but we have to take care of the heuristic task: what information needs to be accessed, what can be ignored and what needs to be transmitted. (Emmit and Gorce 2003.)

LEARNING IN PROJECTS

The lack of information sharing and knowledge management in construction industry is one of the reasons for the known problems: budgets are overrun, timetables are not accurate, needs of the end users are not fulfilled (e.g. Naaranoja and Uden 2007). For example, the designers need to learn what are the requirements of the end users and the end user needs to learn how the designers have understood their need in order to be able to check are their needs fulfilled in the design.

According to Jørgensen and Emmit (2007) it is important to stimulate learning, team learning and exchange of knowledge at all levels of project process and at all relevant levels of the organizations involved. Thus the learning needs are huge. However, we need to be careful since too much information in a learning system will cause information overflow and decision making might become more difficult in the project (e.g. Elonen and Artto 2003). There is also a need for requirement engineering of the learning system that aims to support the learning process of the stakeholders within a project.

For example, the learning of the construction project stakeholders can be supported by an e-learning platform that aids studying and understanding the construction operations in advance, before or during the construction execution (Lin et al. 2005). ICT supported learning system can also be called knowledge management systems (Lin et al. 2005). Many organizations are now engaged in knowledge management efforts in order to leverage knowledge both within their organization and externally to their shareholders and customers (Malhotra 2001). Valuable knowledge can be available in different forms and media, such as in the mind of experts, in operation procedures, and in documents, databases, intranets, etc.; however, knowledge management in the construction phase of projects aims at effectively and systematically collecting and sharing the experience and knowledge of the project by web-based and intranet technologies (Lin et al. 2005).

ICT-SUPPORT FOR COMMUNICATION AND LEARNING

THE STRUCTURE OF PROJECT MANAGEMENT SYSTEM

Ingirige and Sexton (2007) found that the overly short term orientation in the use of project management system lead to inadequate emphasis on leveraging the dynamic to static content and optimizing the user involvement to gain performance improvement in organizations. Static content provides information without any personalization to the individuals in the organization and dynamic content is personalized and enhances knowledge accumulation, for example discussion forum; interactive demonstration, key word search for expertise, and methods of capturing knowledge (Ingirige and Sexton 2007). A project management system may consist of personalization and four main components comprising; active process support, teamwork, e-learning and document management.

Table 1: The functions of a project management system (modified Chong et al. 2007)

Personalisation			
Customising	Personal Inbox	Scheduling	Personal favorites
Search tools	Personal directory	RSS	Hotlist
User Manager	Replication	History	Action reports
Active process support	**Teamwork**	**E-learning**	**Document Management**
Administrative information	Net meeting	Wikis	Subscribe to contents
Project management – costs and scheduling	Discussion groups	Document annotation	Linked to Building Information Model (BIM) server
Workflow	E-mail	Videos	Versions control
Checklist	Find experts	Multimedia	Access control
To-do list	Message boards	Blogs	Append/ modify/ delete
Site diary	Chat rooms		Document sharing
Customers	Meeting planner		Office integration
Employees	FAQs		Content rating
Supliers – e-procurement	COPs		

E-LEARNING

E-learning is a tool for reuse and exploitation of explicit knowledge through its capture, codification, storage, and retrieval. However, explicating tacit knowledge is important for knowledge reuse because when appropriately explicated, knowledge can be efficiently shared and reapplied (Lin et al 2006). The development of e-learning system needs thorough knowledge capture.

Burnside (2001) refers to the internet as a means of delivering and facilitating learning and blurring the line between traditional academic education and traditional job training held at work and focused more on applied skills than on the mastery of a body of knowledge. While continuing the employers' emphasis on skills, businesses also want employees to build shared knowledge about their work that can be transferred elsewhere in the company as best practices. Conditions change so quickly that employers are hard pressed to keep up with the changing knowledge. (Burnside 2001.) Even in construction projects the project stakeholders first need skills that bring success in their current jobs. Second, they need membership in professional networks that keep them up-to-date in their professions. Third, they need the skills to use the new technologies (Burnside 2001).

Online tools for learning can be roughly divided into tools for delivering learning content and for tools for communication. Learning content is, of course, always communicative. In the digital online environment the learning content can be continuously reviewed and improved. Wikipedia is probably the most well known example of this. Also saved online communication may become learning material (Põldoja et al. 2006). These kinds of internet tools enable people to self-organize information or knowledge. One of the technologies used by blogs and wikis to alert users of new postings, as well as to help sort information coming from multiple internet sources, are RSS feeds. RSS stands for "really simple syndication". Wikis, blogs and RSS feeds offer powerful opportunities for online collaboration learners in projects (Goldwin-Jones 2003). It is generally recognized that workers at all levels of the organization are a significant source of creative thinking. Online tools could provide the link to workers so that lessons learnt as the project progresses are captured immediately (Bowden et al. 2006).

Off-site training formats are low cost alternatives for on-the job training and which give a novice opportunities to experience the real working conditions (Wang and Dunston 2006). One simple version of the off-site training system is on-line video sharing sites which allow anyone connected to the web to upload digital video recordings. The system supports the efficient dissemination of project related videos and virtual visits to sites (Kumaraswamy 2004), best practices and technical operations on site e.g. out of the ordinary installations.

BUILDING INFORMATION MODELLING (BIM)

Building Information Modelling (BIM) is a data rich digital representation cataloguing the physical and functional characteristics of design and construction. Its purpose is to make the design information explicit, so that the design intent and program can be immediately understood and automatically evaluated. BIM-based approach supports 'on demand' generation of documents (e.g., drawings, lists, tables, and 3D renderings) from a consistent Building Information Model. In a sense, these documents present views of the current BIM. In particular, Computer-Aided Design (CAD) documents often exclude information needed for effective design evaluation. The information that was sufficient for CAD drawings is often insufficient to meet the requirements of a model–based design process, as industry expectations for analysis using a model-based approach are expanding. (GSA 2007.)

In order to construct a digital model at least two state of the art of the ICT technologies need to be considered: Industry Foundation Classes (IFC) and a variety of advanced communication and integration technologies often referred to as the Semantic Web (Schever et al 2007). Case studies of BIM applications are currently being presented in conferences and workshops worldwide. For example, the International Alliance of Interoperability initiated Building Smart forum for the industry and governments to identify, test, review, recommend and implement smart ways to deliver quality buildings and services to the facility owners using BIM technology (Olofson et al 2007).

REQUIREMENTS ENGINEERING (RE)

BASICS OF REQUIREMENTS ENGINEERING

Requirements engineering is concerned with the goals, desired properties and constraints of complex systems that involve software systems, organisations and people. It also covers how requirements relate to business processes, soft issues, work redesign, system and software architecture and testing (Arayici 2006). The requirements engineering helps the software developer to capture and analyze the user requirements and their hierarchies and define the acceptance criteria of the requirement (Hull et al 2005).

The three main levels of requirements engineering are (Sommerville and Sawyer 1997):

- Business requirements describe why the product is being built and identify the benefits both customers and the business will reap.
- User requirements describe what, captured in the form of use cases, describe the tasks or business processes a user will be able to perform with the product.
- Technical requirements describe how, the specific system behaviours that must be implemented. The technical requirements are the traditional "shall" statements found in a software requirements specification (SRS).

BENEFITS OF REQUIREMENTS ENGINEERING

According to Arayici (2006) the developments of IT systems for construction supply chain have not reached at their ultimate effectiveness. This is mainly due to the lack of communication between the system developers and the industrialists. Arayici (2006) still argues that requirements engineering can be a major factor in determining the success of the entire system development. People from industry have stressed that construction IT researchers should align with the practioners when developing and proposing IT solutions to the industry (Arayici 2006).

Hoffman and Lehner (2001) and Nikula (2002) defined requirements engineering related project success factors and they found best practices for successful RE: involve customers and users throughout RE, identify and consult all likely sources of requirements, prioritize requirements, assign skilled project managers and team members to RE activities, provide specification templates and examples, maintain good relationships among stakeholders.

INTERVIEWS AND ANALYSIS

The previous analysis of the Prolab interviews by Haapalainen (2007) show that the stakeholders of a construction project learn different things from each other. She found out that the diverse background of the project participants create learning needs. For example, the headmaster might be novice in public building project but has built a small house for himself. There is also different kind of knowledge that needs to be transferred between parties. The tacit knowledge needed to be turned to explicit knowledge and it needs to be learned by the other party. The learning needs of the parties are also different. The end users of the project need to learn technical issues and even how they themselves work in the planned building. Designers need to learn the needs of end users and constructability of the building. All the parties need to learn what has earlier happened in the project. (Haapalainen 2007.)

The learning needs have to be taken care of in the project management system.

THEME INTERVIEWS OF THE CONSTRUCTION PROJECT PARTICIPANTS

The informants appreciated the project management systems even if they had not used it effectively. The benefits were efficient information flow which enables faster decision making and up-to-date designs. The need for rules and guidelines of the use of the project management systems was recognised.

> “Everybody needs to follow the given guidelines to insert the data into the databank. Otherwise you do not know what is in there.” Designer
>
> ”The EDM system is good because you leave always a trace when you read a document. But for some reason it is not yet effectively in use, actually I wonder why?” Project manager
>
> “Digital photos were helpful during the construction stage in explaining the projects for the architect and he was not forced to travel 400 km to the site.” Project manager

The constant need for learning occurs in many ways. Very often the informants talked about the end-users incapability to understand the drawings and technical symbols and also their difficulties to specify their needs for spaces and other future needs.

> “Sometimes the users did not understand... One has to use perspective and coloured sketches of the design with the end users of the buildings. The 3D models could be the best but they were still not in use. The process should be so effective that we don’t need to change the designs because of end-users changing needs.” Architect
>
> “I asked some things ... and sometimes I was ashamed and had a feeling that I can’t open my mouth...Rarely I got enough time to inspect and comment on the drawings...” End user

The learning from past projects is the wish of many project stakeholders.

> ”There is a need for a better databank of lessons learned...” Project manager 1
>
> “We are developing a system to create a lessons learned databank...There should be somebody to maintain the system, others it is uncontrolled and there is no use from it.” Project manager 2

The site managers explained if they could be involved during the design process there would be less mess during construction. It will minimize the constructability problems. There are huge needs for designer to learn from site practises.

> ”Often we need to decide on site how to solve problems for example to get big air-conditioning machines inside an old building. It causes a catastrophe and a lot of extra costs if we open floors and walls afterwards for machine installations. Such things should be planned by designers beforehand and not suddenly at site.” Site manager

Quite many of the informants emphasize the communication between the project stakeholders:

> ”Communication is the most important thing, we need real dialog...” Project manager
>
> “It is very expensive to arrange meetings when the participants are far away from each other. We have networks and phone-meetings and net meetings which are in test phase. We save time, the optimization how to spend the time is very important.” Project manager

ICT-tools and applications used in case projects were several but there still are many challenges to use the effectively.

> “I don’t know if we need new systems we just need to use the current ones first...” Project manager
>
> “It takes enormous effort to learn by oneself the ICT-things and it is becoming as a problem in competition.” Project manager

REQUIREMENTS

The interviews were analyzed in Requirements Engineering framework in order to develop the project management systems to support more efficient learning and communication in construction projects. The business requirements are taken from literature and the user requirements come from our interviews.

1. Business requirements describe why the product is being built and identify the benefits both customers and the business will reap (Sommerville and Sawyer 1997):
   - need for cost minimization and productivity
   - improved flow of information and improved process management
   - improved transparency and tracking
   - quality assurance: design quality and production quality and rework minimization
   - fulfil the needs of the end-users of the buildings
   - fulfil the needs of the supply chain in construction process (e.g. constructability)

2. User requirements describe the tasks or business processes a user will be able to perform with the product.
   - help for newcomers, basic rules in system use and support for coordination
   - frequently asked questions (FAQ)
   - access to project information and to common reference information
   - need for documents retrieving just-in-time, in a pull-fashion
   - need for more visual tools (BIM and sketching in 3D)
   - need for e-learning tools and for more effective communication tools
   - need for new technologies to support learning like wikis, blogs, video sharing sites etc.
   - the interface of the application is simple and user-friendly
   - ubiquity of the communication tools (mobile interfaces)
   - concurrency of a communication session triggering (no time-consuming procedures)
   - stability and reliability of the systems (like power supply)

3. Technical requirements describe the specific system behaviours that must be implemented. The functional requirements are the traditional "shall" statements found in a software requirements specification (SRS).
   - black box in this paper (answers to question how the system works)

DISCUSSION

The project management system of a construction project needs to take care of the learning and the communication needs of the participants:

- the participants have different background, experiences and education that always gives a new set of learning needs. Some participants need also more knowledge of the use of ICT. The need to learn from past projects varies since some have knowledge already.
- there is needed to possess different kind of knowledge. This knowledge is often tacit since the participants do not even themselves know they have that knowledge. However, the project management system can aid the parties to turn the knowledge explicit.

The project management system could contain e-learning platform in order to support the learning of project participants by giving information of ICT applications; lessons learned from past projects; techniques; and regulations. A knowledge manager is needed to further develop the e-learning environment and to tutor the on-line courses. The knowledge manager can also respond to the learning needs during project.

Our next step is to further analyze the communication process and learning needs in construction project in order to give precise information for developing project management system.

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REFERENCES

Arayici, Y., Ahmed, V., Aoud, G. (2006). A requirement engineering framework for the integrated system development for the construction industry. ITcon, 3, p. 35.

Bowden, S., Dorr, A., Thorpe, T., Anumba, C. (2006). Mobile ICT support for construction process improvement. Automation in construction (2006), Vol. 15, no5, pp. 664-676.

Burnside, R. M. (2001). E-Learning for Adults: Who Has the Goods? The Technology Source, July/August 2001. Available online at http://technologysource.org/article/elearning_for_adults/. (date accessed 30.5.2007).

Chong, N. B., Uden, L., Naaranoja, M. (2007). Knowledge management system for construction projects in Finland. International Journal of Knowledge Management Studies. Volume 1, Number 3-4 / 2007.

East, E.W., Kirby, J.G., Liu, L.Y. (2007). Automation in Construction. Verification and validation of a project collaboration tool, Automation in Construction (2007), doi:10.1016/j. autcon.2007.04.003.

Elonen, S., Artto, K. (2003). Problems in managing internal development projects in multi-project environments. International Journal of Project Management 21 (6) 395-402.

Godwin-Jones, R., (2003). EMERGING TECHNOLOGIES Blogs and Wikis: Environments for On-line Collaboration, Volume 7, Number 2 pp. 12-16 Copyright © 2003, ISSN 1094-3501 12. Available online at http://llt.msu.edu/vol7num2/pdf/emerging.pdf (date accessed 4.6.2007).

GSA. US General Services Administration. (2007). The National 3D-4D-BIM Program Office of the Chief Architect Public Buildings Service GSA Building Information Modeling Guide Series 01 - Overview Draft. http://www.gsa.gov/bim. (date accessed 30.5.2007).

Haapalainen, P. (2007). Learning within Projects: A Qualitative Study of How Learning Contributes to Knowledge Management in Inter-organizational Construction Projects. University of Vaasa. Vaasa. Finland.

Hartvig, S. (2001). Evaluation Criteria for Project Webs. Working paper, March 2001, unpublished. Technical University of Denmark.

Hjelt, M. (2006). End-user attitudes towards EDM use in project work - A Case study of the Kamppi Center project. Dept. of Management and Organisation, Swedish School of Economics and Business Administration (HANKEN), Helsinki, Finland.

Hjelt, M., Björk, B.-C. (2006). EXPERIENCES OF EDM USAGE IN CONSTRUCTION PROJECTS at http://www.itcon.org/data/works/att/2006_9.content.06879.pdf (date accessed 30.5.2007).

Hull, E., Jackson, K.M., Dick, J. (2005). Requirements engineering, Second edition. Springer, Kent USA.

Jørgensen, B., Emmitt S. (2007). Integrating design and construction from a lean perspective, in Construction for development, CIB 2007 world congress. Cape town South Africa.

Kumaraswamy, M. (2004). Accelerating learning via virtual site visits. International Journal of IT in Architecture, Engineering and Construction. Volume 2 / Issue 1 / February 2004.

Lakka, A., Sulankivi, K., Luedke, M. (2001). Features and Capabilities in the Concurrent Engineering Environment. VTT Publications.

Leung, N. (2002). Web-based Collaboration in Construction Project Management. National University of Singapore. http://plaza.ufl.edu/nnleung/mspapers/LeungNN.pdf (date accessed 4.6.2007).

Lin, Y., Chang, C., Chiou, L.B., Jan, S., Tserng, H. (2005). Towards Web-based learning system for engineers integrated with problem-based learning (PBL) approach in construction. ICT in Construction and Facilities Management. VTT publications

Malhotra, Y. (2001). Knowledge Management and Business Model Innovation. Idea Group Publishing, Hershey, PA.

Nikula, U., Sajaniemi, J. (2002). A Lightweight Combination of Proven RE Techniques, IEEE Joint International Requirements Engineering Conference, Essen Germany.

Olofsson, T., Eastman, E., Lee, G. (2007). Case studies of BIM use, Call for Papers for ITcon Special Issue, http://www.itcon.org/cgi-bin/special/Show?id=2007bimuse&sort= DEFAULT &search=&hits =18. (date accessed 20.8.2007).

Omega Editorial. Knowledge Management and Organizational Learning. (2006). Editorial International Journal of Management Science (2007) / Omega 36 (2008) 167 – 172.

Põldoja, H., Leinonen, T., Väljataga, T., Ellonen, A., Priha, M. (2006). Progressive Inquiry Learning Object Templates (PILOT). International Journal on E-Learning. 5 (1), 103-111. Chesapeake, VA: AACE.

Sarshar, M., Christiansson, P., Winter, J. (2004). Towards virtual prototyping in the construction industry: the case study of the DIVERCITY project, World IT for Design and Construction (INCITE) Conference, Langkawi Malaysia, 581-8.

Schevers, H., Mitchell, J., Akhurst, P., Marchant, D., Bull, S., McDonald, K., Drogemuller, R., Linning, C. (2007). Towards digital facility modelling for Sydney opera house using IFC and semantic web technology, http://www.itcon.org/2007/24. ITcon Vol. 12, pg. 347.

Sommerville, I., Sawyer, P. (1997). Requirements Engineering - A Good Practice Guide, John Wiley & Sons, New York.

Uden, L., Naaranoja, M. (2007). The development of online trust among construction teams in Finland, http://www.itcon.org/2007/21. ITcon Vol. 12, pg. 305.

Wikforss, Ö., Löfgren, A. (2007). Rethinking communication in construction, http://www.itcon.org/2007/23. ITcon Vol 12 (2007), pg 337.