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.

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's mindset 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

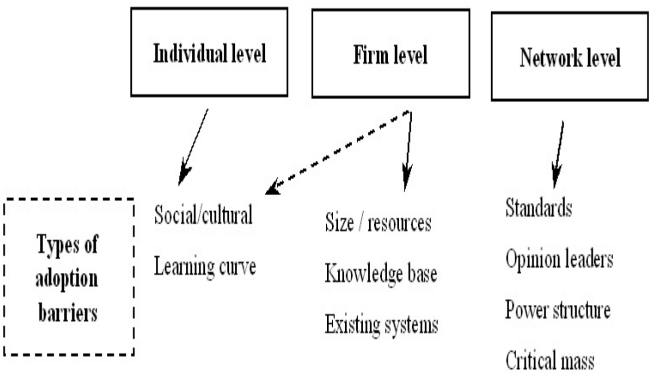

Figure 2 Links between levels and adoption barriers. (Engsbo 2003)

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 interorganisational 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.