MULTIDISCIPLINARY INFORMATION MANAGEMENT IN CONSTRUCTION INDUSTRY, EXAMPLE OF FACILITIES MANAGEMENT

SUBMITTED: February 2002
REVISED: August 2002
PUBLISHED: September 2002 at http://www.itcon.org/2002/14
EDITOR: Abdul Samad Kazi

Lehto Mervi, Ms.
VTT Building and Transport
email: mervi.lehto@vtt.fi

Himanen Veli, Dr.
Relate partnership
email: veli.himanen@poyry.fi

SUMMARY*: Information management is mainly dealt as a research problem of information services or as a database management problem of CAD systems. In this paper several approaches to the construction information handling are discussed; information creation, transfer and retrieval. Actually, construction information management is a multidisciplinary task; a mixture of parameters of informatics, technology, and organisation. The CAD system design and the R&D of CAD systems could benefit from the development and problem solving of the problems not only common to it but also from the problem solving of the fields which are related to it.*
The answer for a specific information request is still best found by various means, also other than those of the ICT. Various aspects, such as [1] the type ICT, [2] the type and form of information, [3] the possibilities to understand the message, [4] information availability and gaps, [5] the purpose of information usage either scientific or industrial, [6] the type of building, for which the information is needed, and even [7] the status of the stakeholder in need of knowledge, all effect on the accessibility of information.
Such means as information gateways, new media, electronic libraries, CAD (Computer Aided Design) in VR (Virtual Reality), and IFM (Integrated Facilities Management), as well as modelling of comprehension and information sharing of knowledge transformation from tacit to explicit are working for the common goal, which is to make the access to construction information easier.

KEYWORDS*: information retrieval, information service, Electronic Information Services (EIS), Intelligent Buildings (IB), Integrated Facilities Management (IFM), knowledge modelling, ba*

1 BACKGROUND

In a world of increasing information flows, data retrieval is becoming more and more important. Finding information is no longer the problem, but *sorting* it for your own purposes is. We have to be able to ask the right questions at the right time, and we need to retrieve the information for that special need *quickly* - the sooner the better. In a world of complexity and globalised businesses one person cannot be expected to know everything. *Information sharing* is power. Furthermore, the information cannot reach a person, if there is *a conflict of interests in communication* or if the *message is not understood*. The information needs of various stakeholder groups are *different*, for example, industry needs different type of information or the information has to be in different form than that of the academic world.

The information retrieval is not only a organisational question, it is also a technical matter. The *Information and Communication Technology* (ICT) is now involved in all information processes employing various tools -

tradition databases, search engines, web sites, electronic libraries, virtual design environments, etc. The capability of various information sources to serve the information needs varies accordingly. Unlike web sites, traditional databases and electronic libraries carry well indexed and checked information. This does not concern all web sites. For example, the web sites of some universities and research institutes which offer references to their work and libraries,

The use of *search engines* is not sophisticated enough for business or scientific purposes. The coverage of the engines is not adequate, and the hits carry lots of vain information. The databases of the virtual design environments using *the World Wide Web technology,* linked to email and *Computer Aided Design* (CAD) systems - benefiting object oriented design and expert systems - are becoming the primary source for construction information management at the same time with the evolution of the Internet services. Also, facilities management business can benefit from this progress, as well as information and knowledge management of all construction sectors. Besides, products and services now used for entertainment purposes in *the new media* may well pave the way for future use for more "useful" or professional purposes.

The technical possibilities of information transfer feed on the image of the easy access to any information. However, in a specific case, such as that of the workspace phenomenon, the information accessibility is no matter of course. Despite this world of vast information flow, personal communication and meetings are needed for information sharing and for better understanding of messages.

The organisation of the information creation and retrieval is an organisational matter. It has to be organised in such a way, that it is possible for the all actor in the construction field to participate to the information creation and to get their message to others. On the other hand, the access to the information often is best, if it is organised via one channel or "window". In other words, it is good that the creation of the information is taken care of several actors, but the information dissemination should be taken care of via one or as few channels as possible. The co-operation between various actors is essential. For example in Finland a construction information service has had a big role in the development of the information systems for the designers and to their CAD systems. On the other hand, other World Wide Web based construction information systems which contain similar information are being developed. For the end user this might be confusing before she or he learns the double systems.

The possible advantage of the focused creation of the construction information service system is the ability to decide on one among several possible system dynamic alternatives as a basis for the system structure. The wide acceptance for the selected systematics is needed for a successful operation of information dissemination. Otherwise other competing systems will follows, as it seems to be most probably the fact in Finland in the future.

The advantage of the several parallel systems is the possible increase in transparency of information system in all. With transparency can mean the possibility to compare information, which is originated from various sources. The comparison of prises is a good example of this. Transparency can also be achieved by the means of more accurate information. Before the down of information age, the manual land use register was created. It revealed land ones who had succeeded in keeping their property secret from tax authorities. Computerised data base of the register makes this information even better available. Another example of the power of data accuracy is the modern CAD technology. It is able to calculate the building and land areas more accurately than what was possible on the basis of the manual drafting documentation. This can be advantage or disadvantage of different stakeholders. The latest progress has been favouring the possibility of negotiate on the basis of the transparent information the win-win solution, which means advantages for all stakeholders.

2 OBJECTIVE

The answer for a specific information request can still be best found by various means, also other than those of the ICT. Various aspects, such as the type ICT, the form of information, the possibilities to understand the message, the purpose of the information usage affect the accessibility of the information. Information management is mainly dealt as a research problem of information services or as a database management problem of CAD systems. The transfer of information is in focus. In this paper the several approaches to the construction information handling are discussed; information creation, transfer and retrieval. The purpose is to draw a wider picture of information management variables or parameters, not to explain how to solve the possible problems of information management.

3 METHODOLOGY

The article is an integrating review of the results of two studies:

INFOTECH, Impacts of information and communication technology on travelling carried out at VTT by Dr. Veli Himanen, Dr. Mika Mannermaa and Dr. Candidate Mervi Lehto, and

- EuroFMWorkspace, Improving the quality of production via workspace design carried out at HUT (Helsinki University of Technology) by Dr. Candidate Mervi Lehto.

In the INFOTECH study, the various means of data, information, knowledge and tacit knowledge (consciousness) transfer has been examined and modelled. In addition to the literature review, research methods include expert interviews, analyses of the data from earlier surveys, system dynamic modelling, anthropological methods such as mapping of basic human activities, examination of human interplay at the end points of trips, or life-cycle analyses of technological systems. The intelligent building survey done within over 500 office workers in the Helsinki Metropolitan area is used as the most important information source for the system dynamic modelling of the INFOTECH project (Himanen et al. 2000, Himanen & Lehto 2001, Himanen et al. 2001).

The second study is a collection of expert knowledge of information sources and their feasibility and usability. It shows problems of information retrieval, if traditional professional or scientific databases are not used. This study is based on Delphy method among leading European Facilities Management (FM) professors and industrialists (Lehto with al. 2001a, Lehto with al. 2001b).

The third study, which has had an influence on this review is

- the Commercialisation of the technologies developed in the RAKET research programme, which was accomplished under the LINKKI 2 Research Programme on energy Conservation Decisions and Behaviour.

During that study the representatives of the Finnish construction product industry were interviewed of the effects of the research results in commercialisation of their products (Lehto 2001b). It turn out to be a study of products of the renewable technology, because the interest of the companies had been to develop them. Also other parties, who are involved in the utilisation of the research results were interviewed. Such parties were dissemination organisations of information of the energy field and science parks. Theme interviews and story telling were used as methods for the interviews.

It is no surprise to anyone that the information retrieval is a matter of organisational and technical issues. But tracking the mechanisms behind these topics is of great interest for the system developers. The objective of this paper is to distinguish the various cases of the information retrieval and the factors affecting the access to the information. It is done by summarising the results of the above mentioned studies.

4 RESULTS

4.1 Several parameters

Both organisational and technical aspects of the information flow within construction process hold within a multidisciplinary world of factors:

Informatics:

- organisation of the building information flow, the roles and businesses of the information providers and that of the gateway keepers of information retrieval,
- lack of certain type of information,
- mismatch of the information needs and the information quality available, for example, needs of the construction industry and the form of information provided by the information providers do not always match, especially this is true, if the information provider is providing information by following the scientific tradition of information handling,

Technology:

- information services,
- design methodology (CAD, Virtual Reality (VR)),
- -ntelligent buildings and facilities management,

Organisation:

- human intelligence or knowledge skills,
- information gabs due to human comprehension problems and need of solving them by modelling, implementation of the concept of ba, etc.,
- organisational statuses of the information providers and users, such as FM companies,
- state of the art of knowledge work in construction industry.

The various parameters of the information handling of the construction industry are under serious development and much has been achieved due to this R&D work. However, the use of CAD is still dependent on several such parameters, which are not normally included to the R&D work of CAD systems (FIG.1.). All subjects relevant of the R&D of CAD systems are not referred here, for example, the usability of them is excluded.

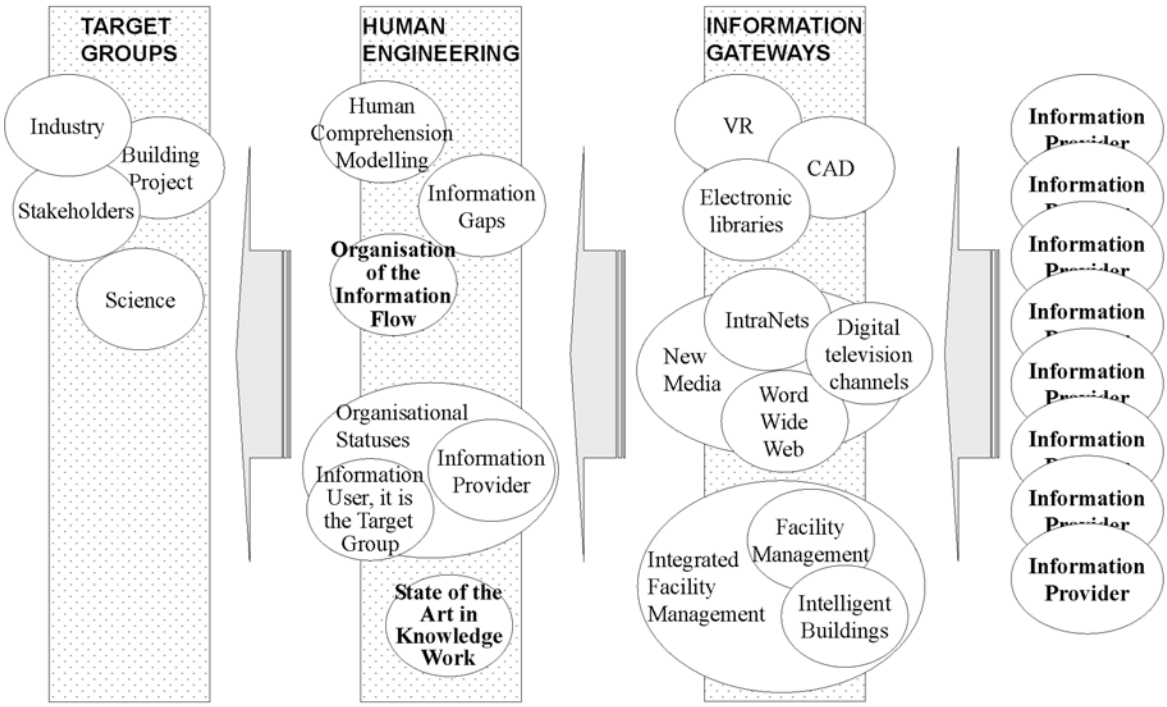

FIG.1: Several factors affect the information transfer of the construction industry. CAD is a parameter among technical gateways. It is or it should be a way to the information sources and it should be the mean for disseminating further the knowledge created from the information and data to the target group of informatics.

4.2 Organisation of Building Information Flow

The majority of construction industry information is concentrated around the *project information* (FIG.2.). The nature of such construction applications as planning, estimating, tendering, ordering, etc. is complex. However, it is widely accepted that the vast amounts of project's information can be extracted from the project's drawings (e.g. Kiviniemi 2000, Dym and Levitt, 1991). The project information's importance does not cancel the need of *non-project oriented information*.

4.2.1 Design database management

To manage the information flows it will be necessary to agree on the content, structure, format and presentation of the data, to be able to develop applications for integrated information systems. For example, the international construction information management RTD (Research and Technical Development) project, VERA include application of product data standards, revision control, jurisprudence, feedback systems and building maintenance services, as well as utilisation of information networks in construction processes, such as project data-banks, general product information and regulations, software to support a virtual company, and copyright issues in information network utilisation (Kiviniemi 2000). Similar construction information research is done

world wide in research institutes, universities and other educational institutes, as well as in private consulting companies.

The construction information research has at least two lines. On one hand, a common centralised building project data base is the target for development of the construction information management (cf. Kiviniemi 2000). On the other hand, there are efforts for solving the construction information management by means of networking various building project databases together, which imitate the process of design work in practise (cf. Haugen 2000, FIG.2). In the first case, the designers are sharing the common design database by the means of the information management system. In the second case, they are preparing their own compatible design data bases to be shared by the information management system. The technical approach to the problem is related to the organisational problem solving. The system is either centralised or decentralised. In other words, the power over the system is dominated by the system structure and procedures or the power is shared between several stakeholders.

A common gateway to the project information is essential for the co-operations between designers (Lehto et al. 1988). Certain operational rules of the design versions and their updating is needed for this type of design work in virtual reality (VR) design environment.

4.2.2 Non-project oriented database management

Despite the importance of the *design* phase in information and knowledge creation, also the other phases of the *construction process* carry important information. The organisation of that information is advanced on the behalf of quantity survey in particular. The data and information systems of constructors and construction production purchase must not be forgotten in this context. Information management of construction site includes sophisticated systems for handling the material and work performance flows. The information of the construction process remains often confidential, because it is generated within a company.

Research, RTD and standardisation have also central roles in knowledge creation, in any industry, including the construction industry. Furthermore, there are other activities within the industry, which provide important information for all. Various *associations* have their own projects on new applicable methods and concepts. *Educational organisations* produce scientific information together with the research organisations, and they have courses which gather valuable information. This is not only the case with public educational organisations, but also with private education and training organisations.

Scientific and commercial libraries and information services provide their customers with the results of information search from databases (Martiskainen 1993). These include bibliographic information, use of keywords, and the output is usually accompanied by an abstract or a short reference and copies (paid) can be ordered. Special databases are not yet available, for example, for such a special subject as Workplace Design, and even facilities management databases are often not listed separately. In a case like this, the expert knowledge of networks of professionals is still needed. The information search is taken place for such a special needs of information retrieval from several information source data bases by an information service organisation.

Another common gateway to information is needed in addition to the above mentioned common gateway to the design project databases. This gateway might be a user-friendly one to the non-project related information databases (Nurminen et al. 1987, Lehto et al. 1987, Lehto 1987, Lehto et al. 1988, Lehto & Aho 1988, Nurminen et al. 1988, Lehto 1991b, Lehto 1992). This connects the information from various sources, where it has been created, together in a manner that is easy to access. On the other hand, via this gateway the information and knowledge created by various sources is also distributed to those who are in need of it.

4.2.3 Decentralised information creation and common gateways to information

In the early days of data handling technology it was discussed if a database system should be either centralised or decentralised. It was not difficult to figure out that information creation activities take place all over the construction industry, but the data retrieval needs a common channel for all to these separate information sources (Lehto et al. 1988, Lehto & Aho 1988, Lehto 1991a).

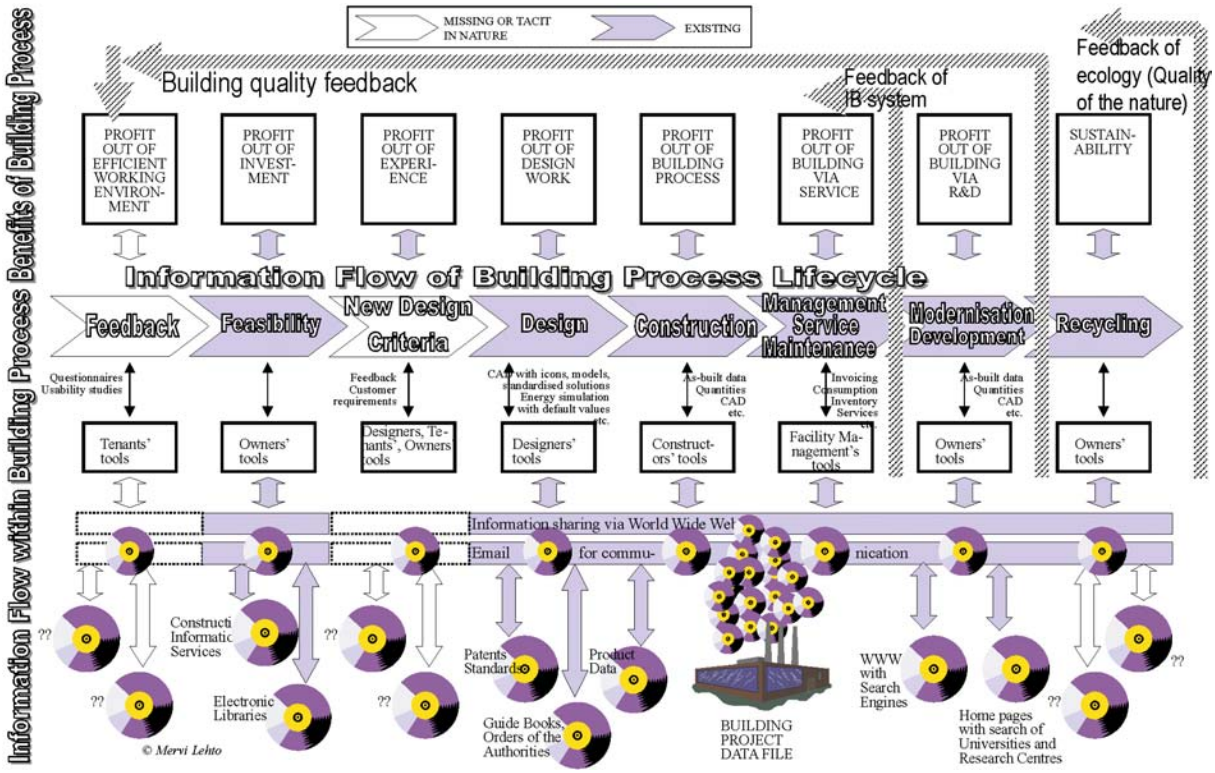

FIG.2: Building information services life cycle

Despite the fact that the Internet and other information networks or highways have made easy access to information possible, as well as it is an effective tool for all to put their information available, the need of a common channel for the knowledge retrieval exists as it will be explained in the next section. The organisation of construction information flow consists (or should consist) of structured rules of information exchange, and a common, easily accessible gateway to the separate information sources. This conceptual organisation of information or knowledge does not mean the same as taking advantage of technological progress by piling up as many ICT solutions as possible to the information management system, but taking advantage of the systems design and thinking from which the useful technological solutions will follow.

4.3 Scientific Information Generation Versus Industrial Information Needs

The industrial sector often demands, and to some extent relies on, *ad-hoc, informal, personal* sources of information, often supplied through a ‘phone call' from someone who is known to know. That is the case,

especially, in the small and medium sized enterprises (SMEs), where the systematic use of databases etc., is the exception.

However, information retrieval by personal contacts might be too time consuming despite the mobile phone and paging technology of the modern business world. Also, the latest information cannot necessary be reached by the phone calls to previously well known information sources. When using one source only, the comparison of different alternatives and solutions is impossible, if the source is not broadminded enough.

Information services are widely used to help enterprises classify and find relevant information, indeed, some of them will scan and *track information continuously for the core areas of businesses of their clients*. On the other hand, electronic libraries give increased freedom to the users and encourage them to search information for themselves (cf. Section 4.5.). At the same time, information specialists aim to provide special expert knowledge of search methods or, in the difficult cases such as those relating to patents, they also prepare information retrieval instruction manuals and source books, and undertake education and training. Those are all activities to encouraging those in need of information to help themselves.

The gaps between scientific information and the information needs of industry and other businesses have been a main concern of dissemination of research results. Sometimes consulting activities can bridge the gap; at other times the seamless *co-operation between scientists and industrial partners* have performed good results in utilisation of scientific information in industry, and vice versa, in making scientists aware of the knowledge of best industrial practises. Products, which are developed by R&D work of a producer and based on the basic research results, are reaching the markets relative quickly. The *role of the best designers* has been that of the supplier of construction information in the form of new construction solutions, and further on that of an intermediary, who through design supply the clients with the product information based on best construction science.

A serious conflict might happen between scientific and industrial information needs, because of the *patent regulations and practises* (Lehto 2001b). Scientist aim often to publish their results because of the funding and professional qualification. On the other hand, patents which lead to new commercialised innovations should be based on non-published research results (Lehto 2001b, p. 140).

Far quicker than in the past, the results of *basic research* are nowadays employed by industries, and new products based on resent research are reaching the markets in a relatively short time period. This is the case, for example, in the information and communication industry and biotechnology. Despite being characterised as conservative, the construction industry could follow the other industries' example of a quick adoption of recent scientific results (Lehto 2001b, p. 141). This type of progress could be typical for the ICT of construction in particular.

4.4 Lack of Information

The *market surveys* measure the customer opinions about the important decisions concerning the products for sale. Similarly the concept of user and stakeholder oriented construction emphasises the meaning of the user and customer *feedback* of the quality of products (cf. Lehto 2002). After each project the feedback information should cumulate to the next cycles of the information flow of construction process. So far, at least in practical terms, this feedback information is missing from the buildings' information life cycle, or it remains as confidential internal information of the construction firms (FIG.2.).

4.4.1 Feedback information

The *post-occupancy studies* have so far been one of the main means of providing a lump of feedback information. Thus, it can be thought, that the feedback can be included into the concept of buildings' information management life cycle, which is shown in FIG.2. It is the phase of the buildings' information management system, which currently is missing. Feedback is essential though, in all phases of the buildings' information life cycle, because of the integrity of construction process and that of facilities management and buildings maintenance. It can cumulate in several phases of the buildings' information life cycle. Then, it is not only a question of the end user response, but there are several types of feedback information; that of expert knowledge and practical solutions.

Furthermore, feedback information has to be *developed into new design criteria* to be used in next building projects. The background information for new design criteria is valuable in wider information context within the company and the whole building sector than just within those, who have gathered feedback from a new built project. The feedback information can be created in an above described all-out manner within the buildings' information management system or form feedback databases as a part of the CAD design systems.

In many cases experts know a lot about customer feedback, but it is tacit knowledge, because it is unarticulated. It remains even still tacit although it will be articulated in the form of new built house (cf. Tuomi 1999, p. 100), which actually happens all the time and which may be in some cases a reason for using certain designer or a certain group of designers. Simplistically, it can be said that tacit knowledge becomes explicit via communication. Explicit knowledge is spoken, written, drawn, filmed, computerised, etc. (cf. Himanen & Lehto 2001). Explicit knowledge is related to explicit information and conscious ideas, which are more understandable by thinking and thus submitted to scientific examination and further on, they can be turned into the practical solutions (Bergson and Husserl in Tuomi 1999, p. 99, cf. Lehto 1999a). Information creation, or more precisely building up a seamless construction information flow system is a way of turning tacit knowledge into an explicit form of knowledge.

In many cases the feedback information collection is a task among the facilities management activities. Much of empirical information about building design and solutions could have remained mostly undocumented. At least two reasons for that can be named. In the first place, in modern constantly changing industrial processes and business life new important issues are to be worked on instead of documenting the recent changes. Secondly, the building changes have been seen mainly as a consequence of the changes of the industrial or the occupants' production, and thus disregarded in the information management system of the occupant, whose core business area lies somewhere else than in the building industry. In the cases where buildings have been carefully planned and the design well documented, the results might have remained *confidential* and thus unpublished. This is often the case with the frequently done post-occupancy studies of the private asset and facilities management companies. Still, several remarkable researches of the post occupancy studies are available, of which many are about office buildings (Anttila 1992, Brill 1985, Duffy 1983, Hood 1993, Junnila 1998, Anon. 1999, Clements-Croome 2000, Aleksander 2001). The outsourcing of the facilities management makes the empirical building information better documented than before.

4.4.2 As-built data

Still, a problem of information gaps has to be mentioned. In Finland, the authorities receive the design drawings after the design phase of the construction process, but the as-built drawings are not compulsory after the construction phase. However, many changes occur after the design during the construction phase, but in most cases, it is impossible to hand over *the as-built data* at the end of the construction project. Repairs and renovations are difficult due to the lack of perfect information about the final solutions in the buildings. As-built

drawings are a part of the basic information to form the databases for the management, service and maintenance, as well as for refurbishment and modernisation. If they are missing, various methods for video measurement, thermographic survey, etc. are used to generate the information afterwards.

4.5 Information Service

Traditionally, databases were produced and hosted by *university libraries or government institutes* in different branches. Information services have been among the pioneers in using computer science in data storaging, in reference management, in searching by using keywords or parts of text, etc. and in creating full text and hypertext databases. Industrial enterprises, even if they lack such resources themselves, will increasingly use such services. The library's and other information services' basic function in providing information support for businesses, teaching, study and research will remain the same even in the information (network) era, though their procedures will change. *Commercial information service enterprises* have entered the branch, and a few of them play a significant role in the market and work together with libraries.

ICT has been long a promising tool for getting the right information at the right time. At the present age of growing supply in the Internet, a variety of non-traditional Electronic Information Services (EIS) suppliers abound. The data retrieval of the *modern information service* is good, but still developing (Lehto 2000). The power of search engines is questionable, according to the Cyveillance study (Arlington in Lehto 2000, p. 20), for example.

The dissemination and search mechanism for electronic information sources is a prime feature in the creation of information flow (Martiskainen 1993, Lehti et al. 1999). Both data storing and information transfer are involved. Working hard to ask the right questions is the basis for using any information system. Finding right *keywords* is ever important. The keyword lists of each subject grow longer (Lehto with al. 2001b, p. 27, Lehto 2000). The keyword selection is related to the *web page design or metadata design*, of which several good guidelines are available (cf. Lehto 2000, p. 25).

Best information sources are easy to access and use, accurate, carrying well-checked knowledge, and giving information of several alternatives. On the other hand, despite the fast progress of the EIS they can lack knowledge of practical experience, and relevant information can be lost in the vast information flow (cf. Section 4.3.). Absence or failings of relevant information, or problems in the information transfer violate the necessary information flow for business relations.

New media is a controversial term, very often connected to advertising in the Web. New media serves a number of purposes, ranging from games and entertainment to producing home pages, from constructing electronic "shops" or marketplaces for commerce all the way to fact and reference books available on off-line media or on the Web (Lehti et al. 1999). According to a more precise definition a new media company is involved in digital media (incl. multimedia and CD-ROM) and/or information networks, e.g. the Internet. Its activities cover content production, electronic selling, consulting, training, distribution, publishing, and acting as an operator, etc. A new media company can be anything from purely system and software solutions to a content provider (Lehti et al. 1999).

4.5.1 Changing role of information services

The number of actors in the information service sector is growing and the roles of service providers are changing as mention earlier in section 4.3. The word professional, in the context of information service, denotes electronic information services (both online and off-line) used mainly for professional purposes in the working places (e.g.

an enterprise, a research organisation or a government institution). To distinguish between professional and consumer EIS is sometimes like drawing a line in water. Besides, products and services now used for pastime or entertainment purposes may well pave the way for future use for more "useful" or professional purposes.

Despite modern search techniques, references have to be *read and understood* and the relevant pieces have to be sorted for particular use (cf. Section 4.8.). It is therefore best to find a source which is based on expertise. Thus, the information transfer cannot be yet substituted completely with the electronic information sources (Lehto with al. 2001b, p. 23, Lehto 2000). The *recommendations of an expert about the source of valuable information* is still appreciated both among scientists and industrialists.

In the future new media can also be able to generate a form of information , which can solve the problems due to the mismatch between scientific information production formats and the needs of the industrial information (cf. Section 4.3.).

The dissemination of information in new media should be done by using *checked references*. The use of EIS and electrical libraries, especially those of scientific origin is a guarantee for checked information. In a whole, the problem of the reliability of the world wide web information is an open question.

4.6 Design Methodology

The building information is made available throughout a buildings' entire life cycle (FIG.2.). All this can be done - thanks to the data processing capacity of the computers - in three dimensional (3D) space, and in 4D, which means that time is the fourth dimension, and thus construction information is rendered to a video format instead of still images. The manual design is presented in general in 2D, because of the time consuming manual work needed for perspectives.

Current CAD software operates for separate system architectures of designers and constructors, as well as that of facilities management. New software is able to link design, construction and maintenance information databases. It is possible to connect databases of electronic libraries, and those of information services and other information sources to the design information networks for generating information chains of land use, design, quantity survey, maintenance, etc. However, the information life cycle flow of the construction information is not continuos due to previously mentioned needs for enhancing the system (cf. Haugen 2000).

The virtual engineering and architects' office concept in the ICT networks can easily employ the construction project data shared by remote partners, even in international construction projects. This type of CAD tools translate the information data banks into a form that is compatible with the World Wide Web, and provide an alternative for the easy access to construction information either within the construction project or within companies of the building industry, as well as to the non-project oriented data banks.

Despite the sophisticated design methods, the utilisation of them, especially those introduced recently, is not very common among the building process stakeholder at least in Finland, which however is not the least advanced in the area of utilisation of CAD and ICT (SuPRO project 2002).

The usage of the 3D and 4D design tools is sensitive to the purpose of application. The matter is explained in more detail by a couple of examples. They are powerful tools not only for the designers for judging of design quality, but also for decision makers, such as politicians, who have to decide whether a future project should be built or not. The difficulties in using 3D or 4D tools may appear when they are to applied for modelling navigation or orientation in space. The design tool calculates distances, but the human orientation is based on

landmarks. The information provided by the tool and the manner of comprehension of the user do not match. If filmed video is used instead of the design model, the end user interface is better. The landmarks tend to change as time passes and repetition of filming is needed.

The information science has adopted the idea of usability. It is used for the user interfaces of the databases as well as for the user interface of ICT tools, such as computers and phones etc. Usability connects the machine's ability to offer information and the human ability of comprehension, a phenomenon which will be discussed further in paper later (cf. Sections 4.8. and 4.9.).

4.7 Intelligent Buildings

The IB (Intelligent Buildings) overall system is in most cases *tailored for each building*. It is based on the system design, the control algorithms and the building project data. The connection between construction information system design and intelligent building equipment is under R&D work in many building automation companies. Particularly, the combining of the building automation to parameters of high quality indoor air establishment and those of the energy efficient solutions is common. The possibility of interaction between the systems is a consequence of the use of internet and web technology for both the building automation and CAD.

Increasingly powerful microprocessors and network technologies provide the building manager with an information intensive environment never before seen in the industry. The idea of connecting, integrating or opening facilities management and building automation systems in order to achieve a unified software architecture by extending the functionality of a standard management tool so that it is capable of handling FM and building control networks, is essential in practise, because of the demand for efficient built environments, the high costs of purchasing, running and maintaining various systems, the data redundancy, as well as because of the co-ordination of multi-vendor systems easily leads to fault situations (Thompson & Plouffe 1999, Redleim & Schmildt 1999).

The discussion on the combination of two new concepts: those of Intelligent Buildings and Facilities Management has started (Thompson & Plouffe 1999, Redleim & Schmildt 1999). The combination of FM and IB has been called *Integrated Facilities Management* (IFM), although any official agreement of the definition of IFM does not exist. Lack of single providers for an integrated IB and FM system is obvious, while only some of them exist (Anon. year unknown, Anon. 2000, Anon. 2001).

The complete rate of IFM services can include such services as (Anon. year unknown): *Security, Catering, Cleaning, Reprographics, Reception, Landscaping, Post / Mail Room, Porterage / Messenger, Office supplies, M&E maintenance, Fabric maintenance, Energy management, Health, Safety & Environmental services, and Office services.*

This work is based on industrial standards, and on business practices within the scope and goal settings of each company. Thus the concept of the connectivity to the construction information flow is lacking, and definitions and specifications for this connection are missing. There is a need for specifying the *information transfer from building data bases to the building automation overall system* (FIG.2.), and the need of standardised, open modules to the intelligent building information and automation systems is obvious on the customers' side.

4.7.1 Values and decision making

The values of any actor are affecting the choices which are made. An simple example of the importance of the values is the purchase of a painting. A certain painting is not valuable at all for some of us and they will not buy it. For another person it worth of a certain amount of money and someone is willing to pay even more of it.

Yang and Chang (2000) have approached the problems of the construction information flow and the understanding of the intelligent buildings as follows:

> "The intelligent buildings (IB) concept is more *popular with researchers and academics than it is among building professionals*. As new products and technologies are emerging, this problem seems to be more evident as the gap widens between available intelligent buildings technologies and the actual number of buildings incorporating IB concepts.
>
> There are many possible reasons for this gap. One of them is the lack of information and understanding of intelligent buildings among owners and developers of commercial buildings. Developers, with *typical least cost mentality*, often consider intelligent buildings expensive to build and maintain. They lack true understanding of the IB technology and information on life-cycle costing of the project. As a result, they often fail to consider the efficiency and flexibility intelligent buildings can bring to their tenants and users, therefore increasing leasing potential. In addition, as architects and engineers develop new designs of flooring systems and energy saving HVAC components, there are no appropriate channels for the dissemination of these new concepts to would-be users and developers. At the same time, building contractors feel reluctant to take on these concepts in their products fearing that it will make their job more difficult and increase project risk and costs. Again, *lack of knowledge and appreciation* on intelligent buildings plays an important part.
>
> To rectify this problem, a research project is being undertaken in the Queensland University of Technology, Australia, with an aim to develop a knowledge based system to provide information and decision support to building developers and potential users on the adoption and application of IB technologies. It involves several major stages of development, such as scope definition of IB applications, categorisation of IB technologies and extraction and formation of decision-making processes of design teams and developers. Unique mechanisms for simulation and knowledge representation developed for the system allow the simulation of *decision making models* while maintaining system flexibility. The incorporation of life cycle costing analysis into the system adds another dimension and creditability to overall process of the identification, selection, evaluation and feedback for the application of IB technologies."

The design of technical systems is a decision-making problem, in which the functions of the system are selected on the basis of evaluation of many different variables, which describe the features of the system. Alanne (2000) has in his licentiate thesis described the decision-making problem of the system design and presents a method for a system configuration tool. The system configuration tool has four functions. It acts as a data management tool, formulates different possible system alternatives as a combination of functions, compares the system alternatives on the basis of the value analyses and gives recommendations and prints out the data of the system.

This is a new and developing method for decision-making. The method is an evaluation process of different variables. In every case, the value analysis of the design system is influencing the result (Alanne 2000, p. 66). An analogy can be drawn between the value setting and the need of appreciation, of which Yang and Chang are writing. The one that is considered valuable, will be included in every system, and will end up in the information system. There can be valuable information which is not considered valuable, or it will take time before it will be valued enough, approved and end up becoming common knowledge.

4.7.2 Valuable information unused

Lack of appreciation is not the only reason for leaving valuable information unused. If enough information is available and it is easily accessible, a reason why, for instance, the adoption of the energy efficient construction is slow, is the fact that the designers are afraid of using new ideas and technology in their buildings. Practically, it is wise to avoid untested solutions. But even applicable working solutions might be left out, because of the fear of lack of accepting attitude among customers (Kasanen & Persson 1997 in Lehto 2001b, p. 108).

4.7.3 The end-user empowerment and usability

Despite the short lifespan of the IB concepts and the lacking connection between CAD data bases and building automation, an end user driven office automation equipment is under development (cf. www.ebob-pro.com). The aim is to be able to motivate office workers to save energy. Influencing the end user behaviour may be the next step in saving energy in the IBs, where the energy consumption is already reduced by advanced technical solution to the one quarter of the nominal energy consumption. The selection of the relevant design parameters to be submitted to the end user control is as difficult task as that of understanding the cognitive decision making models of the office workers, who make choices over indoor air quality. Further more, correct information for motivation algorithms is needed for promoting the energy efficient actions.

It is not only the task of information services to encourage end user to use themselves information (cf. Section 4.3), but it is the task of all sectors of the construction as have been seen from this effort of the building automation. This phenomenon is discussed more in next section (Section 4.8.4).

4.8 Human Knowledge Skills and Information Gaps

The information cannot reach a person, if the message is not understood. *Communication and comprehension* is needed. A well known fact is, that the difficulties in communication are true, both in face to face contacts, and when technical means are used for information and communication.

The transparent ICT information flows, increasing interest in consultation, networking, electrical libraries and other information services are all easing the access to (scientific) information and helping the user feedback information flow to run.

Comprehension, as well as, information retrieval is confusing, also, because of the *various types of information* (FIG.3.) (cf. Keskinen 1999, p. 42).

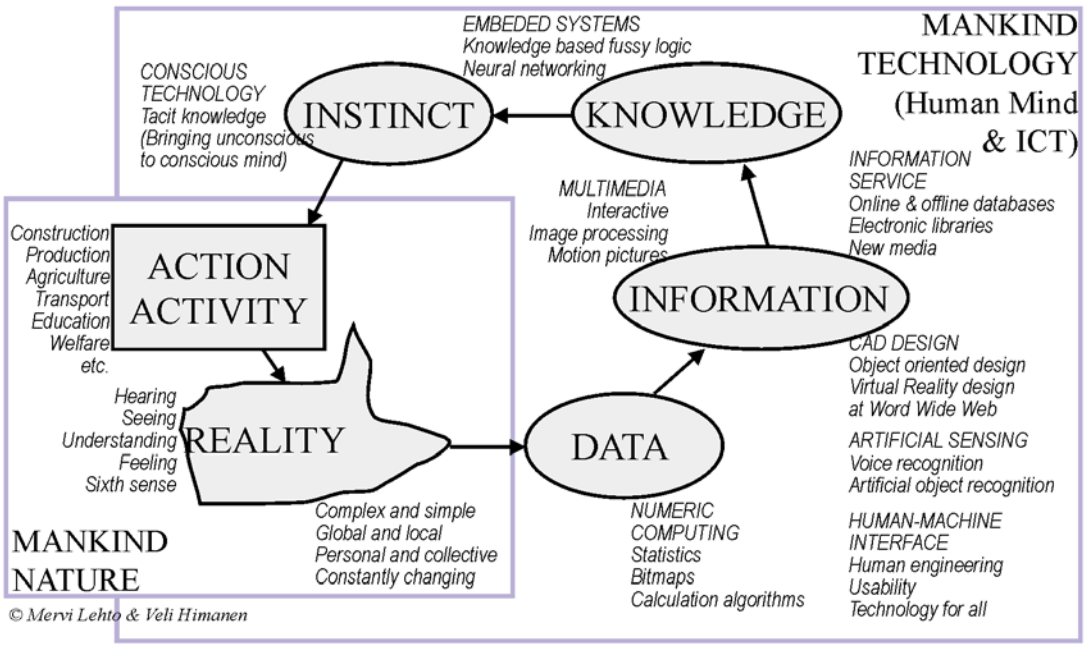

FIG.3: The information types and their expressions in the data processing systems (cf. Himanen et al. 2000, Lehto 2000)

4.8.1 Need of the face to face information exchange

Continuing human contact seems inevitable despite the growth of ICT systems (FIG.4). In business life, growing complexity and globalisation make meetings ever more necessary. Sometimes, it is simply comfortable to meet and work together, and it is important for close relationships or warding off loneliness etc. Meeting means travelling. Travel and ICT are both growing fast (Lehto and Himanen 2001), although their growths are not inter-dependant, as the growth of travel and communication used to be earlier (Himanen et al. 2000). However, the speed and effectiveness of the exploitation of global business opportunities would not be possible without the latest efforts in ICT. This is as true in the disciplines surrounding construction industry - engineering, design, construction, architecture and facilities management, etc. - as in all other areas of international business.

The information exchange is enhancing because the information intensive work is based on *teamwork, co-operation and networking* (Keskinen 1999, Tuomi 1999). It is not possible to manage with superior knowledge and skills alone anymore. Instead managing is the skill to collect experts together, and get and let them work for common targets. Still, the human tendency to stop the flow of information by silence or some other means can be a serious problem in information sharing even in the knowledge work (Keskinen 1999).

Teams do not necessarily work at a same spot, although connectivity and trust between workmates is more important during the information era than before, during the industrial age. Connectivity and trust are created by means of communication or they are due to personal characteristics of the team members. Constantly changing teams can benefit out of the sophisticated spatial solutions (Lehto 1996, Lehto 1999). Particularly, this will be the future challenge of the construction industry in workplace design, if it can follow the progress of its clients' businesses and take into account the needs and wishes of the clients. This feedback information becomes an

important information source for the RTD of the workplace design. The importance of the feedback information cannot be underestimated in other areas of the building industry either.

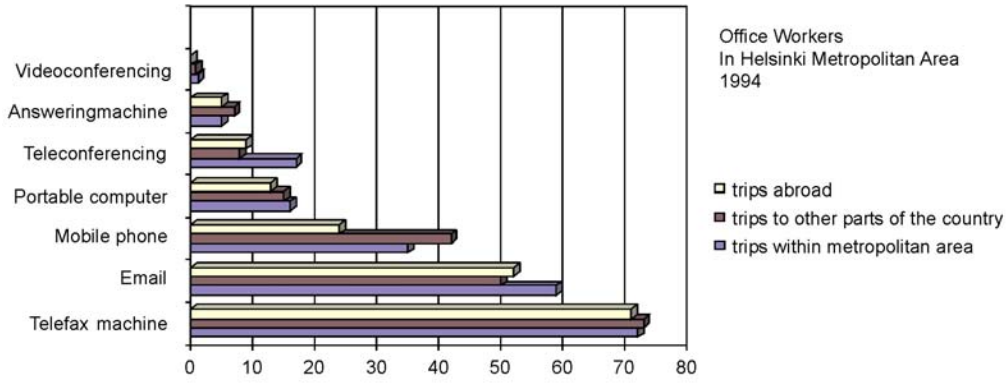

FIG.4: The usage of ICT tools in business trip substitution in twelve office buildings in the Helsinki Metropolitan area in 1994 and 1995 (Lehto & Himanen 1998, cf. Lehto & Himanen 2001a)

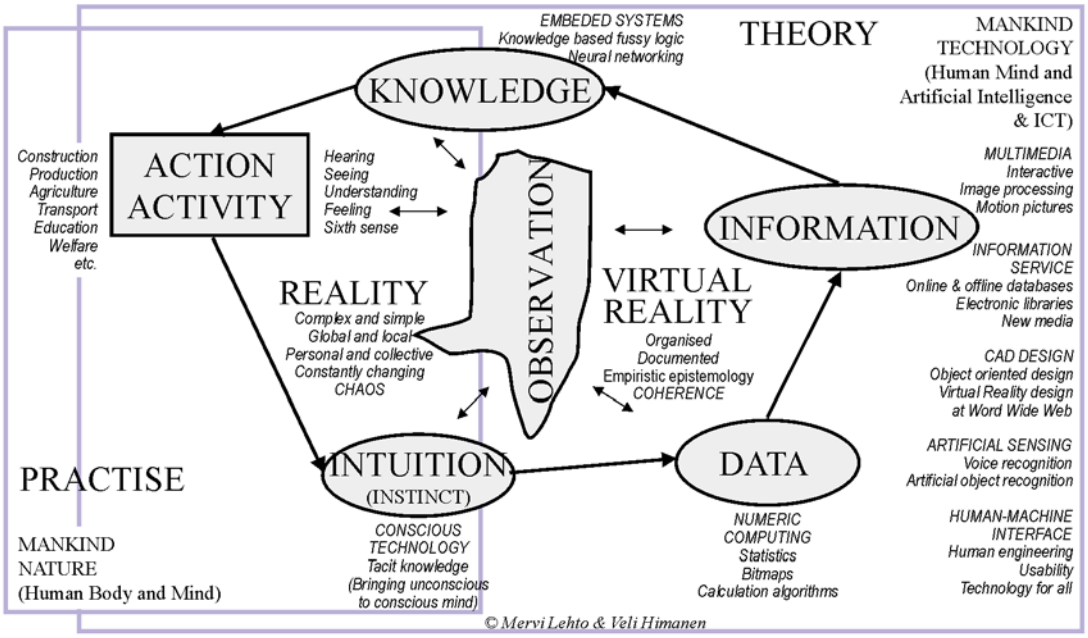

FIG.5: Transformation of information types and human observer

The choice between *face to face conversations and a computer-aided* one has great influence on the status of understanding. In choosing either a computer aided mean for information exchange and communication or a face to face one, the type of information is relevant, because it has great influence on the status of human understanding (Lehto & Himanen 2001, Himanen et al. 2000).

4.8.2 The skills of a computer

The possibilities of a computer to communicate in a human manner are limited. Despite the fact that ICT may be superior in memory management, and tireless in repetitive calculation, or giving endlessly the same advise by interactive education databases, etc., it cannot provide the end-user with information in a manner which matches the subtleties of human communication (FIG.5.). A computer can repeat the fact from its memory in different combinations, but its possibilities in writing creative ideas or code is limited. Although, serious attempts towards a 'conscious' computer are being made (Haikonen 1999). Work within artificial intelligence and, for example, the wider understanding of tacit knowledge phenomenon will enhance the knowledge on differences and similarities of man and machine and understanding of their relationship.

4.8.3 Dependency of the type of task

Although theoretically it seems obvious that routine tasks can more easily be substituted with ICT systems than the non-routine ones, paradoxically, in practice this is often not true (Lehto & Himanen 1998). At least, in occupants' opinion of the offices in the Helsinki Metropolitan area, the modern ICT is able to transmit non-routine information to certain extent, and the business trips for information exchange can be avoided for example in such cases as knowledge dissemination and education in seminars and conferences.

4.8.4 Need of guidance

On the other hand, an interesting curiosity of the buildings information management was found. The office workers prefer a building manager, whom they can meet, to an intelligent buildings management system (Lehto 1999). The need of information of how to use the ICT tools, office and building automation equipment is also obvious among office workers, of whom majority have an academic education and are thus capable of understanding and learning the use of new technology (Lehto 1999). A reason for the fact is, that it is not enough to trust on manuals in information provision of the usage of new technology. Education and personal guidance is needed.

4.9 Modelling Information and Understanding

When modelling the information's role in the substitution of the business trips with Stella program (Himanen et al. 2000, Himanen & Lehto 2001) the modelling starts from a theoretical chain, where reality is described by data, which is combined to information and which then can be used for increasing knowledge or understanding (FIG.6. and FIG.7.). Increased knowledge is used for an action, which changes reality - not necessarily in the same place where the chain started.

The necessary exchange of information can happen with the aid of telecommunication or at a meeting, which usually requires travelling. It can be assumed that transforming information into knowledge is a central element in all information intensive work. The system dynamic model estimates time needed for transforming information into knowledge in different occasions. Time needed for transformation is often a critical factor when pondering between a meeting -needing travelling - or using telecommunication.

The model describes the interrelationships between the source of information and the receiver. Both the source and the receiver can represent a person as well as a working group.

Knowledge is accumulated in the model according to the amount of received information. The efficiency of receiving depends on the characteristics of communication. The model assumes that necessary information is

available from the source. In the beginning information is flowing at a steady speed, for example, according to the reading speed or the speed of information transferring. With the accumulation of knowledge the receiving of information is improved, because it is then easier to pick up relevant information. Simultaneously forgetting is reduced, when the remembering of information is supported with the images of accumulated knowledge.

The model runs proved that the suitability of communication devices has a decisive role in the accumulation of knowledge (TABLE. 1.).

TABLE. 1. Time needed for the accumulation of understanding in relation to the effectiveness of communication facility

Effectiveness (Scale from 0 to 100)	Time (h)
20	11
40	5
60	3
80	2

When the quality and efficiency of telecommunications are continuously improved, the time needed for understanding various tasks becomes shorter. This kind of development decreases in principle the need for travelling. However, it can also be thought that in the world of increasing change - a typical feature of the information society - it is all the time more difficult to understand current issues, or at least, thorough thinking and good ability of understanding various types of messages is needed. This is how complexity becomes a feature of the information society. It is also possible that people will move from simpler tasks towards complicated ones as soon as they can manage these. In other words, there is no stable set of problems, which are repetitively worked out, but a continuously changing world, where new demands emerge as soon as easier problems have been solved. It is not necessary to travel for thorough thinking and good understanding of various types of messages, but often the personal information exchange speed up the information exchange and learning.

Model runs proved also that the time needed for understanding increases in relation to the difficulty of the learning task. The difficulty can depend, for example, on the low level of knowledge at the starting point. Then the need for personal guidance also increases which in turn makes travelling more probable.

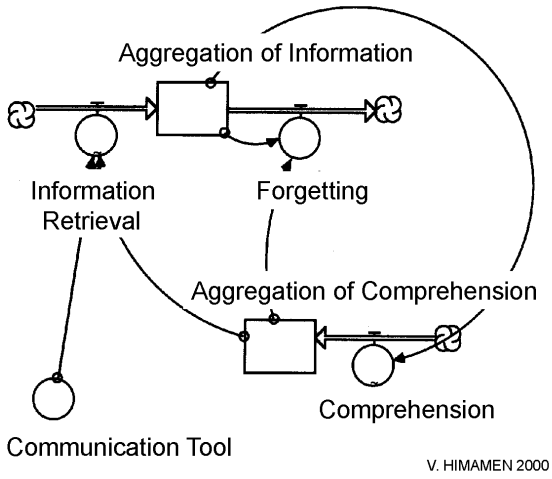

FIG.6: System dynamic model; from information to understanding

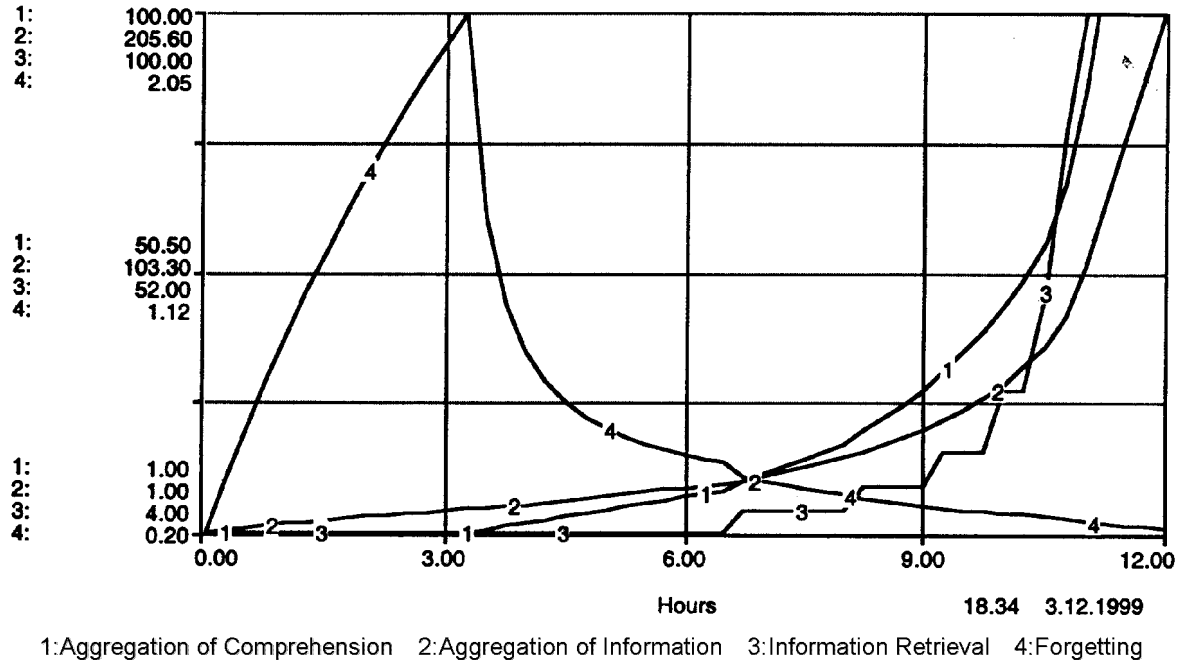

FIG.7: Modelling information and understanding

4.10 Status of Facilities Management

In general, the buildings have not been considered to act as active tools for increasing occupants' productivity and business profitability. In the industrial businesses buildings are *not seen as strategic tools for business.* They can be listed among production factors, but they are not necessarily seen even as investments, which should repay their costs. During the discussion among the members of the Thematic Network of EuroFMWorkspace - project it became clear, that the position of the FM in the industrial companies' decision making may play a minor role.

The research on the buildings acting as an active asset for improving productivity has not been on the main stream of the R&D work on productivity in industry or in service sector. In regard to business transactions the buildings have been considered as a necessary shelter causing only extra costs (cf. Lehto 2000, Thompson & Plouffe 1999, p. 274). That is why they have been built as simply and inexpensively as possible. Consequently, it can be stated that despite many feasible building projects, the fact that the space has been disregarded as one of the profitable business assets has diminished the efforts for developing buildings in accordance to the changes of production in a preventive and systematic manner, instead of ad-hoc type, last minute changes, which are fairly common.

The building sector has a *growing interest* in the progress of asset or property management and FM paradigm, which is confirming buildings' position in profit seeking. The success can be measured not only by productivity in asset and building management and construction, or by energy efficiency, but by the productivity of tenants' businesses, and other benefits in consequence of the R&D work on workplace environments, which are not yet explicit (cf. Anon. 2002a, Anon. 2002b, Anon. 2002c, Anon. 2002d, Anon. 2002e, Anon. 2002f, Becker & Sims 1989, Granath 2002).

Even during the information age the trust on the constant need for goods remains. However, the value of the business is added by ICT - the fourth production factor. At the same time the possibilities of making money out of the construction information itself increase. The international market is reached easier than ever via communication networks. The competitive weapons of the facilities management business of information age arise from the synergy of the development of the construction processes and that of information services (Lehto 2001b, pp. 20-21, 128, 130-131, 141). It is the chance of or the challenge for the domestic construction to become a operative partner of international business activities. Roughly can be concluded that the construction industry is domestic based in almost every country, and the phenomenon is shared intercontinentally.

Given a tradition of informal communication and decision-making in issues relating to space management, problems arise with outsourcing and increased staff turn-over. The way *outsourcing* is being used poses problems for adopting an holistic approach to construction. It is difficult to get an overview, and developing and maintaining knowledge in the construction field gets more difficult. What is the optimal communication structure for such a situation? Although modern production depends on supporting activities, these are not recognised as part of the production process. In some cases, outsourcing helps realise the respective responsibilities between production and support activities, and measures the value of both. Many of these responsibilities concern co-ordination which might be done more effectively if it was done more openly. The implications of the changes should be studied. The implementation of the lean production principles into the construction process might have similar effect. Furthermore, the skills in handing investments, flexibility and the ability of risk-taking are keys to the success in construction (Puskala & Kähkönen 1999).

4.11 State of the Art of Knowledge Work in Construction Industry

Each sector of construction is *under constant development*, which since 60's has meant increasingly integrating and embedding (merging) the ICT to existing products, systems and methods. The progress of ICT is universal. However, the digital technology is not the only tool for increasing buildings intelligence, but all means from mechatronics to biotechnology are used in the intelligent buildings and building component development. Intelligent, green and healthy is the latest keywords of building technology describing the various approaches to the building phenomena (Lehto 1999b).

The *financial input for research and RTD* of the construction industry is not very high, and in Finland it is one of the lowest of all sectors. This is a fact, which makes it difficult to talk about the construction industry as a very innovative and dynamic industry although as argued in the previous Section 4.3. about "Scientific Information Generation Versus Industrial Information Needs", the same business opportunities than for other industries lie there also for the building sector (Lehto 2001b, p. 141).

Within the business of architecture, civil engineering and construction, as well as asset and facilities management the *international projects* have so far been more an exception than a common practise. The information society is expanding simultaneously globally and locally. As mentioned already, the use of ICT in construction and the IB concept might bring with it the change from local to internationalised construction industry (cf. Sections 4.6 and 4.10). If by the means of intelligent construction industry is not in the first place exporting whole houses, the ICT and intelligent solutions can mean export of intelligent building products. Computing and software business have blazed a trail for this type of progress. Information and communication as well as intelligent building technology can serve as expert knowledge in the export of international consulting engineering.

The RTD of construction information management help parties in construction projects to form networks and share project data in networks instead of paper information. The construction design projects taken place in VR support internationalisation of construction industry. The virtual office possibility makes it possible to work with design databases at word wide web, which actually forms the VR office for the designers who are located in different locations, even in different countries (cf. Section 4.6).

At least in Finland, it seems relevant that the construction industry professionals might in certain areas have *no interest in applying new technology*, such as sustainable development although the market demand exists (Lehto 2001b, p. 125). This same finding is made in Israel among transport specialists (Salomon 2000). New ideas might even be considered as a threat to the professionals own expertise, which is based on aged paradigms of construction knowledge. Locality is limiting the possibilities of adoption of new information. The R&D work in construction industry is still focused on technology push type approach, and understanding of market pull type approach to the R&D work is under development (Lehto 2001b, pp. 126, 139, Lehto & Himanen 2001b, Himanen & Lehto 2001). The full understanding of the meaning of the commercialisation hides behind the strong technological concern (Lehto 2001b, pp. 134-135, 137-139). Accordingly, the information needs of the industry are not fully developed in terms of multidisciplinary sciences, which at least within the scope of the research in European Commission projects during the Fifth Framework Programme has included the combination of technology, economy and sociology.

5 DISCUSSION

5.1 Concept of ba

Ba means space, where boundaries between individual and collective minds become diffuse, and the knowledge creation spiral can escape to a new level of analysis (Nonaka and Konno in Tuomi 1999, pp. 323-326, cf. Nenonen & Hendriks 2000). This space can be concrete, e.g. office room, virtual, e.g. video-conference, or mental, e.g. shared ideas and values (Nenonen 2000). The knowledge creation means the creation of various bas into the organisation.

The concept of ba is a very interesting theory on the behalf of understanding the knowledge of construction, because ba includes the idea of a concrete space, and the other more soft forms of knowledge. Within the construction science ba can, most probably, be used in various contexts from organisation theory to building design.

The most used part of the concept of ba is the model of the transformation phases of knowledge (Nonaka & Takeuchi Tuomi 1999, p. 324-326). Both the building project information and the non-project oriented building information are articulated and well documented forms of knowledge (cf. Tuomi 1999, p. 100), which means that, they are explicit knowledge. The explicit knowledge can be found by digging into the design guidelines and other non-project oriented information sources, interviewing experts, etc. The concept of information of the explicit knowledge is quite clear.

The tacit knowledge emerging in construction is a new phenomenon, and perhaps not so well articulated yet. All artefacts or industrial products are results of human intelligence, which human has borrowed to the man-made object (Tuomi 1999, p. 131). The buildings can be an articulated form of construction tacit knowledge as all artefacts can represent the tacit knowledge of the line of business they belong to (cf. Bergson in Tuomi 1999, p. 114, Gregory in Tuomi 1999, p. 114, Vygotsky in Tuomi 1999, p. 114). The buildings themselves can be built by using a combination of explicit and tacit knowledge.

Without venturing deeper to the phenomenon of various forms of building knowledge, it can be concluded that the gaps in the construction information flow (cf. Section 4.4.) represent one, some or all forms of tacit construction knowledge (cf. Tuomi 1999, p. 100). They are entering the explicit form, because their names have been articulated in linguistic form and they are common knowledge, but their content and essence are not shared within the industry, which still keeps them in the state of tacit knowledge. For example, public information of the end-user feedback is a way of making the tacit knowledge of the construction process explicit, or to be more precise to speed up the process of knowledge emerging in explicit form instead of the previous, tacit one.

There are many means of speeding up the transformation of construction knowledge, and they are worth further studies. They all are related to construction and building information management. This process means also the growth in consciousness on the behalf of the construction and building knowledge among those working in the field.

5.2 Formulation of paradigm

Hall (1999) is in his throughout description of Cities in Civilisation discussing shifting paradigms. He is referring to Kuhn, who suggested that there was ´normal science`, which scientists accepted for a time as a basis for everything they did, because it seemed to work for them. They accepted a particular ´paradigm`. Kuhn argued that, at particular points in time, scientists would become aware of anomalies in their world view; they

would find things that the prevailing paradigm would not explain well, or not at all. Science would then enter a revolutionary period, on which the old paradigm would be scrapped and a new one developed in its place. Applied to science, Kuhn's theory has become almost commonplace.

The period of information science can be related to the above mentioned revolutionary period of science. In futures studies, a approach to the phenomenon of information era is, that it is considered to be a relatively short period of change - around 30 years. Castells is calling it the third industrial turning point (Castells in Himanen & Lehto 2001).

In the information age, the revolution is concerning the information itself. Various forms of the concept of human intelligence (FIG.3., Tuomi 1999, pp. 105-191) has emerged. One of them is information.

6 CONCLUDING RESULTS

The previously explained results are summarised in the Tables 2-4. The tables show the parameters of information management divided into groups of informatics (TABLE. 2), technology (TABLE. 3) and organisation (TABLE. 4). The strength is seen in the new means of information sharing, but also the weaknesses of the current information management are pointed out in the last columns of the tables. The phenomena which make the change happen or speeds up the progress are listed in the column called bridges.

TABLE. 2. The solutions and problems of informatics

	Parameters	Strength	Bridge	Weaknesses
Building information flow	Project and Non-project information	Structured easy access gateway to information Encouragement and empowerment of the simultaneous existence of several information providers	Several stakeholders	"Wild" networking Conflicting information service business activities and lack of co-operation
Information needs of the industry and the form of information provision	Scientists - Industrialists Basic research - Applications Long term R&D - Short term profit	New media	Designers Co-operation Information service	Conflict of publication and patents (confidentiality)
Lack of Information	Feedback	Knowledge transformation from tacit to explicit	Transparent team work without killing information	

	As-built drawings Confidentiality	from tacit to explicit	without killing information exchange with silence or human other means	

TABLE. 3. The solutions and problems of the information technology

	Parameters	Strength	Bridge	Weaknesses
Information service	Libraries Institutes Information Service	Electronic libraries	Keyword lists Web page design	Unchecked references Misunderstanding
Design methodology (CAD, VR)	Computer Aided Design in Virtual Reality	Design dimensions		Links to information sources lacking
Intelligent Buildings	Building specific systems (tailored) Academics - Professionals		Knowledge exchange and appreciation Decision making models	Information transfer from data banks to building automation

TABLE. 4. The organisational solutions and problems of the information management

	Parameters	Strength	Bridge	Weaknesses
Human intelligence	Communication Comprehension Information types	Modelling of comprehension	Team work Networking Face to face contacts	Problems of the information gaps due to incomplete comprehension Unpopularity of phone and video conferencing
Status of FM	Building is not a strategic tool of business Outsourcing	Integrated Facilities Management (IFM)	Growing interest in asset or property and facilities management	New area in building industry
Knowledge work in construction industry	CAD Quantity Survey	?	Market Pull or End-user oriented construction concept	R&D input Locality

	Material and information handling of sites and construction process		construction concept	Technology Push Lacking interest in new ideas among professionals

The parameters of *informatics* in the building information flow consist of two types of information sources: project and non-project oriented information. Both the information creation and usage of it have several stakeholders. Information creation is happening in various institutes and companies within the industry and thus it can be described to be a decentralised information management system, which cannot work effectively without a structured information dissemination system, such as a gateway with an easy access user interface based on careful systems planning and thinking and modelling of human cognition and understanding.

The differences between the forms of information in information needs of industry and in the information provided by the information providers, especially that provided by research is challenging. The time span of research and information creation in general might sometimes be long, and on the other hand the industry needs information and knowledge on a short time scale of profit making. Scientists' funding is dependent on the number of publications, but the exploitation of the new knowledge needs confidentiality and protection of patents. Information gabs and the slow process of the information transformation from tacit to explicit are in many cases due to other than technical lacks of the information system.

The databases, especially those in the world wide web include unchecked information, information transfer between various construction sectors and building specific systems is not accomplished yet, and misunderstanding is not always avoided. Correct keywords and structured data bases help in information access. Knowledge exchange and sharing, appreciation of all different stakeholders in the construction field and decision making models are tools for ever better information transfer.

The *technical development* has been perhaps the most progressive part of the building information management development both in information services and in the building industry. The enthusiastic technical progress in various sectors of construction business has lead to many sophisticated information systems. However, links between databanks are not yet working user friendly enough, the information access technologies such as search engines are not accurate enough, and sometimes the way of information handling of the machine does match to that of the human comprehension. Many expectations of easy accessible information channels are put to the progress of new medias. The driving forces of that development are both within the construction information management development and also in any other field of business.

The *organisational* matters have become even more important in the knowledge intensive work. Human intelligence or social skills, open communication, trust on fellow workers, etc. are important in the transparent business environment of information society. On the other hand, modelling of comprehension can bridge the information gaps due tot he differences of the human comprehension and the machine information handling formats.

The stakeholders of building sector are working for getting the building as a strategic tool for other businesses, while so far it has been seen as a necessary costly shelter. The organisational status of FM in companies, as well as the state of the art of knowledge work in construction industry needs modernisation. Outsourcing and Integrated Facilities Management work for this target. The market pull from consumers' side, and the SME's

ability to answer to this market demand together seem to advance the construction field more than the technology push type attitudes of some building professionals.

What else can market the high class knowledge of construction better than the correct information dissemination to the outside stakeholders. Information dissemination can make the change in appreciation of the building industry happen.

7 CONCLUSIONS

This study is bringing forward several issues, which influence the information flow of the construction industry, and consequently, on the R&D of CAD systems. The CAD system design is mainly a technical phenomenon. However, there are several other factors effecting the development of CAD design systems. They have not been considered so far to be part of the RTD of CAD systems. They are either from information science or included to the organisational or human matters. CAD has a strong role in this field of several actors, and it can benefit of the challenging development of the fields or sciences, which are related to CAD or solving the common problems to all sectors in information handling.

Information management throughout the entire life cycle of a building is very important in the modern construction process, while it forms a base for a broader application of sustainable development both in ecological and human respect. Knowledge is the money making tool in the information society. The construction industry is an intensive information processing industry due to the uniqueness of each building project. It is widely accepted that the vast amounts of project's information can be extracted from the project's drawings and from the CAD databases. The information management has focused either on the construction information service or on the database management of the CAD systems.

The answer for a specific information request can still be best found by various means, also other than those of the ICT. Various aspects, such as, [1] the type ICT, [2] the type and form of information, [3] the possibilities to understand the message, [4] information availability and gaps, [5] the purpose of information usage either scientific or industrial, [6] the type of buildings, for which the information is needed, and even [7] the status of the stakeholder in need of knowledge, all affect on the accessibility of information.

Such means as information gateways, new media, electronic libraries, CAD in VR, and IFM, as well as modelling of comprehension and information sharing of knowledge transformation from tacit to explicit are working for the common goal, for making information access easier. Still, managing the integrity of construction information flow is a target to hit in the future. Building up new information structures and keeping up relevant information flow in the world wide scale for global, constantly changing and complex businesses is not an easy job. The multidisciplinary nature of the task including informatics, information and communication technology and organisational aspects of the human information handling is making the task ever challenging.

8 ACKNOWLEDGEMENTS

On the behalf of the INFOTECH study the authors like to thank Dr. Mika Mannermaa for co-work and information sharing on economics and futures studies expertise.

On the behalf of the EuroFMWorkspace project everyone of the thematic network members has been important in creating the visions of the future workspace and thus the authors are thanking especially Professor Anders Törnqvist from University of Karlskrona (Chalmers University of Technology), Professor Kari I. Leväinen from

Helsinki University of Technology, Emeritus Professor Thomas A Markus and Professor Keith Alexander from CFM University of Salford, Professor Frans Van Eijnatten and Professor Jimme Keizer from Eindhoven University of Technology, Mr. Aulis Kohvakka and Mr. Tommi Väisänen from ABB Current Finland Oy, Mr. P. H. M. Schless from Philips Components BV, Mr. Hasse Spetz from VOLVO Car Corporation, Mr. Bill Weald from Rover Group Limited, Mr. Bert Zwikker (Euro FM), Mr. Mats Österblom from LM Ericsson Fastigheter AB, and Mr. Tommy Östman from Thorsman & Co AB.

On the behalf of the study of the commercialisation of the technologies developed in the RAKET research programme the authors like to thank all those representatives of the companies and organisation, who devoted their time and expert knowledge to answering the interview. As well, the authors like to thank Dr. Pirkko Kasanen, the leader of the LINKKI 2 Research Programme for the good collaboration during the project.

9 REFERENCES

Alanne, Kari. 2000. Menetelmä järjestelmävaihtoehtojen muodostamiseksi rakennusten energiajärjestelmien suunnitteluprosessissa. Licentiate Thesis. Lappeenranta University of Technology. 1.12.2000. 70 p. (in Finnish)

Aleksander, Keith. 2001. Managing Occupancy for Productive Workplace. In: Leväinen, Kari, I. (ed.). Facility management and service concepts. International research seminar on real estate management. Espoo. 29th-30th March 2001. Espoo: Helsinki University of Technology. pp. 104-131. ISBN 951-22-5512-X (HUT, Department of Surveying. Institute of Real Estate Studies. Publications. C 72, ISSN 0783-9537)

Anon. 1999. What office tenant want? BOMA/ULI Office Tenant Survey Report. Building Owners and Management Ass. Int. (BOMA) & Urban Land Institute (ULI).102 p. ISBN 0-97420-866-1

Anon. 2000. The new profitability - open, integrated solutions for modern properties - t.a.c. talking buildings. (In Finnish: Uusi tuottavuus - avoimet, integroidut ratkaisut uuden ajan rakennuksiin - t.a.c. Finland. 74 s.) 77 p. ISBN 0-006-0906-0

Anon. 2001. Johnson Controls Fully Integrated Facility Management Services. [www home page] [Referred 6.4.2001] Available at: http://www.johnsoncontrols.com/ifm/services/Facility_Techology.html

Anon. 2002a. Workspace Design at the School of Architecture [www home page] [Referred at 31.1.2002] Available at: http://www.chalmers.se/researchprofile/indarch.html

Anon. 2002b. Lund Institute of Technology, School of Architecture, Environmental Psychology, Research, Education and selected Publications. [www home page] [Referred at 31.1.2002] Available at: htpp://www.ahus.lth.se/mpe/InfE.html

Anon. 2002c. NRC, National Research Council of Canada; IRC, Institute for Research in Construction, Indoor Environment [www home page] [Referred at 31.1.2002] Available at: http://www.cisti.nrc.ca/irc/ie/index.html

Anon. 2002d. NRC, National Research Council of Canada; IRC, Institute for Research in Construction, Building Science Insight '92, Effective and Efficient Lighting [www home page] [Referred at 31.1.2002] Available at: http://www.cisti.nrc.ca/irc/bsi/92_E.html

Anon. 2002e. The University of Michigan, Center for Ergonomics in College of Engineering. Dedicated to improving human performance and well-being [www home page] [Referred at 31.1.2002] Available at: http://www.engin.umich.edu/dept/ioe/C4E/

Anon. year unknown. A World of Workplace Solutions. (year unknown). Johnson Controls. [CD-ROM]. USA.

Anttila, Erkki J. 1992. Toimisto 2000. Hankesuunnittelun apuvälineet. Kansio 1. Tarveselvitys. Kansio 3B. Suunnittelutaulukot. Tampere: Tampere University of Technology (TTKK, Rakentamistalous) (in Finnish)

Brill, Michael. 1985. Using Office Design to Increase Productivity. Volume I-II. New York: Workplace Design and Productivity, Inc. 400 p. + 302 p.

Becker, Franklin & Sims, William. 1989. The Cornell University International Workplace Studies Program (IWSP) was launched in 1989 and under the direction of has focused on the ecology of new ways of working. [www home page] [Referred at 31.1.2002] Available at: http://iwsp.human.cornell.edu/

Clements-Croome, Derek. 1999. Education Needs for Intelligent Building Strategists. In: Ir. G.Klepfisch (ed.). Intelligent and Responsive Buildings. CIB Working Commission WO98. 1st International Congress. Brugge, Belgium. March 29th - 30th 1999. Antwerpen: Technologisch Instituut vzw. pp. 105-112. ISBN 90-76019-09-6

Duffy, Francis. 1983. The Orbit Study. Information Technology and Office Design. London: DEGW, EOSYS. 103 p.

Dym, Clive & Levitt, Raymond. 1991, Knowledge-based Systems in Engineering, McGraw-Hill Inc., pp 182-183.

Granath, Jan, Åke. 2002, Chalmers University of Technology, The Space and Process unit [www home page] [Referred at 31.1.2002] Available at: http://www.arch.chalmers.se/tema/rum-process/

Haikonen, Pentti O. A. 1999. An artificial cognitive neural system based on a novel neuron structure and a reentrant modular architecture with implications to machine consciousness. Helsinki University of Technology. 156 p. (Applied Electronics Laboratory. Series B, Research reports; 4) ISBN 951-22-4730-5 ISSN 1456-1174

Hall, Peter, 1999. Cities in Civilization. Culture, Innovation, and Urban Order. First published, Great Britain: Weidenfeld & Nicolson. 1998. Paperback edition, Great Britain: Orion Books Ltd. 1169 p. ISBN 0 75380815 3

Haugen, Tore. 2000. An Integrated Process from Design to Facilities Solutions. In: CIB W70 2000 Symposium Proceedings. International Symposium on Facilities Management and Asset Maintenance. 15-17 November 2000, Brisbane, Australia. The Netherlands: CIB (International Council for Research and Innovation in Building and Construction) General Secretariat. 6 pp. ISBN 1 86435497 6 (CIB Publication 235)

Himanen, Veli, Lehto, Mervi & Mannermaa, Mika. 2000. Viesti ja matka kulkevat omia teitään. Tieto- ja viestintätekniikan vaikutus matkustamiseen. (Message and travel on their own roads) Helsinki:

Liikenneministeriö (Ministry of Transport and Communication). 140 p. (Liikenneministeriön julkaisuja / Publications of the Ministry of Transport and Communications 24/2000/L) ISBN 951-723-303-5, ISSN 0783-2680 (in Finnish with English summary)

Himanen, Veli & Lehto, Mervi. 2001. Information economy. Impacts in Travel and Communication. In: Nokkala, Marko (ed). Conference proceedings, NECTAR (Network on European Communications and Transport Activities Research) Conference No 6: Transport Innovations, Competitiveness and Sustainability in Information Age. Espoo, Finland, 16th- 18th May, 2001. Espoo: Veli Himanen tmi, VTT Technical Research Centre of Finland, HUT Helsinki University of Technology. Available at: http://www.vtt.fi/rte/projects/nectar/programme.html. (to be published in European Journal of Transport Infrastructure and Research. Vol. 2, 2002)

Himanen, Veli, Lehto, Mervi & Mannermaa Mika. 2001. Viesti ja matka kulkevat omia teitään. Futura 4/2001. 41-50 ss. ISSN 0785-5494

Hood, Christopher, T. 1993. New Work Environment. The Search for a better Solution. Digital Co.

Junnila, Juhani (ed.). 1988. Toimisto huomenna. Työ, rakennukset, ympäristö. Helsinki: Rakennushallitus, Postipankki Oy. 278 p. + Appendixes 153 p. (in Finnish)

Keskinen, Auli. 1999. Towards User Empowerment. On Development of Utilisation of Information and Communications Technology in Decision Making of Administrations. 295 p. (University of Tampere. Studia Politica Tamperensis. No. 6.) ISBN 951-44-4590-2

Kiviniemi, Arto. 2000. VERA - Information Networking in the Construction Process Research program. [www home page]. Espoo: VTT Building Technology [referred 15.9.2000]. Available at: http://cic.vtt.fi/vera/english.htm

Lehti, Merja, Parjo, Lea & Siivonen, Timo. 1999. Assessing the markets for electronic information services in Finland. MSSTUDY II Finland. VTT Technical Research Centre of Finland, Espoo. VTT Research Notes no 1989. 113 p. ISBN 951-38-5495-7; 951-38-5496-5 (VTT tiedotteita - Meddelanden - Research Notes 1989, ISSN 0358-5085)

Lehto, Mervi, Nurminen, Riitta & Heimbürger, Anneli. 1987. Videolevy rakennusalan tietovälineenä. /87. Espoo: Technical Research Centre of Finland VTT. 132 p. + Appendixes 17 p. (VTT:n tiedotteita - Meddelanden - Research Notes 763) ISBN 951-38-2975-8, ISSN 0358-5085 (in Finnish)

Lehto, Mervi & Aho, Leena. 1988. Ratas projektin tuloksia: Rakennusalan yleiset tietokannat. Valokynä magazine. Vol. 8. 2/88. pp. 5-18. ISSN 0780-0843 (CAD/CAM Association of Finland (CCY)) (in Finnish)

Lehto, Mervi, Björk, Bo-Christer & Aho, Leena. 1988. Ratas-järjestelmä. Rakennuksen tietokoneavusteinen suunnittelu. Työraportti. Rakennusalan yleiset tietokannat. Helsinki: Rakennuskirja Oy. 202 p. ISBN 951-682-159-6 (The Building Information Foundation RTS) (in Finnish)

Lehto, Mervi & Himanen, Veli. 1998. Work related travelling and telecommunications: substitution, stimulation, complementarity, and mitigation. From Local to Global Sustainable Transport. Forth NECTAR (Network

on European Communications and Transport Activities Research) conference in Shefayim (Israel), April 19th-24th 1998. 11 p.

Lehto, Mervi, with Markus Thomas A., Lautier François, Leväinen Kari I., Östman Tommy. 2001a. Report on Workspace Research. Euro FM report. Production workspace. Improving the quality of production via workspace design. Working paper - Workspace Sources. Report on Workspace Research. European Facility Management Network. Vol. 10. (Thematic Networks Project BRRT-CT97-5027, Project funded by the European Community under the Industrial & Materials Technologies Programme (Brite-EuRam III), Brussels, Belgium.) Arco Publisher (Arko Uitgeverij BV). The Netherlands (Nieuwegein). April 2001. 31 p. Designed and typeset by Artnic, Deventer, (The Netherlands) ISBN 90-77072-01-2

Lehto, Mervi, with Markus Thomas A., Lautier François, Leväinen Kari I., Östman Tommy. 2001b. Report on Workspace Information Sources. Euro FM report. Production workspace. Improving the quality of production via workspace design. Working paper - Workspace Research. Report on Workspace Research. European Facility Management Network. Vol. 11. (Thematic Networks Project BRRT-CT97-5027, Project funded by the European Community under the Industrial & Materials Technologies Programme (Brite-EuRam III), Brussels, Belgium.) Arco Publisher (Arko Uitgeverij BV). The Netherlands (Nieuwegein). April 2001. 32 p. Designed and typeset by Artnic, Deventer, (The Netherlands) ISBN 90-77072-02-0

Lehto, Mervi & Himanen, Veli. 2001. Marriage of the technology-push and market pull: toys for the boys in the feminine age. In: Conference proceedings [CD-ROM], NECTAR (Network on European Communications and Transport Activities Research) Conference No 5: Transport Innovation; Technology-push or demand driven? Delft, the Netherlands, 20th- 23th Oct. 1999. Delft: The Netherlands TRAIL Research School & OTB Research Institute. ISBN 90-5584-036-x

Lehto, Mervi & Himanen, Veli. 2002. Work-related travelling and telecommunications: Substitution, stimulation and complementarity. In: Stern, Eliahu, Salomon, Ilan and Bovy, Piet H. L. (eds.) From Local to Global Sustainable Transport. Travel Behavior, Spatial Patterns, Implication and Modelling. Transport Economics, Management and policy Series (General Editor: Kenneth Button). Edward Elgar Publishing Limited. UK and USA. pp. 55-80. ISBN 1 84064 707 8

Lehto, Mervi. 1987. Optical discs - Their application in mass data storage. In: Tom Maver, Department of Architecture and Building Science, University of Strathclyde, Glasgow, U.K., and Harry Wagter, Faculty of Architecture, Building and Planning, Eindhoven University of Technology (ed.). CAAD Futures ´87, Proceedings of the Second International Conference on Computer Aided Architectural Design Futures. Eindhoven, The Netherlands, 20-22 May 1987. Eindhoven, The Netherlands: Elsevier. p. 189-199. ISBN 0-444-42916-6

Lehto, Mervi. 1991a. Tietokannat puhuvat kuvakieltä. Tietopalvelulehti. Vol 6. no. 4/1991. pp. 13-17. ISSN 0782-825x (in Finnish)

Lehto, Mervi. 1991b. Datatekniken som koordinator för byggplaneringen. Del. 1: Med boken i databasernas tidsålder. VVS värme- och sanitetsteknikern. Vol. 54. 3/1991. pp. 10-14. ISSN 0356-6439 (in Swedish)

Lehto, Mervi. 1992. Datatekniken som koordinator för byggplaneringen. Del. 2: Programmet - en bild av planeringsmetoden. VVS värme- och sanitetsteknikern. Vol. 55. 3/1992. pp. 12-15. ISSN 0356-6439 (in Swedish)

Lehto, Mervi. 1996. The 'Intelligent Office' Concept Makes the Difference. Kazamian Reza, Rönn Magnus (ed.of the theme). Theme: Workspace Design. Nordisk Arkitekturforskning. Nordik Journal of Architectural Research. Vol. 9, no 1. 1996:1. pp. 61-72. ISSN 1102-5824.

Lehto, Mervi. 1999. Performance of the Intelligent Office Building in Profit Making. In: Ir. G.Klepfisch (ed.). Intelligent and Responsive Buildings. CIB Working Commission WO98. 1st International Congress. Brugge, Belgium. March 29th - 30th 1999. Antwerpen: Technologisch Instituut vzw. pp. 129-138. ISBN 90-76019-09-6

Lehto, Mervi. 2000. Working paper for the Deliverable V, Research interests and bibliography. Production Workspace, Improving the quality of production via workspace design. EU, Brite-Euram III, EURO FM WORKSPACE PROJECT. European Facility Management Network. Espoo: Helsinki University of Technology, Department of Surveying. 38 p. + attachments 54 p.

Lehto, Mervi. 2001a. Älytalon määritelmät elävät ajassa. (Various Intelligent Building Concepts.) In: Leväinen, Kari, I. (ed.). Facility management and service concepts. International research seminar on real estate management. Espoo. 29th-30th March 2001. Espoo: Helsinki University of Technology. pp. 53-65. ISBN 951-22-5512-X (HUT, Department of Surveying. Institute of Real Estate Studies. Publications C 72, ISSN 0783-9537) (in Finnish)

Lehto, Mervi. 2001b. RAKET -tutkimusohjelmassa kehitettyjen teknologioiden kaupallistaminen. (The Commercialisation of the technologies developed in the RAKET research programme.) Helsinki. 160 s. ISBN 951-788-338-2, (LINKKI 2, Energiansäästön päätöksenteon ja käyttäytymisen tutkimusohjelma, julkaisu 25/2001) (The LINKKI 2 Research Programme on energy Conservation Decisions and Behaviour. Publication 25/2001) ISSN 1456-5013 (in Finnish, with abstracts in English) Saatavissa (Available at) http://www.tts.fi/linkrap.htm.

Lehto, Mervi. 2002. The Intelligence of Intelligent Buildings. The Feasibility of the Intelligent Building Concept in Office Buildings. VTT Publications. 279 p. (to be published)

Martiskainen Kari. 1993. Rakennustekniikan tietokannat. VTT Technical Research Centre of Finland, Espoo. VTT Research Notes no 1490. 21 p. ISBN 951-38-4424-2 (VTT tiedotteita - Meddelanden - Research Notes 1490, ISSN 0358-5085) (in Finnish)

Nenonen, Suvi. 2000. Millainen on oppiva toimitila? Toimitilajohtamisen tutkijaseminaari 5.5.2000. Espoo: Helsinki University of Technology, Department of Surveying. 11 p. (unpublished, in Finnish)

Nenonen, Suvi & Hendriks, Eric. 2000. BA -shared space, where the knowledge is created. In: Conference Proceedings. World Workplace Europe 2000, The evolution of thought on the modern workplace. Glasgow, Great Britain. 17-19. June 2000. A EuroFM / IFMA facilities management conference and exhibition, in partnership with BIFM and hosted in Glasgow by CFM, Education Forum. pp.305-309.

Nurminen, Riitta, Heimbürger, Anneli & Lehto, Mervi. 1987. Vuorovaikutteiset kuvalevyjärjestelmät. Espoo: Technical Research Centre of Finland VTT. 78 p. + Appendixes 30 p. ISBN 951-38-2929-4 (VTT tiedotteita - Meddelanden - Research Notes 739, ISSN 0358-5085) (in Finnish)

Nurminen, Riitta, Heimbürger, Anneli & Lehto, Mervi. 1988. An Interactive Videodisc Project: A Case Study from The Technical Research Centre of Finland. The Electronic Library. June 1988. Vol. 6, No.3. pp. 174 - 181.

Puskala, Rauno, Kähkönen, Kalle. 1999. Projektijohtamisen kolme aaltoa. Projektitoiminta, Projektitoimintayhdistyksen (PTY) jäsenlehti, Vol. XXII, No. 1/99 pp. 20-23. ISSN 1455-4178

Redleim, Alexander & Schmildt, Gerhard H. 1999. Integration of the Facility Management and Building Automation: A Basis for Intelligent Building. In: Ir. G.Klepfisch (ed.). Intelligent and Responsive Buildings. CIB Working Commission WO98. 1st International Congress. Brugge, Belgium. March 29th - 30th 1999. Antwerpen: Technologisch Instituut vzw. pp. 259-267. ISBN 90-76019-09-6

Salomon, Ilan & Feitelson, Eran. 2001. The sustainable discourse on sustainable transport: on the benefits of ambiguity. In: Nokkala, Marko (ed). Conference proceedings, NECTAR (Network on European Communications and Transport Activities Research) Conference No 6: Transport Innovations, Competitiveness and Sustainability in Information Age. Espoo, Finland, 16th- 18th May, 2001. Espoo: Veli Himanen tmi, VTT Technical Research Centre of Finland, HUT Helsinki University of Technology. Available at: http://www.vtt.fi/rte/projects/nectar/programme.html. (to be published in European Journal of Transport Infrastructure and Research. Vol. 2, 2002)

SuPRO. 20002.Rakentamishankkeiden suunnitteluprosessin kehittäminen. [www home page] [Referred 21.2.2002] Will be available 2002. (in Finnish)

Tuomi, Ilkka. 1999. Corporate knowledge: Theory and Practise of Intelligent Organizations. University of Helsinki, Metaxis. Helsinki. 453 p. ISBN 951-98280-0-1

Yang, Jay & Chang Weilin P. 2000. Decision Support to the Application of Intelligent Building Technologies. (Queensland University of Technology, Australia) Hong Kong: University of Hong Kong. Abstracts by Environment and Technology. 8-10th February 2000. [www home page] [referred 5.4.2001] Available at: http://mc2000.arch.hku.hk/abstractt.html