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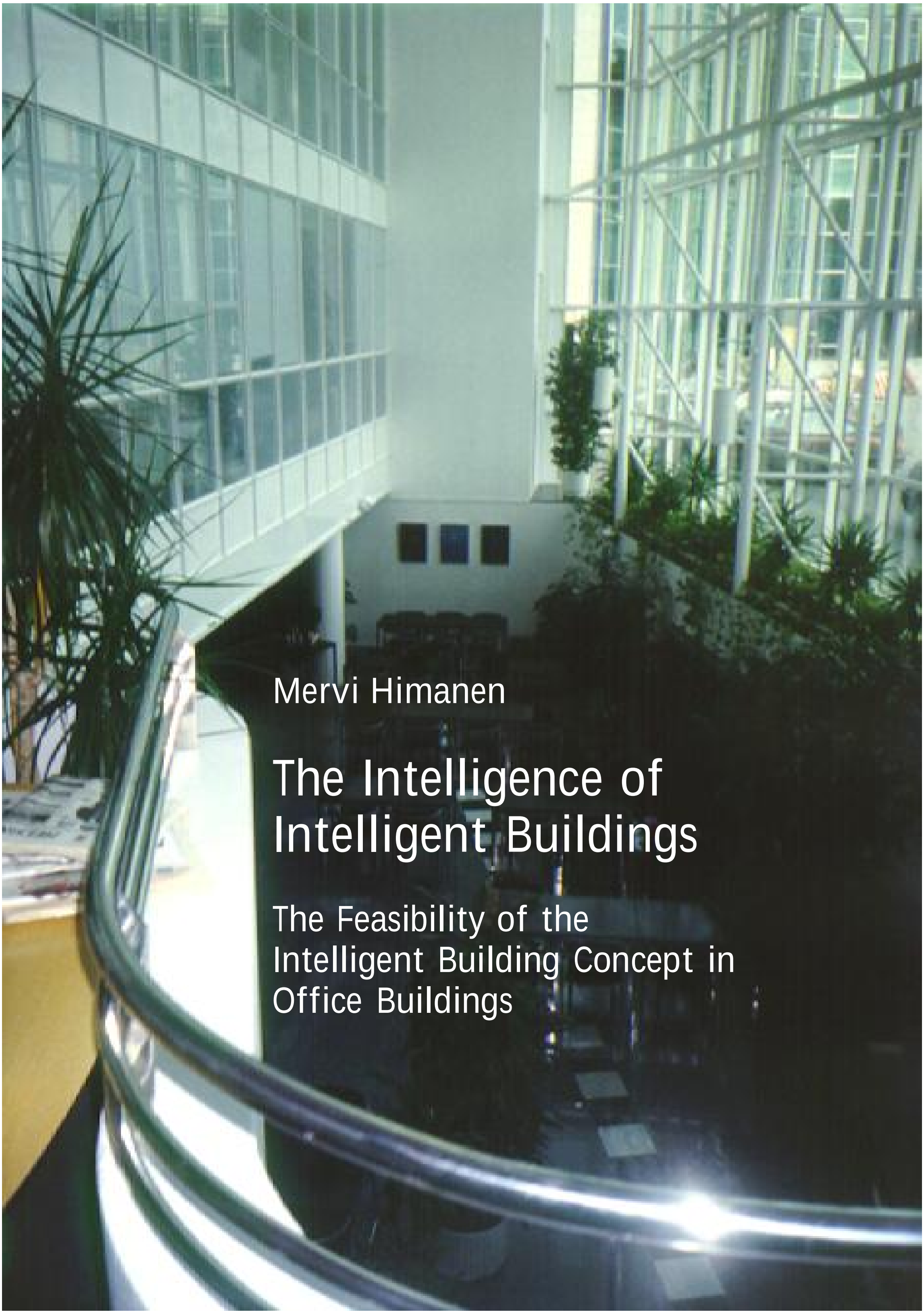

Mervi Himanen

# The Intelligence of Intelligent Buildings

## The Feasibility of the Intelligent Building Concept in Office Buildings

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## The Feasibility of the Intelligent Building Concept in Office Buildings

Mervi Himanen

VTT Building and Transport

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# Abstract

This thesis is based on the author's independent scientific thinking on the essence of building intelligence since 1988, for the purpose of establishing and arguing for the Building Intelligence Framework (BIF). Furthermore, it is based on the Intelligent Buildings (IBs) Survey of twelve office buildings in the Helsinki metropolitan area. The survey was done right after the first boom of construction of intelligent buildings was over in Finland.

There is no universal definition for the intelligent building concept, although a certain consensus about the concept can be found. There is little empirical evidence about the feasibility of or the factors involved in any intelligent building and there is no description of the intelligence of buildings, or if using the concept of intelligence in the context of quality of a building is valid. Consequently, there is no evidence about such an intelligent building, which is defined by the BIF. In fact, at the beginning of the IBs Survey project not only the feasibility, but even the existence, of the intelligent building concept was questioned.

The IBs Survey project was carried out at the Technical Research Centre of Finland VTT, Building Technology, in 1993–1997, in order to study the feasibility of the IB concept and its existence. After finished the IBs Survey project at VTT, the author of this thesis has continued the analysis of the data of the IBs Survey within scientific studies since 1996 and during the research work on this thesis she has gained a deeper understanding of the essence of the building intelligence, which has bothered her mind since the beginning of her studies on the IBs from 1988.

The IBs Survey was a post-occupancy study on office building quality. The quality of the intelligent office buildings was compared to that of the other high quality office buildings. The hypothesis of the IBs Survey project was that the existence of the differences between the qualities of the intelligent and the other office buildings will prove the existence of the IB concept. The lack of the differences between the intelligent and the other office buildings will talk for the absence of any effect of the implementation of the IB concept. The IBs Survey project at VTT proved both some differences between and some similarities in the qualities of the IBs and the other office buildings.

This thesis is a summary of the results of the scientific studies based on the IBs Survey data, and on the other hand this thesis is a monograph on the BIF. The scientific studies based on the IBs Survey data proves or disproves the existence and feasibility of the IB concept and the BIF determines the essence of the building intelligence. The final goal is a synthesis of the IBs Survey and the BIF.

The different intelligent building concepts define the intelligent buildings, not the intelligence of the building. This thesis suggests a definition of building intelligence – called the Building Intelligence (BI) – on the premise that human intelligence can imprint intelligence into an inorganic object, such as a building. The implementation of the BI into intelligent buildings is shown by the BIF. The difference between the IB concepts and the BI is clarified. On one hand, the use of the IB concepts for technical purposes, and on the other hand, the scientific aims of the BI and its implementation into the building practise of the IBs – the BIF – is explained.

The alternation of the tacit and explicit knowledge of the IB concept is shown to form the platform for the appearance of any building concept. The definition of the building intelligence (the BI) is an explicit articulation of the internal stock of knowledge of intelligent buildings. The purpose of the BI is to separate out the buildings built according to the IB concept from the buildings built according to other building concepts. The derivation of the IB from the IB concepts and human intelligence – the BIF – can be used as a starting point for the next phase or version of the definition of a building concept, which can be either intelligent or something new.

The further the analysis of the empirical data on the IBs Survey proceeds the more evidence of the differences between office buildings, which have been designed using the intelligent building concept as a leading design criterion and the buildings, which have not been designed according to the IB concept criteria are found in terms of the efficacy of these office buildings. This difference is witnessed by the quality evaluation of the end product – i.e. that of the building itself. This quality evaluation is an end-user evaluation, which evaluates the importance of quality of the office building and that of its components to the working efficiency of the evaluator. This is how the evaluation result turns into the efficacy of the office building system, which is composed of its components, i.e. of its subsystems. The result supports the feasibility of the IB concept in office design.

The evaluation results from the post-occupancy study correlate with the job description and gender of the office worker. In general, executives evaluate their working environment better than other occupancy groups. The opinions of professionals and clerical staff differ according to the building property concerned and according to the gender of the respondent.

Important parameters of the intelligent office building design have been sought out from among a large number of parameters of the intelligent building concepts. This extrapolation is based on the empirical evidence from the results of the IBs Survey and the definition of the BIF, which highlights certain factors of the IB concepts.

The existence of the IBs is dependent on the application of the IB concept factors during the building design process. It can be concluded, that the IB concept criteria will be fulfilled best, if the building design is based on more than one of the elements of the IB concept. Furthermore, the quality of the intelligent subsystems must not fail, if the target is a good intelligent working environment.

The thesis closes with the synthesis of some of the results of the IBs Survey and the theory of the BIF. Finally, the IB elements should form a functional combination, an integrated solution. Simply adding high technology, is not enough. Embedding the building intelligence by merging it into the building is held up as the intelligent solution to the design of a successful intelligent workplace.

# Preface

I thank the supervisor of this thesis, Professor Kari I. Leväinen of Helsinki University of Technology, for his support and encouragement throughout the years I studied property and facilities management. His kind and broadminded attitude has made it possible for me to continue my line of thinking on the intelligent building phenomenon within the scope of facilities management paradigm.

I thank Professor Derek Clements-Croome from the University of Reading, and Emeritus Professor Raimo Salokangas from Tampere University of Technology, who are appreciated for carrying out the pre-examination of the thesis. Professor Clements-Croome's penetrating, supportive and inspiring comments and Professor Salokangas's dedication to the message of this thesis made it possible to express the profound results in a clear scientific manner.

Modern science is increasingly about group work and gathering together various experts. Although this thesis is purely an individual achievement, one half of it is partly based on the IBs Survey project, which was a research project lead by the author and carried out by a team of experts at VTT Building Technology. The research project group members were Mr. Sami Karjalainen, Ms. Selja Flink, Mr. Sakari Pulakka, and Mr. Keijo Kovanen, as well as Dr. Veli Himanen, Ms. Jutta Jantunen and Mr. Juha Raitio. The team was fortified with Mr. Hannu Isoaho from University of Turku, Dr. Pirkko Kasanen from University of Helsinki and Mr. Juha Lehto from Architects office Juha Lehto. Student for Master of Arts in English Translation Studies Vanessa Sjögren from the University of Turku, English Translation Studies, has taken care of the language consultation without sparing her efforts.

Dr. Albert T. P. So the Associate Professor from the City University of Hong Kong read the early draft of the four first chapters (in Spring 2001) and gave encouraging comments on them and also with his advise strengthened my plans, how to continue the work and hit the goal it is having now.

I am grateful to all of them.

The City of Helsinki, VTT Building and Transport, the Finnish Work Environment Fund, and IVO Foundation are gratefully acknowledged for their financial support for the work and publication of this thesis. I would like to take this chance to also thank K. V. Lindholm Foundation and the Jenny and Antti Wihuri Foundation, which have been funding the post-graduate studies required for the accomplishment of the doctor degree.

The turbulent business environment of the 90th century had an influence on the scientific world. While working with a scientific research centre on project basis, long term research requires commitment and willingness to work on ones own at own expense. In science, a critical approach is essential for the adoption of qualified working methods and for successful results. In a high-class research organisation, bringing up visionary multidisciplinary ideas requires courage and trust. To be able to cope with criticism, I have been lucky to have supportive people around me in private life – also others besides family members. They have been open to new ideas, and also willing and tolerant to have professional discussions. I have been lucky enough to find scientists, who share and agree with my thoughts. Their publications made it possible to argue for the BIF.

I am very grateful to Dr. Veli Himanen, for his highly encouraging and supporting commitment to my work, and close partnership during all these years I have been working on the intelligent building concept. His critical scientific attitude and clear thinking have advanced my own scientific thinking. His unfailing friendship has always been available when I have needed help most. Our co-operation, discussions and common interest on mental human growth have expanded my experience in scientific practice. Maybe even more importantly, his mentoring has broadened my attitude towards life, and given space for the sympathy towards my fellow people, which is essential for good relations in scientific team work and for exchange of knowledge and visions. I have also had the chance to carry out together with him several domestic and international scientific projects researching the information society. It has advanced this thesis directly, and my career as a senior research scientist indirectly. He has also read the manuscript of this thesis and given several suggestions for corrections.

My mother and her family, as well as my godfather, in particular, from my father's side, have taught me trust and to have a kind and loving attitude towards

living. I have often found that while it does not seem to work in life on the short term, and yet it has been the most important thing left to a person in the end. My late father Pekka Loimakoski's many teachings about life, and the memories of his humorous, optimistic and positive attitude towards life have often given me faith and trust to continue in the moments of deepest loneliness. With these loving words about my father – my best friend – I dedicate this work to my two other best friends, my sons Pirkka and Pyry Lehto, who have grown up with a working mother and yet have granted me with the joys common in the lives of the best mothers.

Before the printing of this thesis I was remarried. I have followed the old Finnish tradition to take the family name of the husband as the family name of the wife, although today according to the Finnish law after the marriage it is possible to agree on other last names too. In this thesis I am several times referring to my previous publications under the name of Mervi Lehto.

*To Pirkka and Pyry.*

# Contents

# List of Acronyms

| | |
|---|---|
| ba | a space, where the boundaries between individual and collective minds become diffuse, and the knowledge creation spiral can escape to a new level of analysis |
| BI | Building Intelligence |
| bi | a form of BI |
| BA | Building Automation |
| CIB | Computer Integrated Building |
| EWE | End-user evaluation of building properties' influence on the working efficiency of the office worker |
| FM | Facilities Management |
| GB | Green Building |
| HI | Human Intelligence |
| hi | a form of Human Intelligence |
| IB | Intelligent Building |
| IBI | Intelligent Building Index |
| BIF | Building Intelligence Framework |
| BQ | Building Quality |
| ICT | Information and Communication Technology |
| IFM | Integrated Facilities Management |
| LAN | Local Area Network |

| | |
|---|---|
| PID | Proportional Integral Derivative (Control) |
| QFM | Quality Function Management |
| QFD | Quality Function Development |
| RTD | Research and Technical Development |
| R&D | Research and Development |
| SBS | Sick Building Syndrome |
| VR | Virtual Reality |

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# 1. Introduction

In the later half of the 1980's the intelligent building (IB) concept reached Finland and the building of intelligent buildings (IBs) started. The Finnish building sector participated actively in the RTD work of the intelligent buildings. New design ideas, new structures and spatial solutions were created. ICT and building automation was implemented into the office building projects. Until the beginning of the 1990's several intelligent office buildings and science parks were built, not only in the Helsinki metropolitan area, but in other cities as well, such as in Oulu, Tampere, Turku, Kotka, etc. The economical recession interrupted the progress of intelligent building in 1992 and an actual crisis of the Finnish property management business began. This was the time for evaluating the results of the first boom of the IBs in Finland, and the Intelligent Buildings Survey (the IBs Survey) research project took place. Although new intelligent building projects were not numerous during the first half and the middle of the 1990's, the work with the IB systems was lively (cf. Section 5.3.3.2). The RTD of building automation sector produced several inventions during the 1990's, which had international markets.

## 1.1 Organisation of the Thesis

The study of this thesis is based on two parallel approaches (Figure 1.). Firstly, this thesis is based on the author’s independent scientific thinking on the essence of building intelligence (the BI) since 1988, for the purpose of establishing and arguing for the Building Intelligence Framework (BIF). Secondly, it is based on the Intelligent Buildings Survey of twelve office buildings in the Helsinki metropolitan area. The IBs Survey project was carried out in the first place at the Technical Research Centre of Finland VTT, Building Technology, in 1993–1997. In order to argue for the feasibility of the IB concept hypothesis, the analyses of the IBs Survey data were carried out by the author in scientific studies. This thesis is a summary of the results of the IBs Survey, and a monograph on the BIF. The final goal is a synthesis of the IBs Survey and the BIF.

The organisation of the thesis follows the scientific tradition of introducing first of all the background of the intelligent buildings phenomenon in chapter 2, and

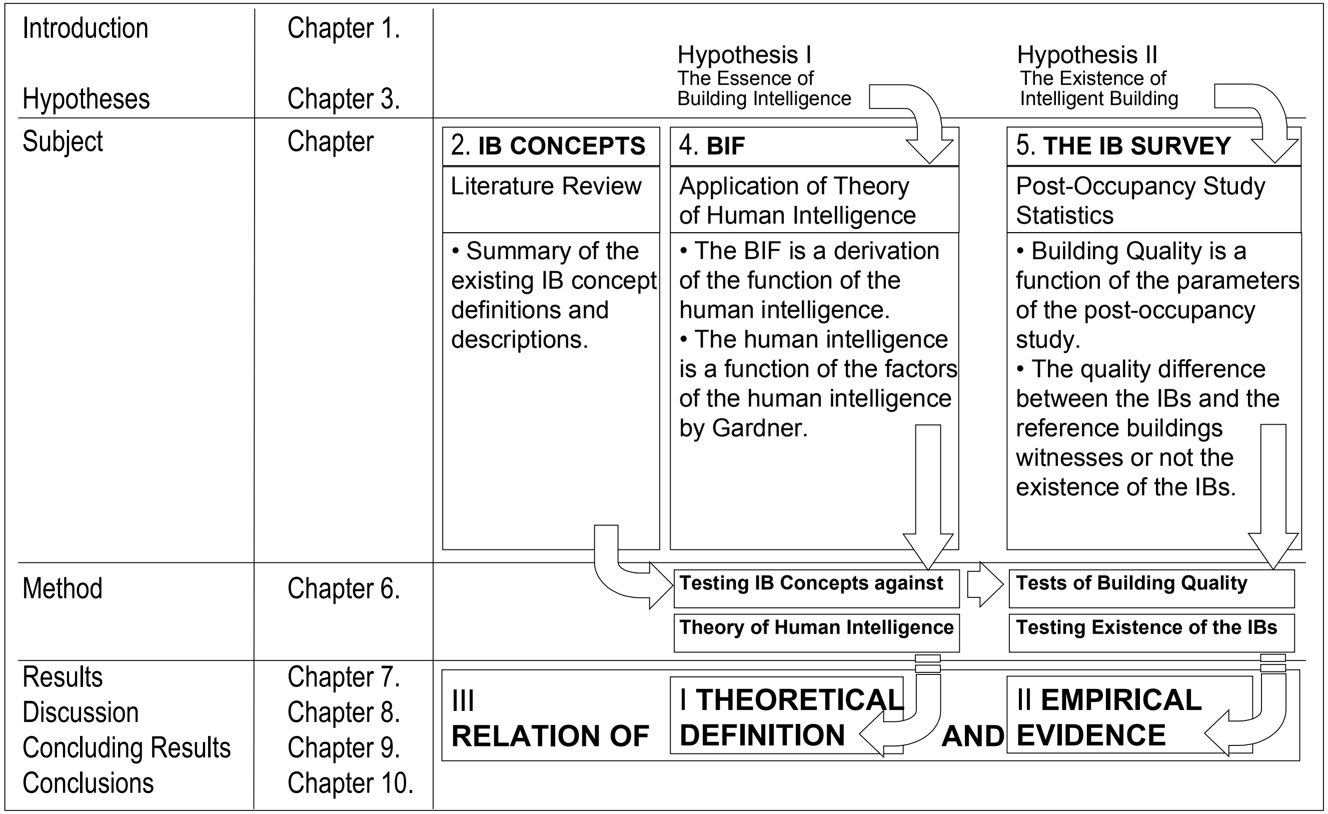


*Figure 1. The organisation of thesis.*

continuing then with the description of the study problem and aims of the study in chapter 3. The section on background introduces various IB concepts and international history of the IB concepts' implementation. The study for this thesis is based on the two hypotheses, which will be presented in chapter 3.

The chapters on the methods (Chapter 6) and results (Chapter 7), as well the discussion (Chapter 8) and conclusions (Chapters 9 and 10) are all presented in the traditional order. However, before them the methodological consideration for the research on this new phenomenon of intelligent buildings is defined in chapter 4.

Chapter 4 on methodological considerations includes the application of the IB-related sciences into the problem solving of this study, and discussion of their relevance in the context of IB phenomenon. The chapter of methodological consideration (Chapter 4) ends with an explanation of a set of scientific breakthroughs in understanding the latest office building and knowledge work phenomena.

While the result of the IBs Survey is actually in the position of being the material for the research reported on this thesis, it is described separately in chapter 5. Chapter 5 describes the entire survey together with its targets and methods, while the actual aims and methods of this study are presented in chapters 3 and 6.

The results of the IBs Survey in all, as well as those of the composition of the BIF are given together in chapters 7 and 9, and discussed in chapter 8. The results of two approaches of this thesis, the scientific analysis of the IBs Survey results and the BIF, are presented in chapter 7 separately (Sections 7.1 and 7.3). They are summarised in chapter 9 after discussion in chapter 8. In chapter 8 also the future needs of the unfinished analyses of the IBs Survey data is discussed.

The connection between the results of the IBs Survey, the IB concepts and the theory of the BIF are then brought together in sections 7.4 and 9.3. They are summarised in the concluding results (Section 9.3.2).

## 1.2 Solving Parallel Problems

Two hypotheses connected with the differentiation of the IBs from other building types or construction concepts have been studied. In the first place, the IBs Survey proves whether and how the intelligent office buildings are different from other office buildings. It proves whether the IB concept exists. Primarily, the BIF defines the BI, which separates the intelligent building from other building concepts. **Actually, there are three elements for the study of the two hypotheses: empirical evidence from the IBs Survey, the IB concept definitions or descriptions from literature review (Section 2.1) and the theory of the BIF which defines the BI (Figure 1.)**.

### 1.2.1 The Intelligent Buildings Survey

A principal research problem for the IBs Survey was the need to find out whether the investment on the intelligent office building concept has an impact on the working environment, which further on – for it's part – can have an influence on the office building market. The Survey compares the office work environment quality or its value for working efficiency of the office worker, in the buildings built according to the IB concept to that of the reference buildings (Chapter 5). Following scientific tradition, the results of the comparison of the two office building type quality on the basis of the end-user evaluation for working efficiency are given (Chapter 7). The discussion leans on the results found from the literature and those of the reference indicators (Figure 2.), which are called additional indicators and measured during the IBs Survey (Sections 5.4 and 7.2). The conclusion follows the discussion.

The description of the IBs Survey, which includes the IBs Survey project and the scientific studies after that in chapter 5 also includes a description of the study methods of the IBs Survey (Sections 5.1, 5.2, 5.3.4 and 5.3.6) and those of the additional indicators (Section 5.4). Questions about indoor air were included in the questionnaire, but in three buildings indoor air quality was also measured using other methods, which are described in chapter 5 on methods (Section 5.3.6).

The quality evaluation of the intelligent and reference buildings is based on the current building practise in use. The comparison should prove the quality evaluation of the two office building types as either different or similar.

The sample was collected in 1993–1994, in such a manner that, despite of the long analysing phase needed for the wide range of results out of the IBs Survey, the sample and results are still relevant. This fact provides a good possibility of repeating the study in case time series will be needed of the data in the future. Consequently, the sample is still relevant in the context of resent scientific review, but for practical reasons due to the writing of this thesis, the literature review will be extended to the end of the 20th century.

The results of the IBs Survey have in part been published previously in scientific referee papers (Lehto 1996c, Lehto 1997a, Lehto 1999e, Lehto 1999f, Lehto & Himanen 2002b) and international scientific conference papers (Lehto & Karjalainen 1997, Lehto 1998d, Lehto 1999c, Lehto 2000c), as well as in the LINKKI research program reports (Himanen et al. 1996a, Himanen et al. 1996b). They will be referred to shortly in this study, which concentrates on the creation of the BIF, the synthesis of the results of the IBs Survey (Lehto et al. 1997), and onwards to that of the IBs Survey and the BIF.

#### 1.2.1.1 Parameters of the Questionnaire

First, empirical evidence about the existence of the intelligent building concept has been explored. The existence of intelligent building concepts influence building quality. The office workers' evaluation of IBs' contribution toward work efficiency is a reflection of the building quality. The difference in qualities between the IBs and the reference buildings will be accepted or rejected on the basis of the results of the IBs Survey (Figure 2.).

The IBs Survey clarifies what an intelligent building is and elucidates its properties. The importance of various factors of the quality of physical working environment to the office worker are ranked. Those factors are the parameters, which are included into the IBs Survey (Lehto 1999f, p. 23). There are altogether 417 parameters (including all the options of the questions). They were analysed within the IBs Survey project and in the scientific studies, which were

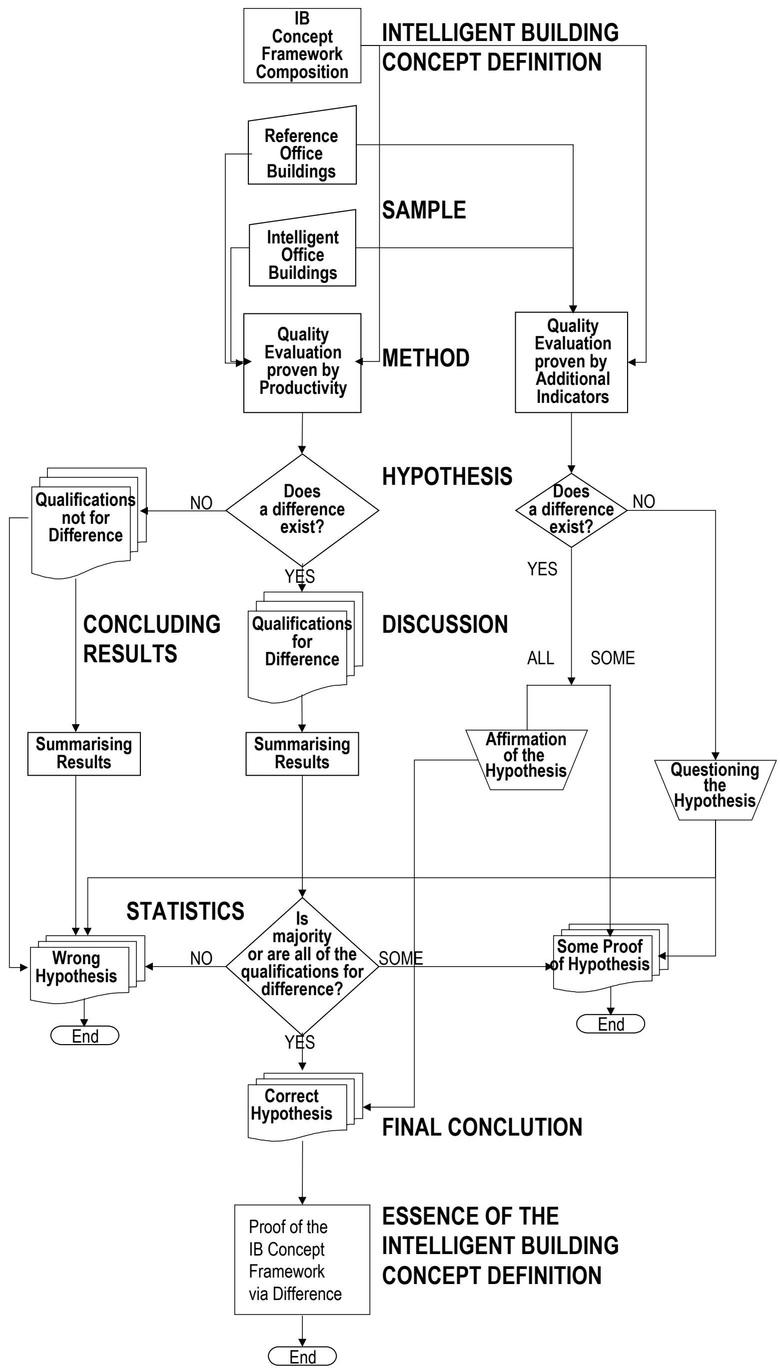


*Figure 2. The flowchart of organisation of the IBs Survey.*

concerned with the analysis of the IBs Survey data.

The IBs Survey measured the building quality with the parameters of the questionnaire as follows:

$$\textit{Equation 1. } BQ_{IBs\ Survey} = f\,(x_{1} \ldots x_{417})$$

where $BQ_{IBs\ Survey}$ is the building quality measured by the IBs Survey or the set of the building qualities measured by the IBs Survey, and x is the parameter of the questionnaire of the IBs Survey.

The choice of the IBs Survey parameters (Sections 3.4 and 4.2) have been influenced by the IB concept definitions or descriptions from literature (Equation 5.), as well as by the common factors of the office design (Sections 2.4, 4.3 and 4.3.5).

There are two different types of buildings in the IBs Survey and the building quality of both of them is measured by the questionnaire of the IBs Survey:

$$\textit{Equation 2. } BQ_{IB} = f\,(BQ_{IBs\ Survey}) \textit{ and } BQ_{Non\text{-}IB} = f\,(BQ_{IBs\ Survey})$$

where $BQ_{IB}$ is the quality of the IBs and the $BQ_{Non\text{-}IB}$ is the quality of the reference building.

Within this study the difference of the qualities of the IBs ($BQ_{IB}$) and the reference buildings ($BQ_{Non\text{-}IB}$) are tested statistically (a variance analysis; F-test (cf. Section 5.3.6)):

$$\textit{Equation 3. If } BQ_{IB} \neq BQ_{Non\text{-}IB} \textit{ then the existence of the IB concept is true.}$$

This analysis of building quality was based on a certain number of parameters in the questionnaire. The important parameters of building quality for the separation of the IBs from other buildings will be:

$$\textit{Equation 4. } BQ_{\,Difference} = f\,(x_{1} \ldots x_{y})$$

where y is the number of the parameters of the IBs Survey questionnaire needed for the distinction.

After testing the results of the IBs Survey, which were based on various sets of parameters in the questionnaire of the IBs Survey, it was found that analyses of the results from the parameters of spaces and equipment were needed for the segregation of the two building types (Equation 14., Section 6.3). Their description and number are found in sections 5.3.6 and 5.5. The results of the test are found in section 7.1.1.1.

The important parameters of the building quality for the segregation or identification of the IBs from other types of buildings in general will be named after the results shown in section 7.1.1, which are based on the analyses of the results of the IBs Survey measured with the parameters of the questionnaire of the IBs Survey (Section 9.1).

#### 1.2.1.2 Parameters of the Intelligent Building Concepts

The primary connection of the IBs Survey to the intelligent building is the sample, which includes both intelligent and other types of office buildings. Comparing the qualities of the IBs to that of the other office buildings is the main purpose. The existence of the IB features in the office building is found from the spatial, structural and technical qualifications of the buildings (Table 3. and Table 4.), as well as from the design criteria of their construction (Section 5.3.3.2). The parameters of this post-occupancy study do not relate only to many factors common to the post-occupancy studies of the office buildings, but also to the factors of the IB concepts.

The factors of the IB concepts are summarised on the basis of the literature review (Section 2.1.6):

$$\textit{Equation 5. } IB_{Concepts} = f\,(z_1 \ldots z_n)$$

where $IB_{Concepts}$ is the summary of IB concepts and z are the parameters of the IB concept definitions or descriptions, and n is their number. These parameters themselves were not the parameters of the IBs Survey. Rather it can be written as follows:

$$\textit{Equation 6. } z = f\,(x_1 \ldots x_m)$$

where z is the parameter of the IB concept definitions or descriptions and x is the parameter of the questionnaire of the IBs Survey and m is the number of them present at the IBs Survey. All the needed x's for all the existing z's were not included in the IBs Survey questionnaire.

The important parameters on the behalf of the IB concepts were analysed during this thesis and are named in section 5.5. The results of the IBs Survey on the basis of the factors of the IB concepts are shown in section 7.1.2. The intelligent building concepts include factors of the FM and also factors, which were studied as additional indicators within the IBs Survey (Section 5.5). Still, they are reported separately in sections 7.1.3 and 7.2. The summary of the results is presented in section 9.1, and that of the additional indicators in section 9.1.5. The factors of the intelligent building concepts will turn out to be a practical tool for the intelligent building industry.

### 1.2.2 The Building Intelligence Framework

There is no standard definition of an intelligent building, because the intelligent building concept is a relatively new idea, and the IB industry is not yet fully developed. The IB concept can be understood in various ways. That is why a definition is still essential information in connection with intelligent buildings, even more so in the case of a scientific work.

Importantly, the lack of a definition of the intelligent building and finally of the building intelligence became obvious during this work. Building intelligence differs from the IB concepts. It became clear that the IBs Survey offers the empirical evidence of the building qualities on a relatively general level. A structured analysis of the essence of the intelligent building concepts and the building intelligence was needed.

Due to the variations in the common understanding of the IB concept's essence, it has been necessary during this work to embed the IB concept in other scientific paradigms (Chapter 4). These have been information society, progress of office building design criteria, and the derivation of the end-user oriented building practises, in addition to the integration of the Facilities Management (FM) and the IB concept into Integrated Facilities Management (IFM, cf. Section 2.3).

The research on the relatively unstudied subject of building intelligence has leaned towards the scientific literature of human intelligence, which has been included in to knowledge management.

#### 1.2.2.1 Parameters of the Building Intelligence Framework

Secondly, because at the moment many building concepts are closely related, the theoretical elaboration of BIF has aimed at distinguishing those factors, which separate the intelligent building from other building concepts. The BIF explores the definition of building intelligence. In the final results of this thesis the relationships between the IB concepts from the literature and the BIF created during the process of this doctoral thesis by drawing conclusions from scientific literature related to the IB phenomenon and the ambiguity of the results of the IBs Survey project will appear.

The forms of building intelligence will be separated from the factors of the intelligent building concepts for defining the intelligent buildings. The factors of the IB concepts will be tested against Bergson's theory of human intelligence (Section 7.4):

> *"A fundamental role of intelligence is to generate distinctions that enable an intelligent being to act in its environment according to its capabilities and needs;"*

The role of the factors of the IB concept will be followed from this test (Sections 7.4 and 9.3).

The hypothesis of building intelligence is tested against the following theories of human intelligence (Section 7.3):

> "*[H]uman beings do not only use existing tools, but also create tools using their intelligence" (Bergson).*

> *"Intelligence ... looks upon all matter as if it were carvable at will. It makes us consider every actual form of things ... artificial and provisional ... indifferent from form ... it also creates a space ... lending itself to any mode of decomposition whatsoever ... Objects, as extended things in an undifferentiated space, symbolize this tendency of human intelligence to fabrication" (Bergson).*

*"[H]uman being are able to create cognitive tools that can become integrated parts of our thinking" (Vygotsky)*,

*"[S]erves as models of world, and guided scientific and philosophical thought." (Gregory).*

*"We live off intelligence stored in artefacts designed by our ancestors." (Gregory).*

The ability of the human intelligence to lend its intelligence to a building is proved (Section 7.3).

Building intelligence is derived from the seven forms of the human intelligence of Gardner's (Section 7.3):

*"Logical-mathematical, musical, linguistic, interpersonal, intrapersonal, visual-spatial and bodily-kinaesthetic."*

The definition of building intelligence is a function of human intelligence:

*Equation 7.* $HI = f\,(hi_{Gardner1} \ldots hi_{Gardner7})$

where HI is human intelligence, $hi_{Gardner}$ is a form of the human intelligence as defined by Gardner.

The definition of building intelligence (the BI) (Sections 7.3 and 9.3) can be defined to be:

*Equation 8.* $BI = f\,(bi_1 \ldots bi_n)$

where BI is the concept of the Building Intelligence, bi is a form of the BI and n is the number of forms of the BI.

Bi can be presented as:

*Equation 9.* $bi = f\,(HI)$

where HI is the human intelligence.

The four possible types of knowledge conversation modes of the concept of ba by Nonaka & Takeuchi (Section 4.3.3.2) have been used as a theoretical basis for the understanding of the empirical evidence of the IBs Survey in the light of the theory of the BIF:

> *"[T]acit knowledge transforms to tacit knowledge through socialisation (sympathised knowledge); tacit knowledge transforms to explicit knowledge through externalisation (conceptual knowledge); explicit knowledge is converted to explicit knowledge through combination (systemic knowledge); explicit knowledge transforms to tacit knowledge through internalisation (operational knowledge)."*

The empirical evidence for the BIF and explanations for some of the results of the IBs Survey, which on the first glance seem inconsistent are found and reported in section 7.4, and their summary in section 9.3.

The IBs Survey revealed some practical problems, which could be understood by separating the concept of the BI from the IB concepts by the derivation of the BI with the BIF. The BIF explains some of the results of the IBs Survey. Vice versa, the IBs Survey provides the reasoning of the BIF with empirical evidence.

The different roles of the forms of the BI and the factors of the IB concepts are stated in Section 7.4.1 and their different use in building industry in Section 7.3.7.

Finally, the total intelligence of the system the Building Intelligence Framework (the BIF) and the interplay between the intelligent building and the end-user is summarised and discussed. The intelligence is common to the end-user and to the building. The building intelligence is due to the human intelligence, which the stakeholders of the building sector have lent to the building. Those are designers, building owners, property managers, etc.

The total intelligence of the interplay between the built environment and the end-user is:

*Equation 10.* $BIF = f\,(HI, BI)$

where HI is human intelligence, the BI the building intelligence.

## 1.3 The Author's Contribution

The intelligent building concept either covers or is related to several other fields in construction. The paradigm of facilities management is relatively new as well. Thus industrial economics and knowledge management have been used as starting points for the scientific consideration of IB research of the author. This thesis relies mainly on the intelligent building literature, and the author's special knowledge on: [1)] industrial engineering and management (previously industrial economics) and its the appliance to construction industry, i.e. asset and facilities management, [2)] information science, [3)] indoor air climate and clothing physiology, [4)] international economics and [5)] futures studies. Experts on transport, energy, architecture and interior design, building economy, indoor air climate, and to some extent on work psychology have helped in completing the IBs Survey (Sections 1.3 and 5.3.4). The literature review of this thesis in chapters 2 and 4 covers these subjects or research problems to such an extent, as they have relevance in the context of this thesis.

The latest analysis of the IBs Survey data, the BIF and the synthesis of the BIF and the IBs Survey are published for the first time in this study, which is an individual accomplishment of the author. The author's contribution to the IBs Survey lies in the individualistic composition of the research project proposal, in the expert knowledge on the subjects included into the Survey and mentioned in the previous section 1.2.2, and in participation in the project as responsible researcher, as well as a team member.

The IBs Survey research project team at VTT Building Technology has had a key role in helping with the production of the scientific material for the argumentation of the second hypothesis of this study. The research project group members were Sami Karjalainen (MSc. in Engineering), Selja Flinck (MSc. in Architecture), Sakari Pulakka (MSc. in Engineering), and Keijo Kovanen (MSc. in Engineering). Mr. Karjalainen has been working on indoor air and energy efficiency, Ms. Flinck on architecture and indoor design, Mr. Pulakka on building economics and Mr. Kovanen on indoor air measurements. Mr. Antti Torkki (MSc. in Engineering, Helsinki University of Technology) was responsible for the odour panel during the indoor air measurements. Ms. Jutta Jantunen (MSc. in Engineering and architecture) and Juha Lehto (MSc. in Architecture, Architects office Juha Lehto) have taken part in the study with their expertise by writing the background reports, which were essential in the composition of the questionnaires.

Mr. Hannu Isoaho (MSc. in Mathematics, University of Turku) has independently analysed the data statistically. His high expert knowledge and flexible working methods have been most fruitful in analysing the results of the IBs Survey and for the papers written on it. During the era of information society evolution we have been working together since 1994 by email, and have actually met only twice. Mr. Juha Raitio (MSc. in Engineering), an expert on the use of neural networks, helped in analysing the result. Dr. Pirkko Kasanen (University of Helsinki) has been the research team leader of the LINKKI research program, where she, Dr. Veli Himanen, Mr. Sami Karjalainen and the author analysed the results of the IBs Survey regarding the energy consumption of business travelling and various tele-workspace alternatives.

The co-writers of the IBs Survey questionnaire are mentioned in section 5.3.4. The steering committee members of the IBs Survey were Dr. Osmo Koskisto (1993–1994) and Mr. Matti Evola (1995–1997) at the National Technology Agency (Tekes) (chair), Mr. Matti Ketonen with Helsingin Puhelin Oy (Elisa Communications Oyj), Mr. Matti Räty with Rakennus-Ruola Oy (current NCC Finland), Mr. Mauri Tolonen with Rakennustoimisto A. Puolimatka Oy (current NCC Finland) (1995–1997), Mr. Veijo Rossi at Rakennushallitus (current Senate Properties) (1993–1994), Mr. Tapani Talvinko at Finnish Institute of Occupation Health (1993), Mr. Ari Korhonen with Komartek Oy (1994–1995), Professor Torsti Kivistö at VTT Communities and Transport (1993), Professor Juho Saarimaa at VTT Building technology (1994), Dr. Reijo Kohonen (1995) and Mr. Veijo Lappalainen (1996–1997) at VTT Building Technology.

As mentioned, the argumentation of the second hypothesis of this thesis is based on the IBs Survey project report written together with the project group (Lehto et al. 1997), the five scientific papers (Lehto 1996c, Lehto 1997a, Lehto 1999e, Lehto 1999f, Lehto & Himanen 2002b) and the four international conference papers (Lehto & Karjalainen 1997, Lehto 1998d, Lehto 1999c, Lehto 2000c). Seven of the nine papers are results of the scientific work done alone by the author.

A paper titled "Work-Related Travelling and Telecommunications: Substitution, Stimulation, and Complementarity" was written together with Dr. Veli Himanen. Dr. Himanen has written chapter 3 of the paper (The Connection between Telecommunications and Transport), and the author wrote the chapter 4 (Questionnaire among Office Workers in the Helsinki metropolitan area) representing the results of the paper. Introductory chapters and chapter 6 (Telematics and Sustainable Transport Policy), as well as the conclusions were products of the two authors' co-operation.

Mr. Sami Karjalainen has taken part as a co-author of the paper "The Intelligent Building Concept as A User Oriented Approach to the Office – Focusing On the Indoor Air and The Energy Consumption" and written the chapter: "Results – the User-oriented Indoor Air and Air Control". Otherwise, the paper was written by the author.

All the publications of the IBs Survey include tables or figures based on the statistics done by Mr. Hannu Isoaho, who has also advised in statistics during the analyses. However, the statistical analyses were based on the author's ideas and plans of the research needs for the analyses of the IBs Survey.

# 2. Background

The keywords for the background of this thesis are the intelligent buildings, the facilities management, the office workspace, and the knowledge work of the information society.

The progress of the intelligent building concepts from the middle of the 1980's to the end of the 1990's will be described. The literature on intelligent buildings is limited, and includes only a few scientific referee articles. On the other hand, the literature in several scientific fields with similar paradigms to the intelligent building concept is extensive. The IB concept has been discussed in several papers and articles written at universities and IB associations, as well as in research laboratories. FM companies' interest in intelligent building concept has been lively.

The turbulent business life of the 1990's brought with it several changes to the office. Consequently, the office work environment changed. Some scientific evidence of the information society and of the knowledge work, which the changing business life brought with it, is also referred.

## 2.1 Intelligent Building Concepts

As mentioned earlier, no standardised definition for the intelligent buildings exists. The different definitions or descriptions of the intelligent building concept used for practical purposes within the research, education and construction industry will be summarised from the middle of the 1980's to the end 1990's.

To begin with, the intelligent building concept has been defined by such organisations as the Intelligent Building Institute Foundation (I.B.I.) in 1989, Associazione Italiana per l'Automazione degli Edifici (AIACE) in 1995 (Anon. 1995), the European Intelligent Buildings Group (EIBG) in 1998, and The Smart Homes Foundation (van Berlo 2001) (Lehto 2001a, Lehto 1999a, Lehto 1998a, Lehto 1996b, Lehto et al. 1993). These definitions highlight [a)]the integration of all kinds of building systems, services and controls, [b)]the importance of techno-economics, and [c)]the needs of the owners and end-users.

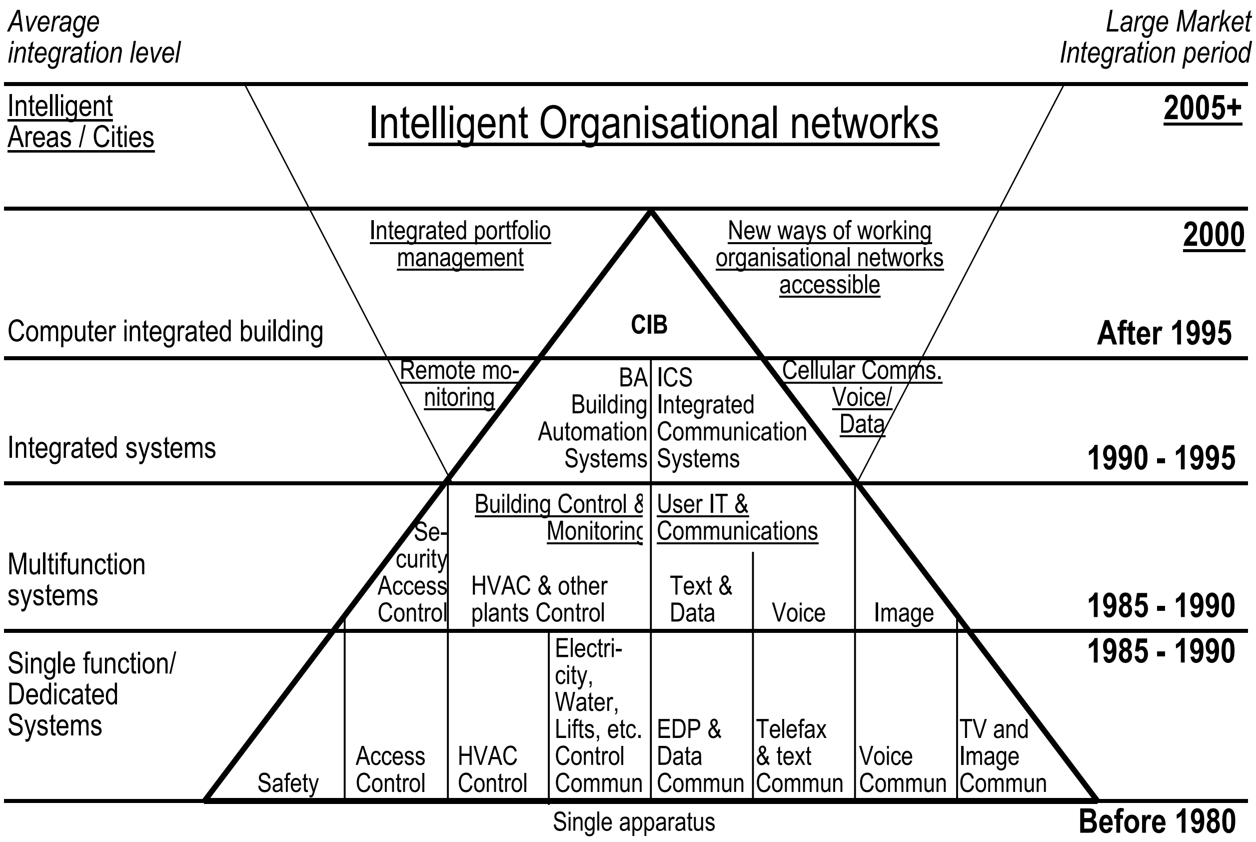


*Figure 3. The Intelligent Building Pyramid (Anon. 1992a, Harrison 1999 [underlined]), or The Integrated Building Pyramid?*

### 2.1.1 Starting from USA

One of the first definitions was that presented by the USA Intelligent Building Institute (I.B.I.), (Anon. 1988, Anon. 2001g, Brown 2001, Lehto et al. 1993, p. 12., cf. also So 2001, p. 3):

> *"An intelligent building is one which provides a productive and cost effective environment through the optimisation of its four basic elements – systems, structure, services, management – and the inter-relationship between them. Intelligent buildings help building owners, property managers, and occupants realize their goals in the areas of cost, comfort, convenience, safety, longterm flexibility, and marketability. There is no intelligence threshold past, which a building "passes" or "fails". Optimal building intelligence is the matching of solutions to occupant needs. The only characteristic that all intelligent buildings have in common is a structured design to accommodate change in a convenient, cost-effective manner."*

The first writings on the intelligent buildings followed the I.B.I.'s definition, but analysed it in more detail in terms of business economy and personnel management, and gave detailed information about the implementations needed for IBs (Gouin & Cross 1986, Bernaden & Neubauer 1988).

### 2.1.2 From the Intelligent Building Pyramid Onwards

The IB pyramid was created during the European Intelligent Building Study (Anon. 1992a) in 1992. It has become a landmark in the progress of the IB concept. The EIBG was a partner of the Intelligent Building in Europe Study, but left the IB concept open at that time. The IB pyramid focused on the integration of the building control and monitoring systems and on the communication technology. The IB pyramid has been developed further towards intelligent areas by DEGW plc (Harrison 1999) by integrating the mobile technology and remote control to the description of the computer integrated building (Figure 3.). Besides the members of the AIACE (Anon. 1995) also the scientists in Institut Cerda (Bedós et al. 1990) have separated this type of building concept from intelligent buildings. They call the result of the integration of the ICT (Information and Communication Technology) and building automation to the building, integrated or automated building (cf.

Bernaden & Neubauer 1988, p. 15). However, they keep it as a part of the intelligent building concept. The computer integrated or computer aided building – as this type of IBs can also be called – can also be understood as the first step towards an intelligent building concept (cf. Salokangas 1987, Filloux & Rubinstein 1988).

The European Intelligent Building Group (Anon. 2001g, Lehto 1998a) gave its definition at the end of the 90's:

> *"An intelligent building creates an environment that allows organisations to achieve their business objectives and maximises the effectiveness of its occupants, while at the same time allowing efficient management of resources with minimum life-time costs."*

The EIBG's latest IB concept is described (Kell 2001) as follows:

- *" Assessed in terms of performance not technology.*
- *Incorporates the best available concepts, materials, systems and technologies and integrates these to achieve a building which meets the performance requirements of the building's stakeholders.*
- *Stakeholders include owners, managers & users, as well as local and global community.*

Despite of the technical orientation at the beginning of the IB concept development, the EIBG has followed the line of the I.B.I. in its definition with an approach to the IB concept that includes economy and stakeholders' needs and interests."

### 2.1.3 The Intelligent Building has Senses

Besides scientists (Bedós et al. 1990, Hamilton & Nelson 1999, So & Chan 1999) also corporate representatives (Yasuyoshi 1993, Anon. 2000a, Anon. 2001b, Hood 1993) have made efforts to clarify this new building concept. In addition to those already mentioned, these different definitions highlight, [a)]the integration of sophisticated operational environment to the building architecture, structures and systems, [b)]the concern of the building life cycle and the necessity of flexibility in the changing economy and due to the globalisation, and [c)]the importance of combining sustainability – human and ecological – to the concept (cf. Lehto 2001a, Lehto 2000a, Lehto 1998a, Lehto 1996b).

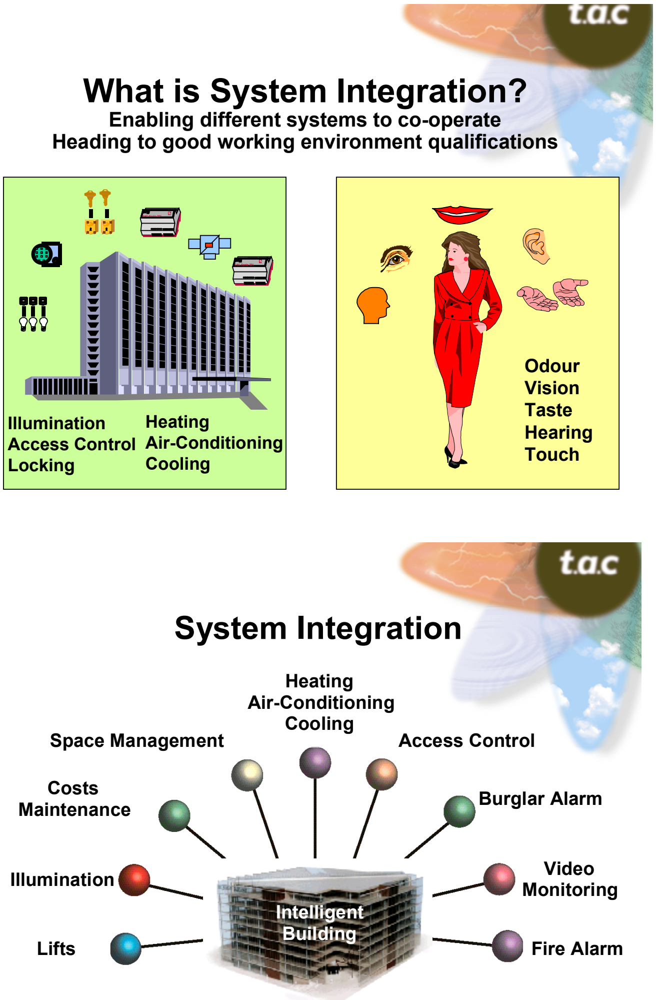


*Figure 4. The metaphor between working environment and human senses (above), and the senses of an Intelligent Building (Huhtanen 2000).*

The following two Japanese examples of the IB concept definition, one from Shimitzu Co. (Yasuyoshi 1993) and another of the Mitsubishi Electric Corporation (Byström 1990), give the central position in the definition to the human being. They describe how the building intelligence is the same as how to connect – on a personal level – the office and building automation and the smart home technology to human mental activities: peace of mind, accommodation and self development. The development among humans and within working environment or home, as well as in other sectors of life, has an effect on the global environment. T.A.C. has added to its IB definition the metaphor of the house and the human senses (Figure 4.).

The traditional industrial driving forces, such as war industry and the exploration of outer space continue to influence product qualifications. Similarly, the availability of the raw materials influences the products. In the modern industry the availability of raw materials often means the availability of the components, and in the future industry it could be the ability to find the creative ideas from the knowledge workers' minds. In one hand, these ideas are needed for IB design and on the other hand, ideas for new types of office space are needed for new types of working methods demanding concentration in the information intensive work. A silent room could be an example of a solution of this kind, or it can be asked, if need for personal space for knowledge work similar to the Eastern gurus' saframs, which are places for meditation, will appear. The meditation takes place in loneliness as often as during certain meditation hours shared by many participants. In the latter case, the sharing of the space is taking place both in privacy and in a certain type of silent communication with others. Could that approach solve the problem of the paradox of parallel need for privacy and interaction in the modern office? Consciousness, well-being and the senses are a key element of the productive office or workplace (Clements-Croome 2000, pp. 29–39).

### 2.1.4 Technology Pushes and Market Pulls

In the Western world the emphasis of the enterprises' IB concepts is often on the equipment integration, which also represents the technology-push-type starting point for the RTD. Despite of the fact, that realisation of the customer and end-user needs – the market pull type starting point – takes place simultaneously, the technology push tends to be the only driving force in the business (cf. Lehto & Himanen 2001). Already in the 1980's it was obvious that the end-user needs are the driving force of the development of the IB concepts (Gouin & Cross 1986, back cover, Bernaden & Neubauer 1988, pp. 3–24). But the development has more or less been based on the implementation of the office and building automation, i.e. the development of the integrated building (Bernaden & Neubauer 1988, pp. 25–250). The more the ICT hardware industry has been growing towards the end of the 90's, the more possibilities for equipment integration has been available.

Not only the need for market pull orientation (cf. Section 4.3.5), but also the vision of the next generation ICT progress towards a content oriented communication industry highlights the importance of the end-user in the R&D work in the ICT industry, as well as in the RTD of the IB construction. All the intelligent building concept definitions place emphasis on the marketing and the end-user needs. The market pull is understood to be as important for the RTD of the IBs as the technology push approach.

Entertainment has been named a driving force in the ICT industry despite of the ICT's profitable effect in information intensive tasks of other fields (Bangemann et al. 1994, Bangemann 1998). Customer needs are in the same position at the consumer mass markets. End-user empowerment can take this position of a driving force in the future ICT business (Figure 19.), and thus in the construction and real estate business of the IBs, on the basis of the win-win and technology-for-all principles. The following is an example of the technology push type approach to the IB concept (Anon. 2001g):

> *"An intelligent building is one that provides a comfortable and productive environment to the occupants through automated control systems such as: heating, ventilation, air-conditions (HVAC): fire safety: security: and energy/lighting management. It is one in which these control systems are integrated and interact with each other. For example, in case of fire, the fire alarm communicates with the security system to unlock the doors. In turn, the security system communicates with the HVAC system to regulate the air flow to stop the flames from spreading. An intelligent building is also one that integrates telecommunications and control services through one structured cabling network and management system that meets current and future technologies, and building/user demands."*

The Smart Homes Foundation's definition for home sector is (van Berlo 2001):

*"Smart home technology is the integration of technologies and services, applied to homes, flats, apartments, houses and small buildings with the purpose of automating them and obtaining and increase safety & security, comfort, communication, and technical management."*

The Smart Homes Foundation indicates also the Smart Home Technology (van Berlo 2001):

*"A house cannot be smart, although certain products and solutions can be". We rather talk about intelligence that can be achieved when products are connected together. A house or working environment, which includes the technology to allow for devices and systems to be controlled automatically, may be termed a Smart Home. The degree to which this control is exercised is variable, being a function of the cost, the person¹s own wishes, and the type of building into which the technology is to be installed. Homes which can automatically adjust the temperature, the level of security and permit efficient communications to the outside world, are of obvious benefit to all, providing they do not go too far and affect the freedom of choice of the person living within them."*

### 2.1.5 Towards Transdisciplinarity

Integration is the ultimate keyword of the intelligent building concept. Professor Derek Clements-Croome, however, places emphasis on transdisciplinarity and interaction, and writes (Clements-Croome 1999, p. 105):

*"Any consideration of intelligent buildings, whether learning, designing or managing them requires a freedom of thinking which can embrace transdisciplinary ideas and systems. The word transdisciplinary, is a truly holistic and highly interactive concept. Intelligent building strategies are dealing with multiple criteria and attempting to integrate ideas over a very wide range."*

Just as the researchers in the I.B.I., Clements-Croome, as well as the directors of the EIBG and the Smart Homes Foundation, Mr. Alan Kell and Mr. Ad van Berlo, base their thinking in the Western tradition. They consider the stakeholders' interests as important as the Japanese consider the human needs.

However, the understanding of the inter-connectivity of the complex technology phenomenon with the diversity of the human life phenomena seems to differ in Western philosophy as compared with the Eastern tradition, if the difference between Western and Eastern versions of the inter-connectivity is understood at all (cf. So 2001, pp. 4–8).

In 1988, the author has described the IB concept as a combination of human intelligence and artificial intelligence (Section 3.4, Lehto 1991a, Lehto 1991c, Lehto 1990a, Lehto 1990b, Lehto 1990c, Lehto 1989b). **The author claimed that the IB concept is better described by listing certain qualities than by a list of high-tech installations. Finally, the IB concept definition received the following verbal form** (Lehto et al. 1993, Lehto & Jantunen 1993, Lehto 1998a):

> *"The IB concept is a correct holistic combination of building solutions satisfying the needs of the occupant, which is growing in wisdom."*

Because a long list of technical apparatus is no guarantee of intelligence, the IBs can be characterised as being integrative, active, informative, interactive, usable, service-oriented, comfortable, healthy (therapeutic), flexible (movable), adaptable, secure, reliable (stabile and accurate), effective, economic, productive (profitable), and based on correct basic technical solutions. The qualifications of the end product are emphasised in the author's definition, which was the starting point for the evaluation of the buildings within the IBs Survey.

Dr. Albert T. P. So the Associate Professor at City University of Hong Kong Intelligent Building Research Centre and the Chairman of Council, Asian Institute of Intelligent Buildings has defined the IBs as follows (So 2001, So & Chan 1999):

> *"An Intelligent Building is designed and constructed based on an appropriate selection of quality environment modules to meet the user's requirements by mapping with the appropriate building facilities to achieve long-term building value. To put it more simple, the IBs are not intelligent by themselves but they can furnish the occupants with more intelligence and enable them to work more efficiently."*

So (2001) has also defined the qualitative modules for the IBs as follows:

> *"There are nine quality environment modules: environmental friendliness, space flexibility and utilisation, life cycle costing, comfort, safety, working efficiency, image of high technology, culture, construction process and structure. Each module comes with a list of facilities, services and technologies. From these sub-elements, are developed an Intelligent Building Index (IBI). This IBI gives a quantitative assessment on an IB."*

Dr. So summarises the existing definition of IBs (So 2001, pp. 4–6) in Europe as being more on the side of the users' requirements than on the technologies. The emphasis of both Singapore's and China's definitions is on control and communications using advanced technologies, while in addition to that the Japanese have placed more emphasis on the occupants themselves. In particular, the consideration of entertainment for the occupants has not been included in any of the definitions used in western countries.

### 2.1.6 Common Factors

The common factors of the different intelligent building concepts can be summarised as follows:

- IBs provide the stakeholders with an effective and productive environment in order to allow them the possibility to maximum performance (in achieving their business objectives and occupant effectiveness).

- The stakeholders are named and can be summarised as follows: local and global community, real estate developers and providers, building managers, designers, building purchasers, building owners, speculators, occupants or tenants and other end-users.

- Either the stakeholders' interests or the end-users' requirements, i.e., the needs of the occupants are dominant in the terms of performance of the building, which puts the emphasis on efficacy (Figure 20.).

- The performance will be gained in a cost effective manner with minimum life-time costs.

- Despite of the cost minimising, the accommodation should be convenient, the management of resources efficient and sustainability should be respected.

- The performance needs will be met by integrating the best available concepts, materials, systems and technologies, architecture and structures, which match the stakeholders interests or needs

- The performance can be evaluated by or implemented with environmental friendliness, flexibility and utilisation of space, movable space elements and equipment, life cycle costing, comfort, convenience, safety and security, working efficiency, image of high technology, culture, construction process and structure, long term flexibility, and marketability, information intensity, interaction, service-orientation, ability of promoting health (therapeutic), adaptability, reliability (stable and accurate), and productivity (profitability) at correctness of basic technical solutions.

The intelligent building concept has, since the 1980's, kept the end-user as the primary stakeholder of the IBs. The constructor and the designer have been the key stakeholders in the building sector. They have not always been mentioned in connection with the stakeholders, although the importance of the role of design and of construction quality has not been ignored. Building developers, designers and building automation experts must work in close co-operation with information technology, telecommunications and artificial intelligence specialists. This idea is winning ground among people for urban planning and community development. The authorities are also missing from the lists of the stakeholders of the IB concepts.

As mentioned earlier, the IB concept is at the same time a concept for spatial requirements and for the means of creating space. The modern means of IB construction rely, to a great extent, on digital ICT, which is highlighted in the IB Pyramid and other corresponding descriptions and definitions of IB concepts. The consensus among professionals of different disciplines working in the field of IBs is that the concept of IBs is wider than that of the integrated building.

Dr. So mentions the problem of the absence of a universal definition that would define the requirements of the future building. He suggests a new definition of IBs from Asia for wider use in the world.

## 2.2 Intelligent Buildings Internationally

The high technology concept of intelligent buildings was introduced in the United States in the early 1980s. 'Smart Buildings' came from the deregulation of Telecoms in the US (Northcroft 2001a). The concept of the intelligent building is well advanced in the United States, because in the US, the law has permitted a third party to resell telephone services (Coggan 2001). Similar progress has taken place in Europe as well.

### 2.2.1 Construction Activities

In the early 1980s, trade magazines began running stories on "intelligent buildings." Publications concerned with mechanical systems did articles on automation systems making buildings more energy-efficient. Magazines serving the communications industry told how advanced telecommunications systems have made buildings more efficient and therefore more intelligent. As a result of extensive press coverage and supplier advertising, there has been growing pressure on owners and developers to build intelligent buildings (Coggan 2001). On the other hand Björkdahl has said (Björkdahl 2001):

> *"I guess one has to recognize that most development is initiated by the manufacturers and not by the buyers."*

Although no formal definition exists, intelligent buildings use electronics extensively and are high-technology-related. In fact, the National Academy of Sciences in Washington, DC, had a committee dealing with "electronically-enhanced" buildings. As in any emerging industry, there will be implications and challenges of different kinds. This added functionality (electronic gadgets and whiz functions) does not necessarily have to be all evil (Björkdahl 2001). Many of the functions and features once introduced as luxury items become standard equipment over time.

A starting point for the development of the IBs was the English architect Norman Foster's Hong Kong and Shanghai Bank building in the early 1980's, which had a structure that allowed change (solar collectors and flexible space among other services).

Even, in the turn of the 1990s, it was possible to name the great IB projects in the world, e.g. Hong Kong and Shanghai Bank, Kajima Headquarters, NTT (Nippon Telegraph and telephone Co.) Twins, Simithu L-Tower in Tokio, Lloyd's of London Headquarters, British Airways Headquarters in London, SAS Building in Stockholm, Digital Future Office, and SOL Head office in Helsinki (cf. Gouin & Cross 1986, pp. 8–18). During the last half of the 90s the progress in the IB construction has been rapid, and it is not any more possible to name all the projects. At the same time, the definition of the IBs has been applied variedly, and thus the combinations of technical qualifications differ from building to building.

In the beginning, the big operators in ICT in Northern America (USA and Canada), Japan and in Europe (Great Britain and France) shared the interest in the IBs. The first wave of intelligent buildings in the USA broke already during the 1980's, while on the old continent it took place in the beginning of 90's due to the economic recession. This world wide economic situation of 90's had an effect also on the North American market (Figure 5.).

However, many companies could continue their R&D work with the IB-related technology during the retarded market pull period, which resulted in the recovery starting before the middle of the 1990's. The small information intensive countries – among them Finland – (Figure 5.) soon adopted the IB concept. The interest in the IBs grew in all parts of the world, and especially Mexico, Italy, Greece, Germany, Switzerland and Australia became active in the field.

In Finland, the focus has been on the LON compatible component development both for the control system itself, and on the building service equipment control units. The remote control systems have been another area where the Finnish R&D efforts have resulted in good market shares in domestic and international markets. The IBs with LON controls have an important role in office buildings also in Switzerland. In Mexico, the interest in the IB technology has relied on several tall office IB projects. In Italy there has also been interest in IB science parks in addition to IB offices. In Greece especially universities have been active in coping the new area of technology and co-operating with industry in various research projects on the IB equipment.

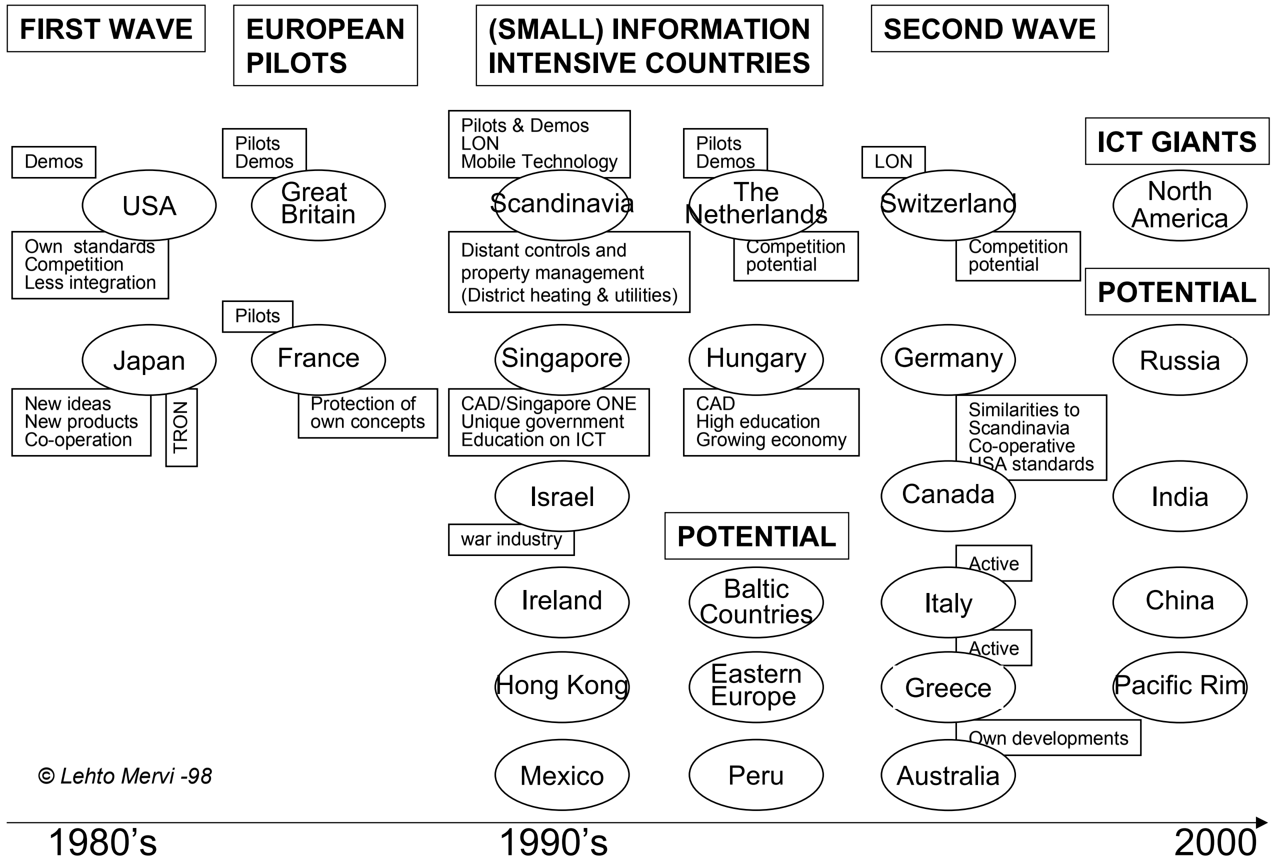


*Figure 5. International intelligent building and smart house activities.*

In Asia, especially the Japanese have built many tall intelligent office buildings, and also in Hong Kong and in Singapore activity took place all the way from the late 80's till the middle of the 90's, after which their economical difficulties started to affect the building sector.

The second wave has brought with it still new active localities: Poland (Anon. 2001i), India (Anon. 2001k), Russia (Anon. 2001h), China (Anon. 2001l) and Peru. Undoubtedly, the IB industry can be characterised as a global business. Thus, it is universal. Similar to the ICT industry, it is at the same time global and local.

### 2.2.2 Associations

After Intelligent Building Institute, the Canadian originated CABA (Continental Automated Buildings Association, previously: the North American Home and Building Automation Association) has been one of the most active organisations of the IB industry. It's purpose and activities are as follows (at their home page: http://www.caba.org):

> *"CABA (the Continental Automated Buildings Association) is North America's key source for information, education, and networking relating to home and building automation. Its mission is to encourage the development, promotion and adoption of business opportunities in the home and building automation industry. Members include manufacturers, dealers, installers, telecommunications companies, energy utilities, builders, consultants, research organizations, publishers, educational institutions, governments and associations.*
>
> *CABA's numerous publications are recognized by many in the industry for providing more information about the home and building automation market than any other single source in the United States and Canada."*

The EIGB's activities have turned to that direction as well (at their home page: http://www.eibg.org or http://www.eibg.net/index.html):

> *"The European Intelligent Building Group is Europe's leading independent network of organisations committed to developing the market for intelligent*

*buildings. The EIBG network includes many of Europe's leading companies involved with the development, design, construction and management of buildings.*

*The group's activities are directed by an Executive Committee, elected by the membership, and supported by an executive office based in London."*

The work group WO98 – Information Technology for Construction – works under the international construction science organisation CIB (International Council for research and Innovation in Building and Construction) and it has also worked on intelligent buildings, organising conferences on the subject.

The Smart Homes Foundation is a new internationally oriented platform for promoting smart home technology, exchanging ideas, initiating projects and implementing technology and services into practice (van Berlo 2001):

*"The Smart Homes Foundation aims to achieve the integration and application of smart home technology as well as to create an international forum. This forum wishes to discuss and exchange information on the various aspects of smart homes, such as technical infrastructure, software & hardware, applications, demonstration and marketing issues (home shopping, smart toys, and other household technologies), as well as societal impacts. In its most advanced form, a smart home is a home where many of the functions typically carried out by the occupants function automatically. In fact, the level of "smartness" can vary a lot. Therefore, the Smart Homes Foundation will particularly pay attention to the "Design for All" concept in all its activities.*

*Consumer electronics industry, computer and software companies and the electronic components industry are developing home systems and network technology to serve a broad public. This will contribute to the comfort of modern living, and everyone can benefit from this technology. A Smart Home can also be used to help disabled people and those senior citizens needing help."*

### 2.2.3 Publications

In addition to the reports on IBs available from CABA, EIBG, Smart Home Foundation, City University of Hong Kong, etc. also regularly published magazines are available. These include the CABA Quarterly publication, the Electronic Home magazine, a Polish Technical magazine "Inteligentny Budynek" (Intelligent Building) and “Inteligentny Dom” (Intelligent House) (Anon. 2001i). The Polish Inteligentny Budynek Integracja Systemów Ltd. also publishes the annual Report, which is the first Polish publication dealing with the matter of intelligent buildings in Poland, and has since 1996 organised a yearly international conference on IBs. It is possible to find information about the IBs in India at Indian Architecture WWWBoard (Anon. 2001k). A reference to the Asian IB projects is the South East Asia Study (Northcroft 2001b). Intelligent Building Research Centre (IBRC) at City University of Hong Kong concentrates on technological developments in building systems and building services, which are closely related to building automation (BA), energy management and information transmission (Anon. 2001n). The role of IBRC is to enhance building automation system technologies and other IB-related issues in the Far East by creating new features that really suit the Asian requirements. An initiative has been taken by the University of Reading to publish a scientific journal on IB research.

### 2.2.4 Education and Research

A number of educational programs on IBs are available. At the University of Reading, Department of Construction Management & Engineering, it is possible to take a MSc in Intelligent Buildings (Anon. 2002). At Temasek Polytechnic in Singapore a Diploma in Intelligent Building Technology can be taken (Anon. 2001j). There is also a Diploma course at Shijiazhuang Railway Engineering Institute in China (Clements-Croome 2002, personal information). At Carnegie Mellon University in Pittsburgh courses for IB are available. At the Center For Building Performance and Diagnostics (CBPD) (A National Science Foundation Industry-University Co-operative Research Center, IUCRC) a living laboratory of Intelligent Workplace or Workplace of the Future, housing a 7000-square-foot laboratory on the roof of Margaret Morrison Carnegie Hall, was created to help researchers test and develop technologies to improve the office environment for the U.S. work force (cf. Hartkopf & Hemphill in Clements-Croome 2000, pp.

275–280). Issues of health, individual comfort, organisational flexibility, motivation, productivity and efficiency are studied there (Preger 2001).

Several EU founded projects within the Fourt and Fifth Framework Programmes have been accomplished and are continuing on smart housing and IB technology, and on the possibilities to untilisize it in working environment, in housing and independent living. In many universities and research institutes all over the world research groups are working on the IB problems either parallel to their core research subject or in various projects on IBs. As an example of this can be mentioned the joint research between the School of Architecture and the Property Resource Management Department at University of Portsmouth, working on smart housing (Anon. 2001p).

The Johnson Controls Intelligent Building Research Centre, established at City University of Hong Kong in 1997, has been involved in all kinds of research work related to the development of building systems within intelligent buildings. The Research Centre is funded by the Research Grants Council of University Grants Council of HKSAR Government, Johnson Controls (HK) Ltd. and City University of Hong Kong (Anon. 2001o).

The main focus of the research at the Essex University is on the development of highly compact intelligent embedded-agents, agent languages and communication paradigms, which form the heart of such devices and environments. They write on their work (Anon. 2001c):

> *"In this context "intelligent" is taken as meaning "automation of activities we usually associate with needing human thought" (Callaghan 99). One manifestation of such an environment can be found now in the so-called intelligent building in which rooms are controlled by computers which are connected to sensors and effectors by means of a network. A more formal definition of an intelligent-building is "one that utilises computer technology to autonomously govern the environment so as to optimise user comfort, energy-consumption, safety and work efficiency" (Callaghan 99). A typical intelligent-building is made up of numerous independent sub-systems, which manage aspects such as heating, lighting, door entry, fire, security, etc. (with many sub-systems being automated). For example, an intelligent-building services-network such as EIBus, LonWorks or BACnet is used to connect*

*these environmental sub-systems together thereby enabling their operation to be synchronously (and intelligently) orchestrated or remotely controlled. Such technology has created the possibility of creating truly intelligent environments in which intelligent controllers enable the environment to react thoughtfully to the needs of the stakeholders."*

Nokia Communications has established a research unit for smart housing in Lindsköping in Sweden, which was, however, closed in 2002.

### 2.2.5 Awards

The I.B.I. has already started the Intelligent Building Awards. Since 1999, WTA (World Teleport Association) has presented annual awards to the Intelligent City of the year, Intelligent Building of the year, and the Intelligent City Visionary of the year (Anon. 2001m). The Teleport Awards are presented during a major conference and are promoted in advance to the media. Winners receive a presentation photograph and assistance with promoting the award to their customers.

## 2.3 Integrated Facilities Management

The facilities management science, which is a new field in construction, is gaining basic information from the other related research sciences (Leväinen 2000). Also, like the IB concept definitions, the Facilities Management definitions vary (Leväinen 2000). This literature of various FM definitions will not be referred to further in this context except in the relation to the IB concepts (cf. Figure 6.).

The discussion on the combination of two new concepts, those of Intelligent Buildings and Facilities Management, has started (Thompson & Plouffe 1999, Redleim & Schmildt 1999). In the properties and facilities management literature, the intelligent building is quite often understood as a tool for building management, which is carried out by installing building and office automation and communication networks into the building (cf. Kyle & Baird 1991, pp. 268–269). Increasingly powerful microprocessors and network technologies provide the building manager with an information intensive environment never before seen in the industry. Lack of a single provider for an integrated IB and FM system is obvious, since only a few of them exist.

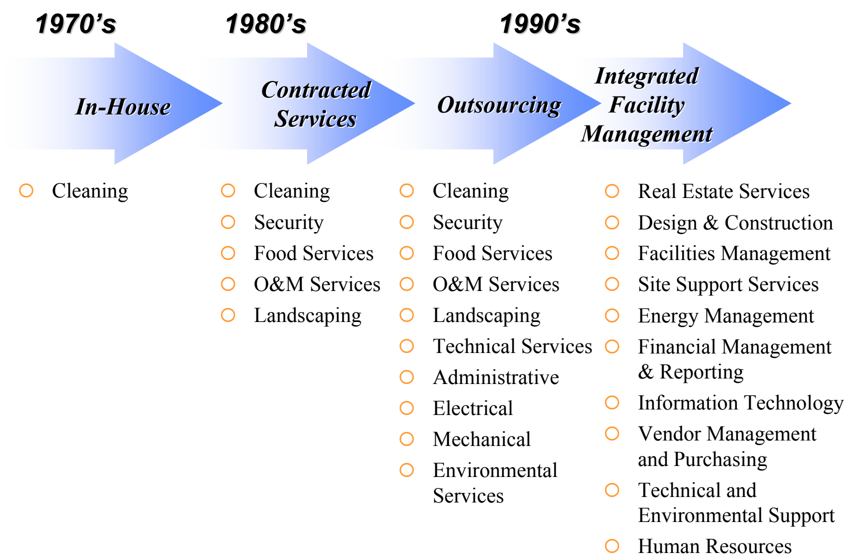


*Figure 6. The evolution of Facilities management into Integrated Facilities management (Anon. year unknown).*

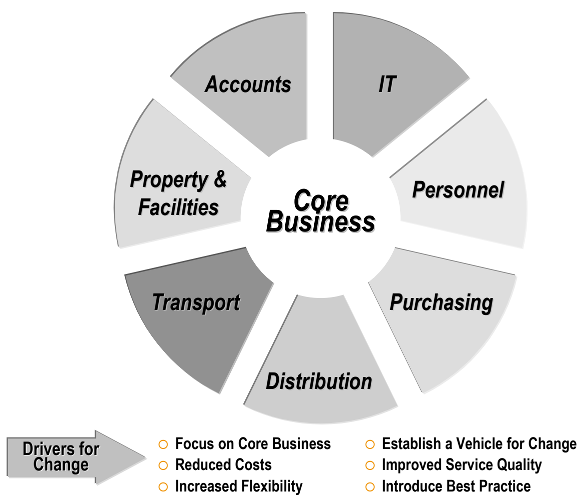


*Figure 7. Integrated Facilities management (Anon. year unknown).*

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 building 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 combination of FM and IB has been called Integrated Facilities Management (Figure 7.), although no agreement on definition exists. Using the term integrated in this connection can be seen parallel to the use of integrated in the connection of the term intelligent building (Section 2.1.2).

The evolution from FM to Integrated Facilities Management is relevant to the paradigm of this study (Figure 6.).

There are some providers for both IB and FM technology. One of them describes their functions as follows (Anon. 2001f):

> *"Our Facility Management Services integrate all the functions necessary to support the daily operations of facilities from landscaping to high tech operations and maintenance. Integrating facility or installation management services provides clients with the advantage of a single point of contact, best practice implementation from facilities world-wide, energy management, tracking and measurement of facility performance factors, accounting consolidation, and the technical expertise.*
>
> *Workplace Consulting Services and Design Services provide clients with expert planning support for critical workplace decisions: Space Planning, Occupancy Planning, Project Management and Move Management. Design Services help plan for change and develop solutions that ensure workforce productivity. Combined, Design and Construction support gives clients the flexibility to take on major workplace redesign projects, or make minor adjustments, without having to subcontract and manage providers.*

*Workplace Consulting and Design Services can be packaged as part of Integrated Facility Management Services, on an as needed basis or implemented as a stand alone service to support client decision making."*

The second half of this thesis, the IBs Survey is based on the IB oriented approach to the paradigms common to IB and FM, such as system integration, flexibility, adaptability, services, productivity of the occupants, security, sustainability and the use of ICT (cf. Figure 11.). The IB and FM concepts both extend to integrate the human functions of building manager and building occupant as a part of the concept.

Flexibility can be divided into two: spatial flexibility and adaptability. The adaptability can be understood as the "skill" of the building to adjust according to the occupants' needs needed for HVAC, energy and lighting monitoring and controls. Spatial flexibility can be seen more as a concern for FM, while adaptability is more often included into the IB systems through building automation, as well as active structures such as automated doors. However, the ability to adjust operations in time is essential for running the FM tasks as well. It seems quite impossible to separate the IB concept from that of FM.

## 2.4 Workspace Phenomena

Several different factors interface in real, material space – that is, in the workspace. Research and innovations in production focus on the plant, machinery or processes. The invention of the assembly line is a good example of these efforts. Also, it has been typical of the industrial processes to create new working methods and tools for increasing productivity, such as the idea of teamwork. Such innovations as the organisational and economical ones for improving productivity are frequent. The knowledge of the improvements on workspace design can be included into the management, human resources, communication and information systems as well. Thus, it is fruitful to track spatial information from these types of sources.

### 2.4.1 From Ergonomics to Empowerment

Virtually ignored in the 1960s, the view that high standards in the work environment would result in improved productivity emerged in the '70s and '80s. Quality levels and standards were sometimes set very high, but no clear relationship between worker satisfaction, productivity and work environment was found (Figure 8.). During the last ten years work organisations have become more team-based. Teams are responsible for planning and carrying out the work as well as for quality control. Organisational issues have been in focus and a more participative approaches have been adopted, involving increased worker-team empowerment.

The role and importance of building-related systems for workspace varies between industries. In mass product manufacturing, for example, the buildings have minimal influence compared to that of an assembly production plant, and the roles of the management reflect this. For office space it is the converse, with building owners and operators predominating, and production and users being less involved. All this gives rise to the differing perceptions of what is the main focus of workspace management.

### 2.4.2 Constant Change in the 1990's

The main streams in office building design have been such as cost effective room and corridor orientation, new ideas of mass variations (cubes for open areas, triangle for natural light), floor plan and the furniture layout variations among other things, work stations allocation which promote flexibility, and make the equipment and tools more accessible, and reduction of the overall amount of space required without reducing comfort (cf. Hood 1993, Ryburg 1993). The typical ideas of the beginning of the 1990's in office design were (Hood 1993, cf. also Ryburg 1993): high density space planning, workspace sharing, free address workstations (or non-individually assigned desk allocation practise such as that of Digital Future Office in Helsinki), working at home, working in the customer's office, and innovative physical design.

The major issues related to the built environment were: accommodating personal privacy on an as-needed basis, ergonomics, personal environmental control, life cycle cost (reconfiguration), problems with interfaces (building to furniture,

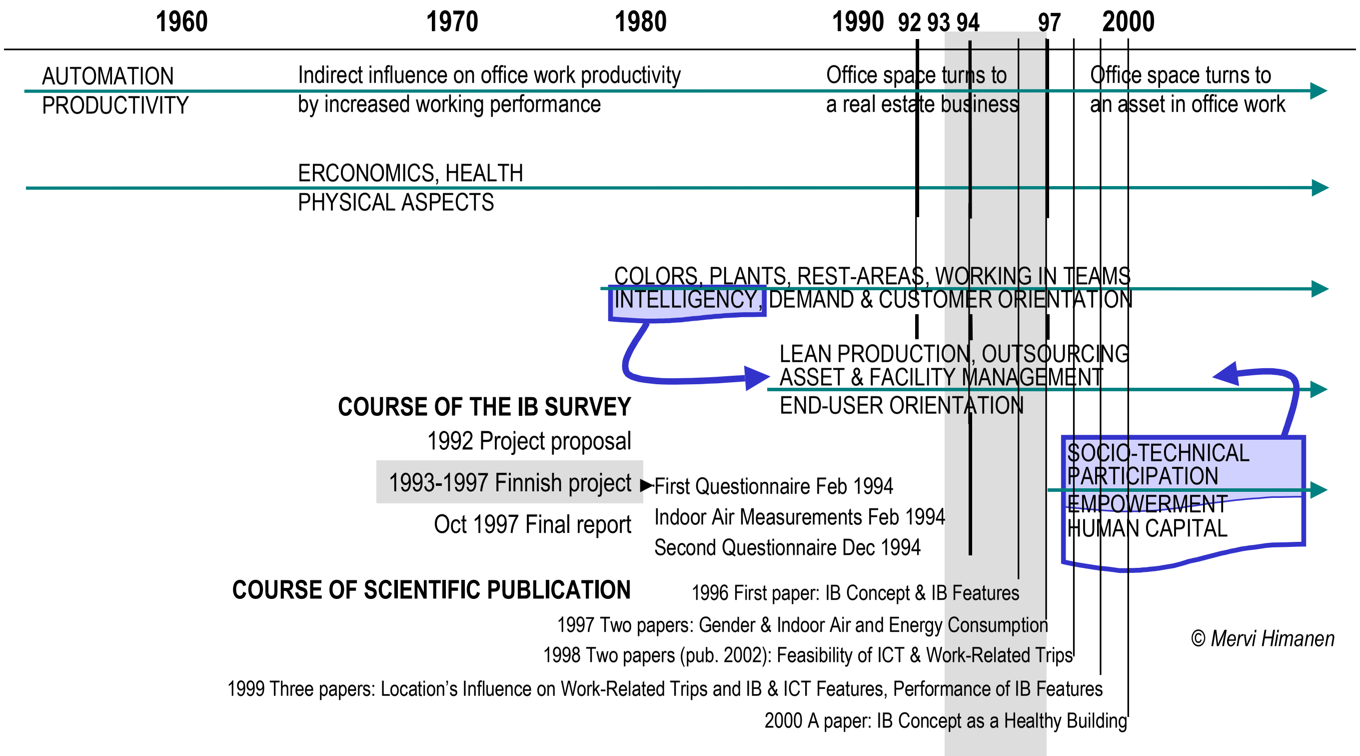


*Figure 8. The R&D work of office space and some key elements of the evolution of industrial production, and the chronological course of the IBs Survey publishing.*

furniture to equipment, etc. (but not to user at that time)), and environmental problems (Hood 1993). These were also the key elements in the construction of the IBs in the turn of the decade from 1980's to 1990's.

The whole 1990s have been a period of constant change in working life (Korvajärvi & Lehto A-M. 2000). Variations of sharing space between personal workplace and shared office spaces have followed each other, aiming to solve the problem of balancing a peaceful personal work environment and the need for space for communication.

### 2.4.3 Shared Spaces – from Canteens to Interoffice Restaurants

Hand in hand with employers, organisations representing workers' interests, such as trade unions, have taken care especially of the development of such spaces as locker rooms, canteens and dining rooms. In the first place, minimalism was the leading design criterion for social spaces, if the rhetorical cases of the bathrooms in the offices of Northern American top managers are excluded. On the other hand, in some working cultures, the lunchroom for example has been under development, resulting in more satisfactory environments, where many organisational and rational improvements of the working culture have also flourished. In the best cases the result has been that the canteen has actually turned out to be a set of restaurants inside a factory or office building. Not only blue- and white-collar workers join for a common lunch, but also clients can be invited to the same table (Joronen 1993). Not only the actual workplace, but shared spaces such as meeting rooms, restaurants, sport halls, parking, etc. are important in improving work or office space quality. If the fit is good there can be significant gains in productivity, profits, innovation and morale (Hood 1993, cf. also Joronen 1993). The variety of services available in a modern office building is considerable, and the number of them is growing. Due to the concept of outsourcing, these services are increasingly brought from outside the office building. New design criteria is needed for spatial layouts and security, for example.

### 2.4.4 Straight Contact between Office and "Factory Floor"

Often, studies on the working environment have taken place in offices, and in research laboratories where office rooms have been set up for research purposes.

Research results of this type serve the interests of the office builders, owners and tenants. Many lessons from that research can also be used for increasing performance in other types of work. The workers in a modern factory may sit behind their computer monitors, and their work may not differ from that of the office worker's. Entertainment and information businesses are literally called industries. They are industries with immaterial products. Modern industry cannot any longer afford to keep up barriers of any kind (Eoyang 1993) – neither between office space and factory floor, nor in organisational and spatial forms. The lower the barriers between various workers' groups become, the more closely the factory floor is integrated to the office space and the more similar those two working areas become. Much can also be done through proper building design parallel to the improvements in production, which too affect the space positively. For example, due to the process automation, in some cases, the production space is as clean as the office, if not cleaner.

### 2.4.5 Occupational and Environmental Psychology

The occupational or industrial psychology of information or knowledge workplaces has been studied frequently with various methods (Zuboff 1990, Huuhtanen 1985, Ranta & Huuhtanen 1988, Teikari 1991, Järvenpää 1991, Fredriksson & Tuunainen 1992). Especially, the studies where the workplace is seen as a positive resource for the office work seem interesting in the terms of the facility or asset management (Zuboff 1990, Järvenpää 1991, Fredriksson & Tuunainen 1992). The first studies on the mental load of the information intensive work – or computer-aided work as it was then called – showed positive occupant response to the use of ICT (cf. Järvenpää 1991, pp. 158–161). Today many subjects of the knowledge work psychology and work environment are still under constant research (cf. Härmä 2000).

### 2.4.6 Automation, Ergonomics and Psychometrics Enter the Office

After the office automation conquered offices, workspace research has been responsible for ergonomics concerning personal machinery and furniture, followed by studies with such interior parameters of the workspace as colour and materials of floor, wall and ceiling coatings as variables. Such studies belong to work (or occupational) psychology and environmental psychology (Horelli 1982, Horelli 1992, Farshchi & Fisher in Clements-Croome 2000, pp. 60–63) and interior design. Psychometrics are carried out in various types of rooms and spaces (Kwallek 1998, Küller 1995a, Küller 1995b, Anon. 2001e).

### 2.4.7 Indoor Air – Comfort and Productivity

The paradigm of IBs is absorbed into that of indoor climate and its control. There is a vast literature on indoor air research. Availability of this scientific information is among other efforts guaranteed by continual work in two main conferences: Indoor Air and Healthy Buildings. The indoor air industry can rely on associations, such as American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), International Society of Indoor Air Quality and Climate (ISIAQ), Air Conditioning Associations (REHVA), Scandinavian Federation of Heating, and Air-Conditioning and Sanitary Engineering Associations (SCANVAC).

#### 2.4.7.1 Productivity

Indoor climate research has covered aspects of workplace productivity. Tests on physiological reactions – stress, body temperatures, various controlled office activities, etc. – have been included in laboratory studies on indoor climate measuring humidity, carbon dioxide, air particles, odours, etc. Professor P. Ole Fanger (the Technical University of Denmark) has been one of the leading pioneers in this field (Fanger 2001). For example, Dr. David Wyon (International Centre for Indoor Environment and Energy, the Technical University of Denmark) has studied occupant response metrics on health, comfort and productivity of various tasks (Wyon 2001). The UK consultants Davis, Langdon & Everest (Anon. 2001a) have calculated the financial effects of room temperature changes on the total building costs including the salaries of the occupants.

The lack of sick building syndromes (SBS) has been a measure for the productivity. It has been found that, if the number of the typical sick building health symptoms reduces from six to two the work productivity rises 10 per cent (Wyon 1993, cf. also Wyon in Clements-Croome 2000, pp. 192–206). The performance of the office will be considered more closely in section 4.3.5.8 and sick building syndrome in section 2.5.5.

#### 2.4.7.2 Clothing

Comparable tests on physiological reactions to indoor air studies have been included in work clothing research (Kuosa et al. 1985, Meinander 2001). Thus, studies on the best macro- or micro-climate and their combinations for certain types of work have been made (cf. ISO 7730). Sometimes they have included tests on work performance in various conditions. The lack of research on various combinations of micro- and macro-climate has been realised among indoor air specialists, for example, professor Olli Seppänen from HUT (Helsinki University of Technology) has involved himself with it (Kuosa 1985, Vilkki et al. 1987, Lindholm et al. 1987, Majanen 1987). This problem is highlighted in certain types of buildings, such as shops, where the clients are dressed for outdoors and saleswomen and -men for indoor work. Due to the cultural differences in dressing codes, this problem is not unknown in office environment, either. For example, gender and even job description can vary the dressing code of the office workers in such an extent that it has an influence on the indoor air quality requirements.

The sick building syndrome correlates with the factor of women (Section 2.5.5), a fact often difficult to explain merely with building related factors. According to office dressing code women have long been using blouse and skirt as a type of business uniform. A thick sweater has been an optional cloth for cold days. The heat insulation (the clo-value; 1 clo = 0.155 $m^2\,{}^oC/W$) of women's clothing in the office is not usually as good as that of the men’s suit (Lehto 1978). No wonder then that the factor of women correlates with the sick building syndrome. Nowadays, the women’s dressing code has become more flexible, and particularly female professionals and executives have since the late 1980's dressed in offices in a dress and jacket or in a jacket suit.

### 2.4.8 Team Work, Participation and Empowerment

After teamwork oriented production methods have come in to use, the standard of the physical workplace became less important as participation and empowerment increased, giving solutions that were more economical. This has given significant results; for instance when the workers were granted more influence, their demands concerning the standard of work environment actually decreased, along with the costs. The participation, teamwork and empowerment in general lead to a better work situation and level of commitment, which in turn produces improvements in productivity. Thus, worker influence on the total work situation seems to result in high satisfaction as well as in high productivity, while improvement of work environment above a basic level is then considered less important. At the same time space design can promote teamwork and prevent the workers' isolation. The risks of negative processes adversely affecting on the less productive team members can be prevented. User participation in building projects is considered to be important both to ensure fitness for purpose and the correct assumption of user wants. It could also give the opportunity to change the work organisation. The criterion for a solution to be 'good' needs questioning, as short-term acceptance by the users is not always enough. (Kadefors et al. 2000).

##### 2.4.8.1 Enjoying One's Work

Productivity is no longer the only goal (Kaplan & Kaplan 1977). At least it should be considered carefully, which are the right choices when making work environment productive (Aronoff & Kaplan 1996). Sometimes, it is even claimed to be a wrong starting point for the R&D work of working environment. Increasingly quality and work satisfaction, as well as a healthy and enjoyable working environment, is valued more than pure productivity. It is a well-known fact that a mentally and physically satisfying working environment has a positive influence also on productivity (cf. Fredriksson & Tuunainen 1992). Even relaxation helps (Dryden & Vos 1996) to achieve the same or better results than pushing hard after production records. On the other hand, a certain amount of stress is needed for superior performance. Many new research topics can be identified, if one looks at the phenomena from these new points of view, relevant to the goals of workspace design.

##### 2.4.8.2 Sustainability, Usability and Human Capital

Sustainability, flexibility, usability, and participation and empowerment are new variables of the workspace design, and they are not at all as well studied as the previously mentioned properties of workspace. These studies employ the latest knowledge of human engineering, usability (cf. Usability laboratories at Helsinki University of technology, Information Technology in Industrial Production and at Tampere University Computer Human Interaction Group, or at VTT Industrial

Systems Man-Machine-Psychology) and the new approach to the economy and the organisational factors (Chang 1988, Chu 1995, Koivula 1997, Kulkki 1996, Myss 1997, Rantanen 1996, Roos et al. 1997, Sveiby 2000, Zuboff 1990). The meaning of such issues as the tacit knowledge and the human or intellectual capital are included in the common business practises. They are reported in more detail in the section of industrial economics (cf. Section 4.3.5, Figure 19.). In addition to financial assets and results, the enterprises are now reporting their intellectual capital.

The human variables indicate the research paradigm of workspace design today. It is a fact that intelligent buildings are in a similar position as other new information or knowledge production factors such as intellectual capital. The image of the building is a good example of the phenomenon of tacit knowledge in construction, which is becoming together with the implementation of the IB concept a matter of financial importance in profit making from construction knowledge. Especially human factors and values are important in combining various sides of workspace qualities.

It becomes obvious that in order to hit the targets of sustainability, technical progress (cf. Sections 2.1 and 2.3) alone is not enough, but the social and economical means have to be used parallel to it. Technical progress has been seen on various occasions as a synonym for economical. Both of these sectors are seeking for solutions beneficial in terms of spatial costs, work efficiency, energy efficiency, cost-effective business travelling, etc. It seems obvious, although still mostly unstudied and thus unverified, that if techno-economical solutions have increased efficiency – although not always in a nature and user friendly manner – the socio-technical solutions could have similar potential in beneficial terms. Actually, socio-technical problem solving could in the end, at least to some extent, offer more sustainable results than techno-economical, especially if it is remembered that sustainable development consists of human (or social) and nature's well-being. The development of the user oriented building design, or human engineering and usability of spaces, which aims towards procedures and products encouraging occupants to save energy, space, etc., can be pointed out as examples of a kind of a new idea of socio-technical progress. They can also be called examples of user empowerment.

Worker empowerment means, among other things, [1)] to let the end-user use her or his own power over the things concerning her or his work, [2)] a new type of communication between experts and end-users, [3)] communication between genders, [4)] to encourage let go of the killing by silence attitude, [5)] trust in co-workers, [6)] the will to make the enhancements to become a practise, [7)] new means for studying end-user opinion (Keskinen 1999), and [8)] re-conceptualisation of existing theories of knowledge management for making a difference in practise (Tuomi, 1999, p. 414). This progress is simultaneous with the turn of the R&D works or RTD from technology push to market pull (Lehto & Himanen 2001). Technical advancement exits nowadays also for the satisfaction of the end-user needs and for end-user empowerment, not only for the traditional product development or for increasing the effectiveness of the use of limited methods and resources of production.

The concept of the conscious human mind has long been classified as a mystical phenomenon or a part of religion and studied only as a theoretical philosophical phenomenon. Nowadays, the concept of the conscious human mind is becoming a serious part of the scientific paradigms of other sciences than psychology or philosophy including technology, as well as a part of competitive business activities. The conscious mind is studied e.g. in universities as a consequence of the growing interest in ethics (Glenn 1990, Whitbeck 1998), and within the technical sciences, as a part of the information science (Aleksander 1999). It has been realised that information flow can have different forms such as intelligence, knowledge, and competence (Tuomi 1999, pp. 128–135); even a conscious computer is under development (Haikonen 1999). Further, information flow from data to intelligence, via knowledge and action to intuition (Figure 13., Section 4.3.3.2) is used for understanding and implementing the best practises of knowledge management. Nonaka–Takeuchi learning cycle has been used for the same purpose (Nonaka & Takeuchi in Tuomi 1999, pp. 325). The ability to bring thoughts and ideas – behaviour patterns – from the unconscious mind to the conscious one is considered a measure for the growth of the human being in consciousness (Saaristo 2000, pp. 129–149).

The concept of the consciousness technology is an attempt for understanding and implementing technology in a context of growing consciousness (Glenn 1990). Within the workplace science paradigm the consciousness has also been introduced as a new approach to building research (Clements-Croome 2000, pp. 30–32).

### 2.4.9 Knowledge Work

Receiving or retrieval of information, information handling and creation of new information are typical tasks of information intensive work. ICT-tools are often used for information intensive work. Typically, knowledge has great importance for the individual worker, working groups or teams at any organisation level of information intensive work (Härmä 2000, p. 6). The terms, information and knowledge work, have so far been used without distinguishing them from each other.

#### 2.4.9.1 Description

For distinguishing the concept of information intensive work it can be relevant in some cases (e.g. when studying vision or cognitive processes) to separate those, who are computing from those, who don't. This separation is not relevant in the case of a study of social context, or in the case of a study of work nature and autonomy, or in the case of studying working time dynamics (Julkunen & Nätti 2000, p. 173).

Professor Manuel Castells has divided those who work with information handling, transfer and creation into two groups: generic labour and self-programmable labour. These can be distinguished from each other by the level of the workers' education and their ability to become better educated (life long learning), i.e. to get hold of the accumulated knowledge and information needed in information or knowledge work (Castells in Julkunen & Nätti 2000, p. 179).

#### 2.4.9.2 Nature

Research results from workplace surveys speak of the importance of social skills and customer relationships and relationships to customer organisations. They speak also of the importance of the home organisation, which in sophisticated ICT-aided work is a more central criterion for work than before (Korvajärvi 1998a and 1999a in Korvajärvi & Lehto A.-M. 2000, p. 191). As a matter of fact, in information intensive work the emphasis is ever more strongly on social and cultural skills instead of the technology (Korvajärvi & Lehto A.-M. 2000, p. 191).

The organisational progress and the influence of ICT make living, working, and the society – with easy access to governmental and municipal information – more transparent than before. All interests are made visible. Transparency is a good basis for negotiations and teamwork. On the other hand, it gives opportunities for hurting the neighbours', workmates' or others' interests. To achieve a creative interaction it is necessary that the parties involved trust each other – which requires a 'dialogue in continuity'. The trend of outsourcing non-core activities, networking, etc. together with transparency makes trust even more important. Turbulent business life is faced with the difficulty of introducing long-term considerations, which the creation of true trust often requires.

Since the 1970's, the amount of unpaid overtime work has increased in many countries among professionals, executives, and in general among those who work autonomously and are well paid and highly productive, and among those who make a career for themselves (Julkunen & Nätti 2000, p. 175). New management routines and lack of workforce cause haste and pressure in all sectors (time limited tasks, growing demands in knowledge skills), not the change in the work itself or the growing use ICT-tools (Korvajärvi & Lehto A-M. 2000, p. 191). The information age is introducing softer values in managing in a more serious and practical way than before (Lehto & Himanen 2001, cf. also Keskinen 1999, pp. 32–34).

#### 2.4.9.3 Knowledge Workforce

The structure of the European information workforce has wide similarities (Julkunen & Nätti 2000, p. 180) such as good education, similar age pracket (from 25 to 44), and also a low unionisation rate.

According to the Finnish work barometer in 1993 half of all employees had a job, which at least partly included information intensive tasks. The work of a quarter (25.7 per cent) of all employees mostly consists of information handling, transfer and creation.

The knowledge intensity correlates with socio-economic status; 90 per cent of the higher-grade professionals have jobs which are, at least to some extent, knowledge oriented, 75 per cent of lower-grade professionals have such jobs, and 33 per cent of other workers (Pekkola & Ylöstalo 1996). If the status of information intensive working is defined on the basis of a set of such factors as regular use of computer, work consisting of planning tasks, and minimum education level at secondary education, the amounts of the knowledge workers reduce to 65 per cent among the higher-grade professionals, to 33 per cent among the lower-grade professionals and to 9 per cent among other workers (Blom et al. 1999 in Julkunen & Nätti 2000, p. 179). The latter definition of the information intensive work does not necessarily correspond with that of the knowledge work, because some of the executives are not qualified to be in the group, for example, because they do not regularly use a computer.

Goleman foresaw the change in the workforce composition from the traditional pyramid structure to a diamond-shaped structure in 1983 (Goleman 1983, in Gouin & Cross 1986, p. 29). The pyramid structure is top down organisation "standing" on the largest worker group of clerical staff. Above this bottom edge of the triangle are smaller worker groups of managers and professionals, and executives, in this order from larger group to smaller. The transformation from pyramid to diamond organisation means the deduction of clerical staff to such an extent that there are as many clerks as executives in the organisation, which is then an organisation of knowledge workers.

Morgan looks even further when he criticises the functionality of the pyramid structure in future office work organisations (Morgan 1989, pp. 8–9, 68–69, 166, Morgan 1993, p. 66). Within the old pyramid organisation may exist invisible organisation networks, which can be changed into networks of formal organisation. In the future, some connections of the pyramid organisation will be cut and replaced with the knots of the new network.

#### 2.4.9.4 Women and Knowledge Work

The gender differences have been of scientific interest particularly within the women studies. Women have their own organisation of female scientist in economics: Women in Development Europe (WIDE 2001). In this context a few points on gender differences are referred to in the context of the ICT paradigm, in order to understand the gender differences in the end-user evaluation of building properties influence on the working efficiency of the office worker.

The following conclusions have been drawn about the position of women in the Finnish society in general and in the information intensive work in particular (Korvajärvi & Lehto, A.-M. 2000):

- The women's position is relatively good compared with many other countries, as the conditions for women and men to operate equally in the labour market exist, and because women work full time, they are well-educated (better than men), child-care is well organised, and women's employment is ideologically and culturally accepted.

- According to the equality barometry both men and women think that women's position in society is poorer than men's position.

- The attitudes for gender equality are better in family life and politics than in business and working life.

- It is not clear that the gender equality at workplaces will flourish even in future, as in many workplaces the gender equality plans are undone, and this is the case some times even, when one is required by law.

- Women's earnings are 20 per cent less than those of men.

- Most professions are categorised to belong to either women's or men's jobs, one fifth being neutral; jobs are classified also on organisational level, where the gender orientation is hierarchically strong, for example, among clerical employees.

- The glass roof effect exists, i.e. the hierarchical ladders are meant almost solely for men.

- At the moment (2000) the unemployment rate is higher among women than men, and temporary contracts tend to be given to educated women rather than men, especially in the public sector.

- Women took part in the information (intensive) sector increasingly till the beginning of 1990´s, but since then the interest has diminished.

- The female activity in the beginning of the ICT industry did not make the field gender neutral.

- The mothers of small children have limited possibilities for information intensive work, since the child care is provided mainly for normal working hours, and not for overtime hours, or working hours in evenings or in weekends (necessary in information intensive work either because of the nature of the job or because of the life long learning), and because grandmothers also work full-time and are not in position to take care of grandchildren.

Changes in gender-related relationships follow the general changes in work life. Korvajärvi and A.-M. Lehto speculate, whether haste and pressure will concern certain gender-oriented working groups, or if haste will have different cultural content for women and men.

The amount of long working hours and unpaid overwork correlate with the socio-economic position and gender (Julkunen & Nätti 2000, p. 176). They cumulate to entrepreneurs and executives, as well as men. In Finland the difference in working hours between genders is the smallest in Europe. Long working hour careers accumulate to the same families. A half (52 per cent) of those women who work long hours are married to men, who also have long workdays. In Finland, there are couples who do not work at all, and career families, where the weekly workload is 90–100 hours (Julkunen & Nätti 2000, p. 177).

Women take care of the home to a greater extent than men. Women can feel that they carry a larger load at home than men, and even greater responsibility (Friberg 1990, p. 332). The women in the career life (well educated women, who place their career possibilities first, and try to adapt their family life to suit this) see injustices between women and men. The women in the paid work life (little or no job training, low position in the labour market and working primarily out of need of money) experience differences between those at low level and those higher up in the hierarchy of the workplace. Simultaneously they are apt to accept these differences as being due to the competence that those high up have. (Friberg 1990, pp. 331–332) The third group in Friberg's study is the women who balance life styles, who are well educated, and try to balance their working life and family life for example by working part time when the children are small.

According to Goleman (in 1997) the differences between genders cannot be found in all social indicators. The differences are qualitative rather than quantitative. Men and women think, communicate and feel in a different manner, when reacting emotionally.

It can be concluded that the service type work can be connected with women and the sale and marketing with male workers (Leidner 1993 in Korvajärvi & Lehto A.-M. 2000, p. 192).

Korvajärvi and A.-M. Lehto mention the relevance of technology, i.e. the ICT-tools as being among the factors which differentiate genders from each other in office work, although the social and cultural skills, as well as haste and pressure, have been scientifically proven according to workplace surveys to be more important than technology among the work environmental factors, and thus in the gender differentiation at work (Korvajärvi & Lehto A.-M. 2000, p. 191).

Women use computers more than men in the office, although boys use computers more than girls. Women have worked with the information intensive tasks and jobs actively in Finland, and their share among the computer users has not decreased as it has done in other countries. Until the end of the 1980's, computer science was popular among female students at Helsinki University of Technology (HUT), as well as in other countries (Lehto 1997a). At that time, it was expected that women and men would operate equally in the ICT field. However, in the beginning of the 1990's the amount of female ICT students in Finland as well as in other countries started to decrease (Lehto 1997a). At same time, the numbers of female student of construction science have risen at Helsinki University of Technology, because the courses of environmental knowledge.

The development and implementation of the ICT have revealed the gender differences. Women have turned out to be more interested in the ways of using ICT and how to get advantage of the tele-services than men, who are more interested in the development of computer architecture. There are examples of female activities in the area of ICT. Female computer users make suggestions for new ways of using the technology. For example, female mobile phone users at the social sector made the request to the phone manufacturers for phones with different colours, when they found that after meetings it was difficult to find one's own one from the pile of several similar ones. Later the colour coverage manufacturing turn out to become a growing industry and an effective marketing tool for mobile phones, although it needed a great deal of chemical, mechanical and electrical engineering and their combinations as well as artistic design for attaining a state of effective production and marketing. Also, the idea of using computer networking for emailing has been said to be of female origin.

Research has proved that men are more eager to use media and services than women (Darian in Puirava 1997, p. 133). However, Puirava has found that gender cannot explain the attitudes towards technological development. This fact also holds with age, education and incomes.

Nevertheless, differences between women and men have also been found in the way of using information network services (Anon. 1998). Women are more interested in the content of services and their usefulness than how the services have been carried out technically. Women use the home computer for education and information retrieval more often than men, who are more often interested in technology oriented ICT-services (Anon. 1998, p. 167), which can give them the chance to enjoy of the possibility to enhance their own skills in computing (Puirava 1997, p. 83). Men are also more interested in games, sports and entertainment in the media.

It has been argued that the world of computers is so masculine, that only men are interested in it (Spender in Anon. 1998, p. 167). The simple truth is that men who are skilled in computing have created the content and structures of the computer world (Vehviläinen in Anon. 1998, p. 167). Latest studies show that women are as interested in computers as men (Anon. 1998, p. 167), but they do not have as much time as men for using the computer at home, because taking care of the household takes up their time (Anon. 1998, p. 167, Puirava 1997, p. 168). Women use computers mostly at work and they like to use the computer to reduce haste at work, as well as it is typical for women to find for the computer rather useful than amusing purposes in general (Anon. 1998, p. 167). It is worth mentioning that the children in the family have the best chances for computer use, and both parents lack time for it, but women more so than men (Puirava 1997, p. 168).

Novice computer users are afraid of revealing their incapabilities and do not want to use computers in public places. They like to make acquaintance with computer use in peace at home for instance. This is typical for women in particular. (Puirava 1997, 85)

It is worth noticing that the previously mentioned attitude towards technology refers more to the use of computers than to the RTD of computing, and thus the argumentation does not concern the male and female differences within technology (cf. Lehto & Himanen 2001).

### 2.4.10 Facilities Management Service Assortment of Intelligent Office Buildings

The IB concepts included plans of including facilities management services into them. On the other hand some facilities management services are ICT aided. These both facts makes it important to study the facilities management services or the building amenities as they are called in the Office Tenant Survey of the BOMA and the ULI (Anon. 1999, p. 83). The parameters of the amenities are concierge, reception, shared video-conference facility, shared teleconference facility, shared business services (e.g., data and word processing), food service or food and drink vending machines, banking or cash dispenser (ATM), travel agency, kiosk or grocery or other convenience retail stores, hairdresser or barber, fitness centre, hobby halls, health care services, child-care facility, natural care, massage or healing, car wash and service station.

The trend of outsourcing was an almost absolute truth for good space design and management in the 1990's. However, towards the end of the decade discussions about the extend of the outsourcing have started. On the behalf of the core business of the occupant the question of outsourcing needs case by case consideration. There are other elements of the service assortment of the office building, which were included in the IB concept applications in the late 1980's and in the beginning of the 1990's, which will be next brought up in the light of the latest research (cf. Section 8.1.4.6).

The business world is a world of adults. In the working life the end-user cannot – of course – be anyone else than an adult according to the laws concerning work. However, from this fact does not follow that the R&D work on the working environment should neglect the existence of children. The day-care centre can be included in the building space plan. Interest in organising day care was the case more often in the 70's than in the 90's. A good exception of this rule is the head office of SOL Co. in Helsinki, where a special corner for children is provided with games, books, coloured chalks, etc. for allowing the parents the possibility to drop in or spend a short time in the office with the youngest ones. Another example of this type of a family friendly building is the SAS Headquarters (built in 1989) in Stockholm, where also the family members of SAS workers can use the gyms and swimming pool in the office building. Both the SAS and SOL Headquarters office buildings have been introduced in several intelligent building conferences as good examples of the implementation of IB concept (for example: Anon. 1987, Anon. 1989, Future Build '93. I.B.I., Chicago. Oct. 25.–27. 1993; Seminar on Intelligent Buildings for the Next Millennium. Temasek Polytechnic. School of Engineering. Singapore. Centre for Intelligent Building Technology. 14.–15. April. 1997). The SOL Headquarters is in principal based on the same design criteria as the Digital Future Office in Helsinki, which also is of the same good quality (Hood 1993).

In the 90's, especially in the ICT industry companies, the employers were anxious to grant the employees with the possibility to hire on the employer's expense an extra help for the sick child to home. Parents use this opportunity instead of staying at home themselves to take care of the sick child, despite of the legal right of sick children allowances that are a part of the social care system. The trend in Scandinavian societies is towards ever more independent childhood in families with two careers. The consequence is that the mental problems of the children are growing rapidly due to a lonely childhood, and the children lack the feeling of being welcome members of the family or the society. An increasing trend in attitudes is that everything fun and important happens outside the home and to individuals without children (Tamminen 2000, Puura & Tamminen 2000a, Puura & Tamminen 2000b, Räsänen & Tamminen 2000). Accordingly, this means that the office building complex is built accordingly as fancy as possible for the needs of the adults.

Further, as mentioned earlier, women use home computers more often for education or for other types of utilisation of information and knowledge than men. In office buildings, the choices for the use of space seems more concentrated towards comfort and sport than the rationalisation of the everyday domestic work responsibilities, which are as important as the work itself for one's living. Day care, easy shopping, banking or car service station near by your office have been included in some IB designs, such as Spektri Pilotti in Espoo Finland, but these household-related services are not there today. On the contrary, outsourcing has taken even many work-related services out of the office and moved them into facilities management activity or to the company owning the office building.

As Spender and Vehviläinen (in Anon. 1998, p. 167) have argued, the reason for the world of computers being so masculine that only men are interested in it is simply, because men have created the computer world. It could be thought of the attitude towards work environment design, that it could also be seen more as a male phenomenon than as a female one, as in many cases so far men have in fact been in charge of the office space design. Continuing the comparison to computer world, it can be noted that women are interested in the use of the computers although they sometimes find difficulties in using them, because the information content is so oriented towards male thinking pattern (Anon. 1998, p. 167). Thus the women may be interested in using the office space and equipment but they might face certain problems in doing so or find it lacking for their purposes. Another attitude influencing the office design in the masculine direction can be the individualistic social attitude, which is more typical for men especially in the best manhood, while young women are socially oriented since the beginning of family life.

The office design criteria which either focuses only on adults without children or does not pay any attention to the worker’s family life, can also be categorised as the employees' interest seeking.

The roles of the core businesses, as well as the roles of the company and society are both becoming differently important and thus separating. Earlier the social values dominated in the society and no company values existed, if the tacit knowledge of them is excluded. Today individualism – individual rights and responsibilities – are seeking their position in the society. The march of individualism does not delete social relationships.

The international business operating in various cultures and societies needs to rely on the company culture for a good atmosphere of co-operation within the group of companies. Further, it has to rely on company values for good customer relationships. The director of Nokia Communications, Sari Baldauf, is convinced that company culture and values are growing in importance; especially if cultures will separate – as it does seem since September 2001 – people even in greater extent than earlier. In a win-win type society and company, both-and are the keywords, not either-or.

## 2.5 Productivity

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

### 2.5.1 The Building as an Active Asset

In many cases nowadays, the well designed, open production space – factory floor or office – is well suited for various work arrangements, production lines, machinery, and furnishings. The project teams can improve their constant learning (life long learning) from past experience in workspace design and management projects, and flexibility and adaptability have been taken into account during the building process by providing structures for the future installations. The necessary changes within growing renovation projects may be constructing new light walls, assembling doors, and adding building services. In some cases, the building may cause bigger problems for it's owner, for example, if it is out of repair, has several floors, or production is changing too rapidly or so dramatically that many new building services will be needed.

That is why research and problem solving of workspace, in general – not only that of office space – is needed. Likewise, the implementation of new ideas possesses unused potential for the increase of productivity, as well as other important goals of the work environment. The building sector has a growing interest in building quality. The progress in the asset or property management paradigm, as well as that of facilities management, is confirming the 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 the tenants' businesses, and other benefits in consequence of the R&D work on office buildings, which are not yet explicit (cf. Anon. 2002a, Anon. 2002b, Anon. 2002c, Anon. 2002d, Anon. 2002e, Anon. 2002f, Becker & Sims 1989, Granath 2002).

### 2.5.2 Productivity of the Occupants

The trend that started in the 90's is towards measuring and managing building performance that is increasingly tied to business performance. For optimising the building we need to ask ourselves what role the facility plays for the user that it supports (Thompson & Plouffe 1999, p. 274). It is a fact of managing not only building costs, but the building performance, in other words, making the facility into a strategic asset not only for the building owner, but also to the tenants whom it supports.

This type of information about occupant effectiveness has also been connected to the possibilities of the building automation in making the working environment more effective (Huhtanen 2000, Anon. 2000a, pp. 11–12). Managing buildings through automation is only a part of solution. Technology should be applied to the management of skilled labour as well (Thompson & Plouffe 1999, p. 275). The implementation of IB technology has brought the building managers into the offices. At the same time occupants are served with better technology and with human assistance.

Interestingly enough, historically the relationship of high performance building and business performance surrounded managing has been planned as a high-performance environment for equipment, not for human occupants (Thompson & Plouffe 1999, p. 274). The progress is towards machinery able to run in normal environmental conditions when the environmental criterion for human well-being is not in conflict.

Occupant productivity includes the work performance of the workforce. As mentioned earlier, indoor air quality, proper lighting, good spatial ordination and orientation, ergonomic furniture arrangements, correct materials and colours, pleasant acoustics has a positive influence on office work performance. Simultaneously, health and comfortable working conditions are guaranteed. The problem is that despite of the research done on the subject, it is still unknown how building subsystem qualities influence separately and together humans and which kinds of building qualities best promote best the intellectual capital, especially in the knowledge and information intensive work. The next research problem is, what else can be done to the building in order to support the occupants' businesses. The office and building automation and the IB features have been an effort for occupants' productivity (cf. Section 2.5.3). Unknown is if there is a limit to the knowledge and information intensity of the building due to human ability to digest information, or if electric allergy and effects of magnetic fields will limit the use of digital technology and cabling, or if some kind of shielding will be necessary. The several possibilities for change, which the new technology is still keeping back, are unknown as well.

The best progress has several benefits. Proper materials for a comfortable work environment are durable and easy to clean. These are all benefits the building can provide to the tenant, as well as savings in travelling (substitution or mitigation of commuting and business trips due to the ICT and IB features). This is an example of the indirect benefits due to the ICT being used in building technology implementation (cf. Section 4.3.5.6).

### 2.5.3 Profitable Intelligent Buildings

Much of the empirical information about workspace design and solutions could have remained mostly undocumented, as new important issues are being worked on in the modern, constantly changing industrial processes and business life, thus finished, working solutions will be rather left as they are than any kind of notes would be made of them. The building changes have been seen mainly as a consequence of the changes in the production and no files of them are necessary.

In those cases, where workspace has been under careful planning 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 on offices are available (Anttila 1992, Brill 1985, Duffy 1983, Hood 1993, Junnila 1988, Anon. 1999, Clements-Croome 2000, Alexander 2001).

The first ORBIT study explained the impact that the new technology was having on the design of offices in England, and indicated how this would increase over the next ten years. It developed an expert-based method for evaluating existing and proposed buildings, and applied it to office buildings of various ages, sizes, shapes, heights and plan types, occupied by a variety of organisational types and functions (Duffy 1983).

The ORBIT study carried out by the Harbinger Group of Connecticut showed that many existing buildings in North America lacked the "intelligence" to effectively handle the information technology systems used by the businesses that were tenants in the buildings (Coggan 2001). The Intelligent Building in Europe research team came to the conclusion that the intelligent building is a productive office concept (carried out by DEGW in London and Teknibank in Milan in association with the EIBG) (Anon. 1992a).

The productivity of the occupants has been an argument for the introduction of the intelligent building concept, because it has been calculated that in office work the cost of labour is 80 per cent, other costs 10 per cent, and the space costs 10 per cent (Mölsä 1991, Anttila 1991, Martela et al. 1991), or alternatively 86 per cent, 9 per cent and 5 per cent (Huhtanen 2000). Hence, the small increase in work productivity can easily pay back the investment costs, especially if it is true that the cost of building automation is 1 per cent of the total building investment (Huhtanen 2000).

The Office Tenant Survey of the BOMA and the ULI the office occupants have been asked to evaluate the office features and amenities on the basis of their importance to the organisation of the occupant and to the level of satisfaction of the occupant (Anon 1999, p. 77). Among those features are also a list of 13 "intelligent" features (fiber-optics capability, Internet access, automatic sensors, wiring for high speed networks (LAN, WAN, ISDN), satellite accessibility, redundant power source, high-tech energy efficient HVAC system, automatic on/off sensor in the lighting system, "smart" elevators, automatic sensors installed in faucet/toilets, computerised/interactive building directory) (Anon 1999, p. 42). Respondents were asked to rank the three intelligent building features that are most important to their organisation, specify any such features that their organisation needs but are not available in their building, and indicate whether they would be willing to pay additional rent to have those features made available.

The study report of the Office Tenant Survey of the BOMA and the ULI puts the terms intelligent and smart in inverted commas. The terms have not been defined. The intelligent features of this survey are rather more relevant for the integrated building than for the intelligent one. Nevertheless, they are representing the best information there usually is available of the IBs.

Only 56 per cent of the respondents were located in buildings with any of the intelligent features listed in the Office Tenant Survey. General building functions are less common and are found in 12 per cent of buildings. Features involving communications functions are the most commonly available, with built-in wiring for access to Internet, found in almost 25 per cent of tenants' buildings. Also the high-tech, energy efficient HVAC systems are found in 23 per cent of buildings. (Anon 1999, p. 42)

According to the result of the Office Tenant Survey no single intelligent building feature stands out. However, the relatively high ranking of HVAC systems in this survey corroborates the importance tenants place on having a comfortable temperature in their office and having control over the office temperature (Anon 1999, p. 43).

Only 11 per cent of respondents mentioned any such features, which they do not have but would like to have. Meanwhile, many respondents (72 per cent) are willing to pay additional rant to have the features made available. The top five of the features tenants are willing to pay for, in order, are computer-related features, HVAC systems, security system, telecommunications capability, and a redundant power source. (Anon 1999, pp. 43–44)

Far more of the largest tenants (in terms of numbers of employees and square footage of office space) are located in buildings with intelligent features (Anon 1999, p. 49). A higher proportion of tenants in insurance, high-tech businesses, and government have chosen buildings with intelligent building features (Anon 1999, p. 44). The groups that have the lowest proportion in such buildings are retailers, medical services, legal services, consulting firms, and accounting firms.

Intelligent building features are much more prevalent in owner-occupied buildings (Anon 1999, p. 50) in North America. It has been suggested by the Office Tenant Survey of the BOMA and the ULI that building owners and managers need to be careful before retrofitting their buildings with any intelligent building feature to make sure their tenants really want or need it (Anon 1999, p. 49).

Architect Christopher T. Hood summarised his studies on the Digital Co. office space world wide as follows (Hood 1993):

- Management involvement is essential for setting correct expectations and for consulting with the employees, and the focus must not be on cost reduction as the sole objective.

- Employees respond well to bright, modern, functional surroundings, resulting in greater productivity and greater synergy between groups.

- Behaviour can be improved with well-implemented facility solutions, and investment in high quality communication systems is vital to assure the effectiveness of the work force in the future.

- The ability to personalise is important.

- Non-individually assigned desk allocation practices (free address workstations) have proven successful from financial, employee satisfaction and productivity viewpoint when the approaches are productivity rather than cost driven.

Spatial interaction can promote communication. According to Brill (1985, p. 54) four physical aspects of the office affect ease of communication:

- *"[D]egree of enclosure, with more enclosure being better (a high degree of physical enclosure relates to high ease of communication and openness to low ease of communication)*

- *[T]he amount of space a person has, with more being better*

- *[T]he layout of a workstation with greater suitability for the work at hand, correlated with greater ease of communication*

- *[R]elocations, with higher frequency of location correlated with more disruption of ease of communication"*

Four ambient conditions in the office affect ease of communication (Brill 1985, p. 55):

- *"Hearing and being bothered by telephone ringing and by others talking on the telephone (this reduces ease of communication).*

- *Noise, in general, but with more noise related to higher ease of communication*

- *Frequent intrusions into workspace by others (reducing ease of communication).*

- *Easier path finding – the ability to find one's way around the office (increases ease of communication).*

- *[T]he big number of interoffice moving disturbs communication.*"

Brill has found the connection between fewer people in any given space experiencing higher ease of communication, and with higher densities of occupation there is less ease of communication (Brill 1985, pp. 70–71). He continues:

*"Where ease of communication is important, lower occupancy is beneficial."*

There are other findings from the Brill's survey on office tenants, which are useful in the analysis of the differences between the IBs and reference buildings of this IBs Survey (Brill 1985):

- *"There is a sameness to office design, and it is recognised by office workers. Yet they'd prefer more distinctiveness. Overall, workers felt their office areas are not particularly distinctive either before or after the facility change. However, those who felt their office were distinctive were more satisfied with their visual quality. For half of the employees, having a distinctive work group area was not important. (p. 64),*

- *[T]he increases or decreases in occupancy do not affect job satisfaction (p. 70)."*

### 2.5.4 The Benefits of Integrated Facilities Management

The need for integration has been seen as important in the R&D work of building services, such as cabling, in-house traffic, interoffice communications and integrated structures. The integration of design disciplines has been seen as a tool for integration of the whole construction project. (cf. Gabrielsson 1975, Kiviniemi 2000) The traditional HVAC industry is lacking integration (Virtanen 1999, cf. also Lehto 2001b). The sophisticated system integration could allow good control and adjusting without overlapping technology due to the intelligent device under the intelligent control system. Lower life cycle costs for building, higher reliability that is matched to the needs of the business, and improved productivity of both equipment and building occupants are aimed to be achieved with the IB and FM system integration.

Building profitability of the IBs mainly concerns the improvements in management. Various kinds of possible effective managerial tasks can be found: 1) energy management: room-specific control, categorising the consumption by target of use; 2) real estate management: validation of the investments, especially in new technology and constructions, rent invoicing, furniture and equipment inventory; 3) facilities management: automatic space reservation system, cleaning control, flexible space use (such as, decreasing office space rents when shared spaces are paid according to the rate of use, and increasing rent income total through more effective use of shared spaces), etc. Flexibility and adaptability, activity (movable space elements and equipment), energy and spatial efficiency are examples of the common factors for building profitability and occupant productivity.

Facilities Management is the natural link to Energy Management. It is an information system in which control technology is integrated with other technical functions in the building. The resulting system affects not only the building, but also the efficiency of those working in it.

As a tool to measure and report building performance in real time, FM systems are becoming increasingly capable and useful. Energy management system sends budget results and reports to specified recipients, at appropriate intervals and with contents tailored to the needs of the recipients. These reports provide a basis for fault-tracing and fine adjustment of the control system. If something happens during the day the system generates an alarm and a list of suggested responses. T.A.C. Co reports that such a simple system reduces the annual running costs of a building by 20–30 per cent, in particular if no extensive modernisation of the building have been carried out simultaneously with the energy management system installation (Anon. 2000a, p. 40). The modernisation of the building in the cases of renovation seems to increase the consumption of electricity and reduces the consumption of heating (Leskinen et al. 2001).

In many countries there is a potential for significant energy cost savings based on the aggregation and profiling of loads by using information from energy management system to negotiate energy prices. Also, the real time electrical pricing from competing utilities is becoming more common (Thompson & Plouffe 1999).

### 2.5.5 The Sick Building Syndrome – Healthy and Green Buildings

It is known as a rule of thumb that sick building syndrome is related with such factors as women, clerical workers, passive smoking, lack of control, large offices, speculative public sector properties, and air-conditioning (Kell 1989, Orr 1989), which all have been studied within the IBs Survey.

On the other hand, it is known that health is related with personal control, views out of windows, fresh air, daylight and natural ventilation (Kell 1989, Orr 1989). Good work productivity, long life cycle, good market value and image of the building are also related with health (Seppänen et al. 1997, p. 107). These all were studied within the IBs Survey.

Within the IBs Survey the possibility of having control, not the level of the control possibilities is studied. Wyon has shown that individual control equivalent to ±2 K can be achieved and would satisfy 90 per cent of the building occupants, while the individual control equivalent to ±3 K would be necessary to satisfy >99 per cent of them (Wyon in Clements-Croome 2000, p. 204). The possibility to change office room temperature in the range of ±3 K would increase group average performance by up to 7.0 per cent depending on the nature of the task (Wyon in Clements-Croome 2000, p. 205).

The sick building syndrome is measured with the health symptoms and sick leaves of the workers, which were studied within the IBs Survey. A scientific approach to the healthy building concept and the measurement of the workers' productivity is based on the ASHRAE recommendation (Wyon 1993, p. 3). It is a comprehensive list of fourteen factors, many of which are included in the IBs Survey, such as health symptoms, sick leave, self-assessment of productivity, voluntary overtime or extra work, and individual measures of performance, health and well-being at work. Wyon expresses the problem that there is no research that covers all the ASHRAE measurements of productivity.

Lorsch gives the following causes for sick building syndrome: building occupancy being higher than intended, low efficiency of ventilation, renovation using the wrong materials, low level of facilities management, condensation or water leakage, low morale and lack of recognition (Lorsch in Clements-Croome 2000, p. 12).

Simplistically it could be said that the belief during the turn of the decade from 1980's to 1990's was, that the intelligent building concept implementation could, if not solve the sick building syndrome, at least bring with it further resources into the buildings, and the construction of healthy buildings could begin. On the other hand, it is good to remember that for the building to be intelligent does not necessary mean that it is either a healthy building or that the sick building syndrome can be avoided. The same is true for the Green Building (GB) concept.

Green buildings are according to the U.S. Green Building Council (USGBC), buildings that are environmentally responsible, profitable, and healthy places to live and work in (http://www.usgbc.org/). These are targeted properties or product qualifications for the IBs too. Particularly, in the beginning of the 1990's the environmental issues were discussed in the IB conferences (for example in Future Build 93, in Chicago) before the Green Building concept was launched. Sustainability has been included into quite many of the IB concepts (2.1).

## 2.6 Intelligent Building Features of the Office Workspace

The common design criteria of the Finnish IBs in the late 1980's and in the beginning of the 1990's according to the articles and building brochures of the IBs were summarised for the needs of the IBs Survey of being (Anon. 1990a, Anon. 1990b, Anon. 1990c, Anon. 1990d, Anon. 1990e, Anon. 1990f, Anon. 1991, Anon. 1992b, Anon. 1992c, Ahtiainen & Erkiö 1990, Löfström 1991a, Löfström 1991b, Löfström 1990a, Löfström 1990b, Martela et al. 1991, Mölsä 1991, Taipale 1991, Seppänen 1991, Siitonen & Verhe 1991):

- Energy savings.
- Increase in office work productivity:
  - workers save time from unnecessary routines for creative work,
  - need of interoffice everyday-life-related services (Section 7.1.3.6),
  - building is able to answer the future challenges of the end-user needs by flexibility and ability to change,
  - the nature of the technical installations is service oriented, they are not in a dominant position,
  - the interoffice network does not limit the selection of the office equipment, and the freedom of interior design according to the desires of the end-users' preferences,
  - the visible and functional part of the intelligent building is able to take into account the requirements of interaction and individualism.

- Decrease in building maintenance costs:

  - the integration of the access control, building and office automation, fire- and burglar alarm, telephone, ADP- and video equipment and other telecommunication will rationalise the construction, construction industry and the building maintenance,
  - the maintenance personnel's knowledge on the building condition will be increased by IB features.

- Increase in rental incomes:

  - the IB features create the possibility to increase the standard of equipment with the current nominal office space costs.

- Increase in the return on capital of the investment.

- Need of flexibility and changes:

  - the future occupant is not always known during the design and construction,
  - more seldom the same occupant uses the building during its whole life cycle,
  - in addition to the changing occupants, the needs of the same occupant changes,
  - the occupants do not necessary know their own needs,
  - the occupant activities change,
  - the office tools develop and regenerate, new innovations emerge.

- The influence of human factors on the design of the IB features is taken account:

  - a person is able to top performance repeatedly, if she or he has the possibility for full relaxation after the performance,
  - different personal needs,
  - the work efficiency and productivity is dependent of the possibility of keeping up connections, making new acquaintances and the possibility of stimulation and inspiration.

Some general ideas followed in the construction of the intelligent buildings can be found in the Sections 2.4.2, 2.4.10, 2.4.10, 2.5.3, and 4.2.1.

Typical aspects of the intelligent office design in the end of the 1980's, when most of the studied (by the IBs Survey) intelligent buildings were designed and built, can be listed as follows (Gouin & Cross 1986):

- *"The business case of the IBs: information society economy, need of increase in office productivity by office automation, IBs facilitating office automation, change opening new chances for telecommunication and IBs, management of energy and management costs, IBs as a tool for tenants' and owners' benefits.*

- *Tenant services offered by IB: office automation.*

- *Building information centre: availability of equipment and shared tenant services, support and training.*

- *IB information system: networking.*

- *Automated building control system: energy management, security, and life support systems.*

- *Information networking architecture integrating the technologies.*

- *Impact of the information technology on buildings and people.*

- *Intelligent building features – a response to information technology requirements: flexibility, space requirements, air-conditioning, special machine rooms, wiring."*

For the needs of other IB studies in Finland, in the end of 1980's the requirements of the IBs were summarised as follows (Piirainen 1991, pp. 44–45):

- *"The improvement of the work performance of the occupant,*

- *The expansion of the business,*

- *Consideration of the individuality, and*

- *Enabling the change of the content of the office work."*

At that time Salokangas was calling in most of his papers current buildings as "Computer Aided", which was quite the same as integrated or automated building with all its ICT systems (Salokangas 1987). However, he was also introducing the intelligent building as a system of activities and he was highlighting the importance of various stakeholders and their interests concerning the functionality of the building (Salokangas 1989). He was also referring to the Japanese ideas of the creative building, but again focusing on communication, networking and new media (Salokangas 1993), which refer rather to the integrated than intelligent building. He was using the correct, modest framing of the building of the time of being in the late 80's by the term Computer Aided and not Intelligent, but his writings of the building qualities and requirements were perhaps more close to the essence of the intelligent building than many of those written by others studying the phenomenon at that time.

Piirainen and Salokangas were introducing also the quality requirement system, which was based on the Performance Concept in Buildings (Piirainen 1993, p. 4) and included levels of intelligent buildings from one to four (the best) (Anon. 1993, Piirainen 1991, pp. 98–165). These were rather similar to stars, which are used to rank hotels than for example intelligence quotient of humans. That is why those ideas were not interesting as a starting points for this study, which was hunting the definition of the intelligence of building. Piirainen ended up to represent a Doctors Thesis on the Activity-based feasibility of construction project, which introduces a systemic business space requirement evaluation model for the feasibility study stage of the construction project (Piirainen 1996).

Piirainen had studied the quality requirements of the building and Huovila (Koivu & Huovila 1992, Huovila et al. 1995, Leinonen & Huovila 2001) started to study the end-user requirements at the time being of the start of the IBs Survey. For me it was difficult to look the relationship between the end-user and the building from the perspective of the requirements but rather from those of end-user needs. That is why, purely the ideas of the IB concepts and the post-occupancy studies were followed in the IBs Survey.

# 3. Aims of the Study

Next the research problems of the two parallel subjects of this study, that of the BIF and that of the existence of the IB concept as a building concept of its own proven by the IBs Survey, will be defined (Lehto et al. 1993). The hypotheses for these research problems will follow. They are originated from the beginning of the author's studies on the IB concept in 1988, as well as from the writing of the project proposal of the IBs Survey in the 1992, independently by the author.

## 3.1 Research Problems

There are two research problems for this thesis:

1. There is no universal definition for the intelligent building concept, although a certain consensus about the concept can be found (Section 2.1). The actual question within the intelligent building concept paradigm for the author has been the problem of the intelligent building concepts defining the intelligent building, not the building intelligence (Lehto 1997a, p. 285).

2. There was not much empirical evidence of the feasibility of the intelligent buildings, and the factors involved in 1992. On the other hand, it was known that some information of studies of intelligent buildings already existed, but it turned out, among other things, to be difficult to get hold of such studies as the Intelligent Building in Europe Study (Anon. 1992a). The existence of the intelligent building concept was questioned.

Dr. So has been working on the same or similar problems (So 2001, So & Chan 1999).

## 3.2 Hypotheses

The two hypotheses of this thesis are:

1. That the ability of human intelligence to lend intelligence to an inorganic object, such as a building, is the key to the building intelligence.

2. Office buildings, which have been designed using the intelligent building concept as a leading design criterion, are different in the terms of the occupants' productivity from office buildings, which have not been designed according to the IB concept criterion. This difference can be witnessed by the value of the quality evaluation of the end product for working efficiency of the office worker. When the end-user evaluation takes place on those factors, which are included in the IB concept, the existence of the intelligent buildings will be proved.

## 3.3 Feasibility of the Building

In this study, the key of the building feasibility is the measured performance of the building properties, which has been studied in the IBs Survey. The second criterion for the feasibility is the intelligence of buildings, which is based on the theoretical examination of the BIF. The performance of the building is described in Section 4.3.5.8. The IBs Survey measures the performance with the end-user evaluations and not for example with money, which is an often used measurement of performance. The performance of the building measured with the BIF is based on the related paradigms (Section 4.3), such as the concept of ba (cf. Section 4.3.3.2), concepts of human intelligence (Section 4.3.3.1) and that of knowledge management in general.

The main research problem in the IBs Survey is the differences between intelligent buildings and other types of office buildings. The result actually reflects the efficacy of the whole building or the efficacy of each building property, because this difference is witnessed by the quality of the end product, i.e. that of the building itself by measuring it with the end-user evaluation of building properties' influence on the working efficiency of the office worker, of which is used the term the end-user evaluation or the acronym of EWE.

## 3.4 Cultivation of the Theme

Since 1988 I have worked with the IBs and information society phenomenon before writing the research proposal (1992) of the IBs Survey. I had adopted international knowledge of the IB concepts and building projects, and participated in building projects in Finland, where my duties were concerned with IB expertise. The definition of the IB has bothered my mind since 1988.

Already in 1989 the metaphor of the human intelligence and artificial intelligence appeared in my description of the IB concept – quite intuitively (Figure 9., Lehto 1990a, p. 224, Lehto 1990b, p. 64, Lehto 1991a, p. 25, Lehto et al. 1993, p. 13).

The study problem of the IBs Survey was based on the information needs of the companies, who participated the IBs Survey project (Section 1.3) and on the information about the post-occupancy studies on office buildings (Section 5.3.4). The hypotheses of the IBs Survey research problem were based on my ideas about the IB concept (Section 2.1.5, cf. also Section 2.6).

In several articles I have talked about the use of human senses, intelligence, feelings and mind or soul, and spiritual skills in housing and in building (Lehto 1989a, p. 22, Lehto 1989b, pp. 8–9, Lehto 1990b, pp. 64–65, Lehto 1990c, Lehto 1991c, pp. 28–29, Lehto 1991d, pp. 27–29, Lehto et al. 1993, pp. 12–14). With housing and building is here meant both design and use of buildings, in other words the stakeholder groups involved are both the building professionals and the occupants. I have highlighted the importance of human growth in consciousness, the importance of being aware of ones needs not only when making wishes and listing the needs of space of the user, but also when the designer is suggesting solutions. It is good, that she or he is not unconsciously repeating solution suggestions for her or his own needs, but she or he is able to listen openly to the needs of the client, and suggest solutions for them. I have also suggested the need of social and spiritual design criteria for buildings (Figure 9., Lehto 1990a, p. 224, Lehto 1990b, p. 64, Lehto 1991c, p. 27), which is not discussed further in this context although it could be the next step for the development of the BIF. The connection of the human wisdom and the responsibility of the nature have been discussed within those above mentioned articles about the use of human abilities in housing and building (cf. Section 7.3.3.7).

Actually, the hypothesis of the BIF was first published in 1991 (Lehto 1991a, p. 24, Lehto 1991d, p. 29, Lehto 1992b, cf. also Lehto 1996a). This thesis connects the hypothesis to scientific theories of human intelligence. The idea of constant change of the IB concept has been also a part of my thinking from the beginning of my studies on the IBs (Lehto 1990b, p. 64, Lehto 1991a, p. 24, Lehto 1991c, p. 27). This thinking included the change from tacit to explicit, although I then used the terms conscious and unconscious. The source for the idea of change came from the futures studies (Section 4.3.1), and it has found the scientific form in this work from the concept of ba (Section 4.3.3.2).

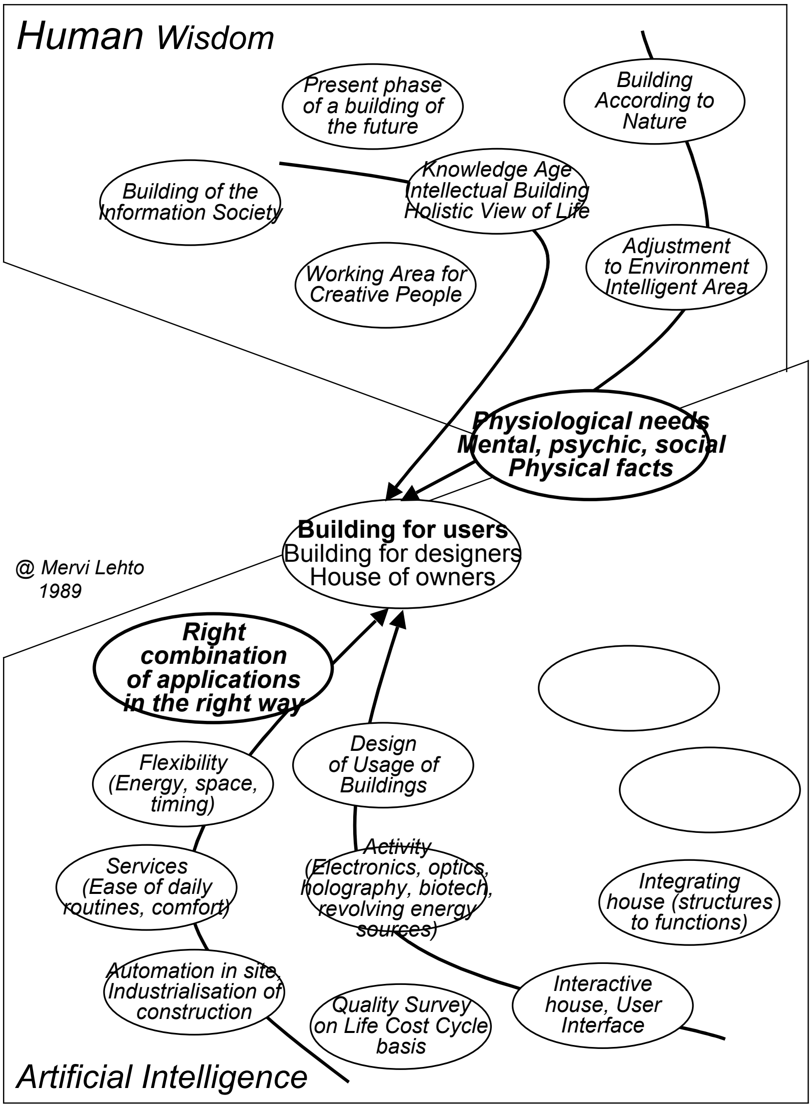


*Figure 9. The formulation of the IB concept (Lehto 1989a).*

# 4. Methodological Considerations

As mentioned earlier the intelligent building is a relatively new invention in construction industry similarly to the FM (Section 2.5.4). To be precise, the new part in the IBs is actually the IB concepts, which are originated from the 1980's, but the idea of an intelligent building can be traced at least back to the Egyptian times, which will be explained in more detail in section 4.3.1. There was neither theory nor methods for studying the IB concepts in the very beginning of the 1990's. It was possible to research the existence of the IBs and to identify the IBs by the building intelligence definition, by the expressions and methods borrowed from other sectors of construction industry or other applied sciences. These sciences will be presented in this chapter by keeping the emphasis of the description in the scientific problem of the IBs. The author have made some applications of these expressions and methods for the scientific problem setting of the IBs Survey, which are shown in this chapter. They form a set of scientific breakthroughs in understanding the latest office building and knowledge work phenomena.

## 4.1 Technology as a Science

As mentioned elsewhere, the IB concept is a very new idea and thus comparable with the FM. They both seek new definitions and discussion about their scientific importance swings from for to against. Also, the relationship between technology and science in general has been discussed in that connection (Himanen 1987, p. 7). Technology is older than sciences. Not until the 20th century has the technology based on scientific inventions (Giarini in Himanen 1987, p. 8). A basic difference between science and technology is that science produces knowledge and technology products. Professor Niiniluoto has sorted the sciences into two categories: pure sciences and a group of applied sciences and disciplines, which produce also knowledge of greater instrumental value according to the practical interests than the knowledge produced by pure sciences (Niiniluoto in Himanen 1987). Technical sciences and economics are by nature, applied sciences and disciplines. That is, of course, the case with the IB concept and the FM paradigms, as well.

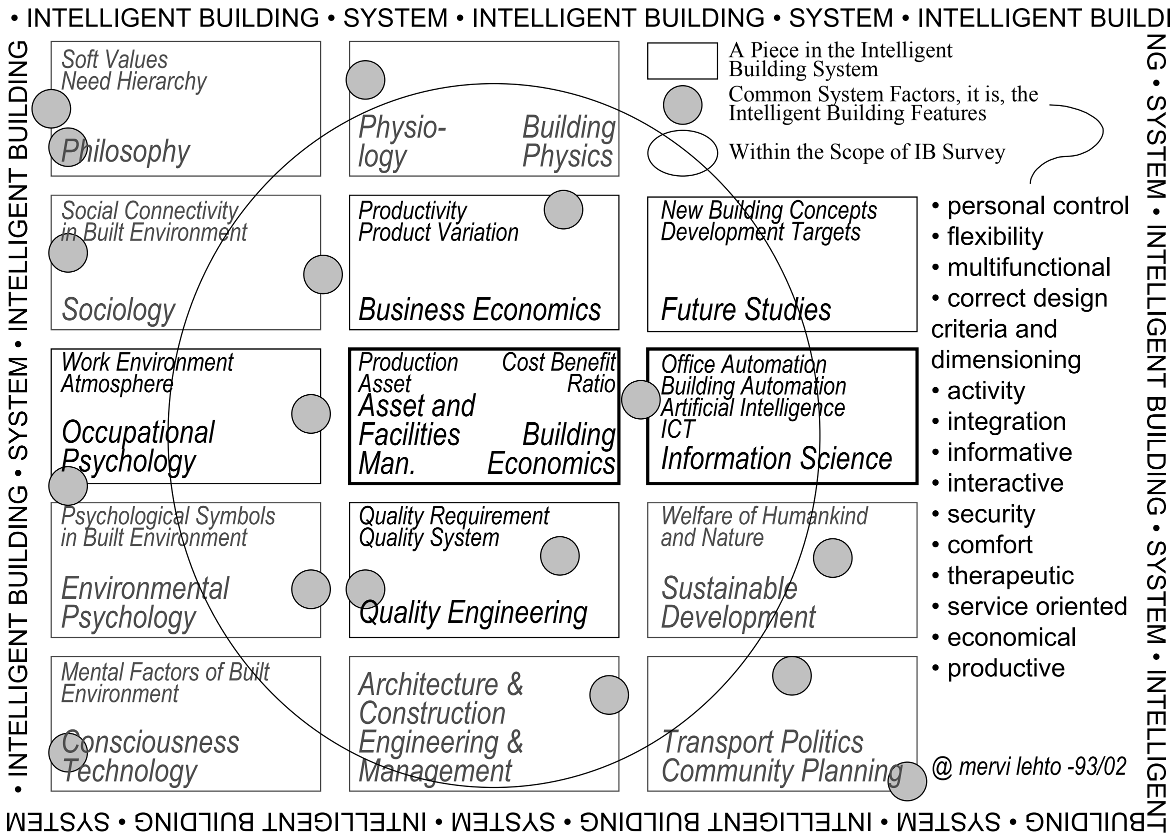


*Figure 10. A multidisciplinary approach to the end-user evaluation criteria of the intelligent building concept by systems thinking.*

Since this study is among the first scientific works on the IB concept, it has been necessary to embed this work in the other sciences or to be more precisely, in the scope of other applied sciences. There has not been other way than being as honest, as open to criticism and as insistent as possible, when studying these problems of intelligent buildings and building intelligence (cf. Giarini in Himanen 1987, p. 8).

I have sometimes gone beyond the mechanistic and the reductionist approach, and developed holistic views (cf. Capra in Himanen 1987, p. 8). In the first place, this has been due to the long lasting interest in quality systems, where creative solutions go beyond the specialised parts of the task, combining various aspects to a functional solution. On the other hand, it has been due to the interest in the futures sciences, where solutions are sought from the multidisciplinary problem setting and from the use of knowledge from several different sciences.

## 4.2 Systems Thinking

The increasing use of ICT was seen in the beginning of the 1990's, as if it has made the office into one large system – very often an inoperative system, because of the lack of flexibility, inadequate utilities, and myriad other problems (Hood 1993). If so, the design process would benefit from systems engineering techniques, and the components used would serve well if they were a part of proper systems architecture. Technology alone was not enough, as the system architecture was addressing organisational structures and work processes, and changing market conditions required responsiveness and flexibility in offices.

### 4.2.1 The Multidisciplinary Approach

The background for the IBs Survey was in a multidisciplinary approach to the intelligent building concept (Figure 10.). For the creation of the evaluation criteria systems thinking was taken into use (Chekland 1985 in Himanen 1987, pp. 14–27).

In the beginning of the IBs Survey (1992), the thread running through the research proposal was the well-known system analytic concept that systems are built up of subsystems. The scientific platform for the survey was composed of various scientific areas (Figure 10.), and the focus was in applying knowledge of industrial economics into the building sector. Later on in the analysis phase of the IBs Survey (1996) this turned out to be quite similar to the scientific platform of asset and facilities management.

Actually, the information science and the industrial economics (or production engineering and management) were not included in the figure of the evaluation criteria in 1993 (Figure 10.), as they were actually the angles where the observer (the researcher) was standing, and it was impossible to explicitly "see" them. They have been added to the picture during the evaluation process, and they have some different meanings for the IBs Survey than other subsystems. Facilities management aspects of the IBs Survey are not due to the FM concept, but such intelligent building concepts, which have a wide approach to IB phenomenon and include economical factors. In the research methodology and scientific approach selected for data gathering the same wide approach was typical (cf. Sections 5.1 and 5.3).

The relations between the IB concept parameters based both on the author's IB definition (Section 2.1.5) and on the scientific platform were studied. The subsystem parameters together form the set of system parameters. Thus, the IB concept parameters should also include the parameters from the subsystems of the scientific platform, i.e. parameters of the IB concept relevant in the scientific fields.

However, it was difficult to decide if the relationship between these two types of parameters – the IB parameters and the IB-related sciences' parameters – was hierarchical or if they were forming a network. Nevertheless, the idea of the systems thinking with structured and unstructured recognised problems was the key to the usable setting of the relationship of the IB concept parameters and the scientific platform shown in the Figure 10. (Chekland 1985 in Himanen 1987, pp. 14–15).

> *"Unstructured problems cannot be explicitly stated without oversimplifying the situation. There exists a feeling of unease, but no clear definition to the problem can be given. ... [P]lanning can be considered to include unstructured problems in chaotic situations. ... Chekland states that a system,*

*which serves another, cannot be modelled until a model of the system served is available."*

Thus it was possible to understand that the IB concept parameters can be included in each of the subsystems of the scientific platform, i.e. they do belong to all IB-related scientific fields, not only to a certain category as the IB-related sciences' parameters. Thus, although the IB parameters describe the IB concept, they can all be included in any other scientific fields mentioned – and most probably to other fields in the future as well. The existence of intelligent subsystems became clear, although they remain unstructured and tacit (not explicit).

As a working hypothesis it was defined that the building can be intelligent, if it is built according to IB parameters or if it has one or more intelligent subsystems (cf. Section 8.3.6). IB parameters – features, properties or product qualifications – are similar to economic, social or information science parameters, which can be inseparable parts of any scientific paradigm.

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 attributes of the system. Alanne (2000) has in his licentiate thesis described the decision-making problem of the system design and presented 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. It can be used in cases, where the results of the end-user evaluation of different variables are compared, which very often needs the establishing process of the method itself. This method was not available during the IBs Survey, but due to its advantages the method evidently has possibilities for being applied as the tool for the evaluation based on the IB concept parameters.

In every case, the value analysis of the design system influences the result (Alanne 2000, p. 66). Value setting has several parameters which can be applied differently. This cannot be avoided, but it is good that it has been taken into a consideration within the implementation of method.

### 4.2.2 Identification Method of Intelligent Buildings

The actual methods for qualifying and measuring IB parameters were in the beginning of 90's and are still lacking. The IB – and IB subsystem – can be quantified according to IB parameters of the IB concepts describing the IB features. Also the IB-related sciences' parameters can describe the quality of the IB or IB subsystem. Neither of those above mentioned sets of parameters, which were used for the IBs Survey, cannot explain the intelligence of the building.

For understanding the essence of the IB parameters and developing qualification methods for IBs, the comparison of IBs to other buildings was found to be a practical solution. The previous theoretical studies had resulted in a hierarchical approach to the IB concept (Piirainen 1991), which did not – in the author's opinion – give the IB properties the power to prove their nature and feasibility, especially when integration is in question.

Because no quantifying methods existed the parameters of the IB-related sciences were measured and the study focus was set on understanding the relationships between all parameters describing the IB. At the same time, a first attempt to give form to the IB parameters was in mind. In the beginning of the study it was uncertain, which – if any – of the parameters would be relevant for the set of indicators for the intelligent building concept in office buildings.

Under the reporting phase of this study So (2001) published his efforts on the new IB definition and the method for its implementation, IBI[1], which seems feasible for evaluation purposes as well. The existence of wide set of the IB parameters described in the previous section (Section 4.2.1) helps to understand the confusion about the need of several IB concepts. Similar to the Quality

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[1] The IBI (So 2001, p. 1) is the first quantitative assessment method for an IB. It is a score within the range from 1 to 100 per cent. IBI is further categorised into nine indices, namely such indexes as green, comfort, working efficiency, culture, high-tech, safety, structural and cost effectiveness respectively. A weight of each element is used in assessment.

Function Development or Management (QFD or QFM) Method (Leinonen & Huovila 2001, Turunen 1991) the IBI uses weight values, which are dependent on the expertise of those who have set them. In the case of the IBs Survey it would be possible to use the grades from the evaluations as weight values. That type of QFM is taking the end-user feedback into account. I have had the aim of fiding a method which lets the gathered data tell its story without the expert knowledge interference. Expertise is formed after the data. This was the reason behind the try to analyse the data with the Kohonen mapping (Section 8.1.1). As well as the statistics the use of the Kohonen map turn out to mean expert knowledge interference, because the algoritms and used parameters are based on the experts' determination. However, the analyse based on the QFM with weight values from end-user evaluation or corresponding method will be used in the future.

## 4.3 Related Paradigms

The multidisciplinary intelligent building concepts cannot be studied without a multidisciplinary approach. A selection of sciences has been used for this purpose in this study. The progress of workspaces during the 1990's has been strongly affected by the information sciences and the application of the ever developing economical ideas in the property and facilities management has been typical (Sections 2.4 and 2.5). Especially in Finland the understanding of the facilities management and economics has grown remarkable during the 1990's due to the economical depression.

### 4.3.1 Reflection on the Information Society

A starting point for the creation process of the BIF was in the information society phenomenon. The information society has been studied widely as a futures studies science paradigm and the World Futures Studies Federation has been the integrator of the activities done in the area all over the world (WFSF 2001). Among the information society studies literature are also publications on the IB concept (Himanen et al. 2000a, Himanen et al. 1996a, Kivistö et al. 1996, Lehto 1998a, Lehto 1998b). In terms of the IB literature, also publications on the sustainable information society are interesting (Kahilainen 2000, Lehto 1999b, Heinonen 2000).

One can claim that buildings have always been built intelligently. For example, some of the earliest active structures can be found in the mechanism of the Egyptian pyramids stone and sand structures, which are activated by sun beams, or the well known idea of the secret passage door opening by pushing a button in a bookcase. The clarification of an intelligent building concept is a process of awakening the conscious mind of long existing unspoken reality of intelligent construction tradition. At the same time, it is copying also the latest innovations, which in any scientific field of the turn of the millennium are based on innovative combinations composed out of findings from across sciences rather than on the deep understanding of one special area. The latter research method has been typical for science and R&D work in the industrial age. Not only the data, information and knowledge, but also the tacit knowledge comes a part of our everyday practises and routines by developing the IB concept paradigm (Figure 19., Figure 13.). The combinations of the tacit knowledge of working, living, behaving, resourceing, etc. are essential for the construction and building industry practices and routines during this post-industrial time (cf. Figure 18.).

Each sector of construction is under constant development, which since the 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 building intelligence, but all means from mechatronics to biotechnology are used in the intelligent buildings and building component development. At present, it might be difficult to distinguish the sophisticated intelligent building innovations from those of the green or healthy building ones (Lehto 1999b). Intelligent, green and healthy is the latest in technology describing the various approaches to the building phenomena, which looks different from different angles. But those keywords refer to the same building or at least to the buildings of the same era. The holistic multidisciplinary approach shows the reference points of the building – the building properties – seen as a whole and described with different indicators.

### 4.3.2 Information Science

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 (Computer Aided Design) databases. The information management has focused either on the construction information service or on the database management of the CAD systems.

#### 4.3.2.1 The Life Cycle of Construction Information

The majority of construction industry information is concentrated around the project (Figure 11.). The nature of such construction applications as planning, estimating, tendering, ordering, etc. is complex. However, it is widely accepted that the vast amounts of that project's information can be extracted from the project's drawings (e.g. Kiviniemi 2000, Dym and Levitt, 1991). The importance of the project information does not cancel the need of non-project oriented information (Lehto 2000b, Lehto 2001c). The data retrieval of the modern information service is good, but still developing (Lehto 2000b, Lehto 2001d).

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 project, VERA includes 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. On one hand, efforts are on the common centralised building project data base construction (cf. Kiviniemi 2000), and on the other hand, efforts for networking various building project databases together imitating the process of design work practise in detail (cf. Haugen 2000, Figure 11.). The common gateway to the project information is essential for the co-operation between designers (Lehto et al. 1988). Another common user-friendly gateway is needed for the non-project intensive information databases, which connects the information from various sources together in a manner easy to access (Nurminen et al. 1987, Lehto et al.

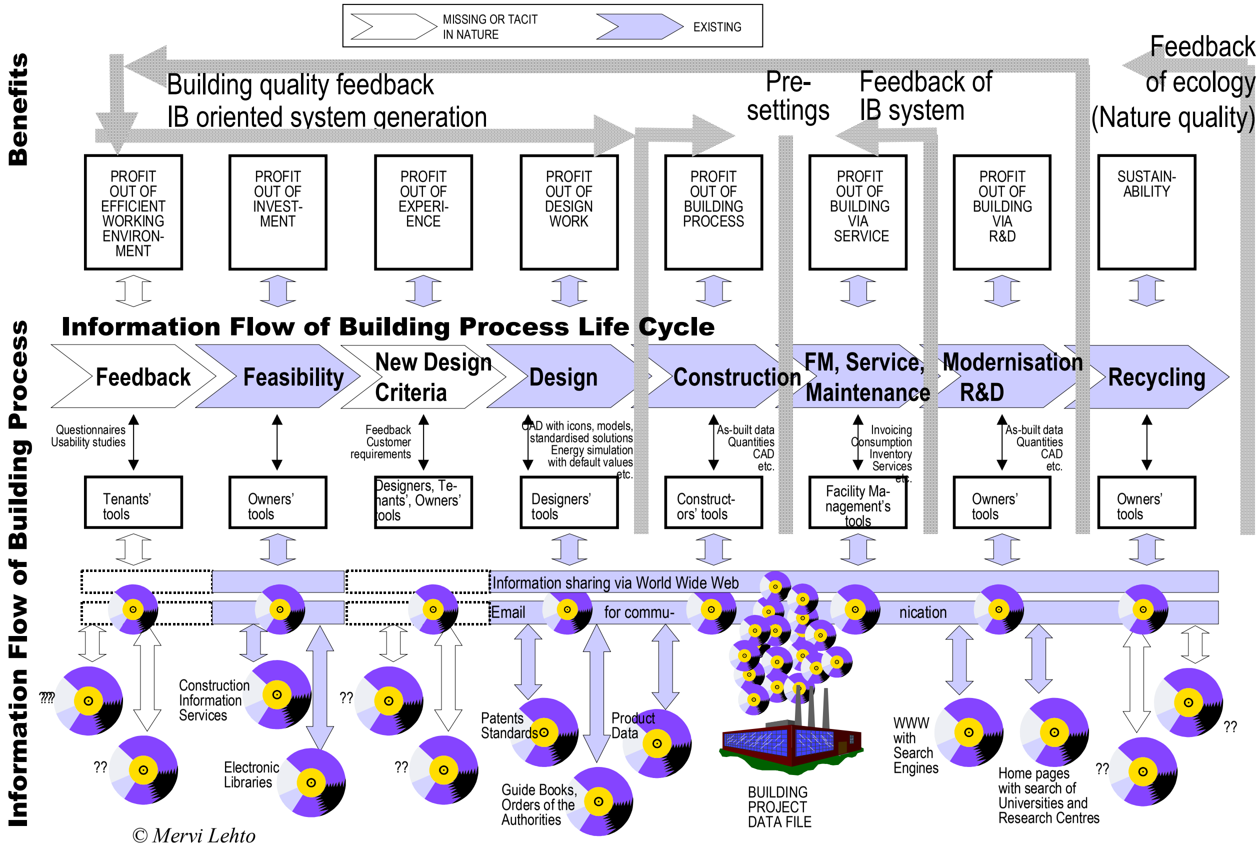



*Figure 11.The life cycle of the building information services (cf. also Lehto 2000b, Lehto 2001d).*

1987, Lehto 1987, Lehto et al. 1988, Lehto & Aho 1988, Nurminen et al. 1988, Lehto 1991b, Lehto 1992a).

The building information is made available throughout the buildings' entire life cycle (Figure 11.). 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 stored in the video form instead of still images. The manual design was presented in general in 2D, because of the time consuming manual work needed for perspectives. New software is able to link design, construction and maintenance information between building databases and current software, i.e. designers', constructors' and facilities management's tools. It is possible to link electronic libraries, the information services and other information sources to this same network for generating design, maintenance, etc. solutions as well.

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).

In Finland, there is a special problem: in most cases it is not possible to hand over the as-built data at the end of the construction project. The authorities get the design drawings only. As-built drawings can form 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.

#### 4.3.2.2 The Intelligent Building's Role in the Flow of Construction Information

The overall system of the IB 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 the intelligent building equipment is under R&D work in the building automation companies.

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 connection to the construction information flow is lacking, as well as definitions and specifications for this connection are not studied. There is need for specifying both the information transfer from building data bases to the building automation overall system (Figure 11.), and on the customers' side, the standardised open modules to the building information and automation systems is obvious.

The second problem is the need for feedback information to the new design phase. It is not only disconnected but lacking totally. Furthermore, this feedback information has to be developed into new design criteria, not only for special building projects, but to be used wider within the company and the building sector. The IBs Survey, the IBI (So 2001) and many post-occupancy studies can provide information for this phase of the information flow of the building process (Figure 11.).

A problem to be added to the above mentioned research needs of the construction information life cycle, important in the context of the intelligent concept paradigm, is the lack of feedback during the buildings' life cycle (Figure 11.). In many cases experts know a lot about customer feedback, but it is tacit knowledge. The user and stakeholder orientation of the IB concept definition emphasise the meaning of the user and customer feedback of the user oriented approach to the construction process and information flow.

The customer feedback databases can be created in the above mentioned proper manner as a part of the CAD design systems without any information gaps. It has been added to the beginning of process (Figure 11.), but it could also point each phase separately describing the integrative nature of the IB concept or that of the facilities management. It could be included after the maintenance as well, while in many cases the feedback information collection is a task among the facilities management activities.

Dr. Yang and Professor Chang (2000) have raised the problems of the construction information flow and the understanding of the intelligent building as follows:

*"Sustainable development and intelligent buildings are becoming one of the current highlights in the construction industry. However it is identified that the intelligent building (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 building 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."*

### 4.3.3 Knowledge Management

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 use 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 (Virtual Reality), 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 information service (informatics), information and communication technology and organisational aspects of the human information handling is making the task ever challenging.

#### 4.3.3.1 Human Intelligence

As already mentioned earlier, the knowledge about the human mind is mostly related to the philosophical and religious literature. New interest on the deeper understanding of the intelligence of the human mind has risen in psychology (Dunderfelt 2001) and sociology (cf. Section 2.4.8.2). New interesting ideas have been spoken about in cognitive science as well, where new monitoring methods of the human brains have inspired researchers. These new parameters together with the results from the futures sciences form the other edge of the scientific platform of the IB concept, as they do in the information science, especially when the nature of the information and knowledge management, etc. is concerned (Tuomi 1999, Keskinen 1999).

A fundamental role of intelligence is to generate distinctions that enable an intelligent being to act in its environment according to its capabilities and needs;

and according to Bergson, the competencies and structures that are required to make appropriate distinctions are focused on perception and memory (Tuomi 1999, p. 103).

The seven forms of human intelligence according to Professor Howard Gardner are (Gardner 1983 in Dryden & Vos 1996, pp. 120–123, Gardner 1991 in Dryden & Vos 1996 pp. 345–352, Gardner 1993 in Tuomi 1999, pp. 107–110, Gardner (1993) in Dunderfelt 1998, p. 28, (Figure 12.)):

> *"[L]ogical-mathematical, musical, linguistic, interpersonal, intrapersonal, visual-spatial and bodily-kinaesthetic."*

These have been selected as a starting point for the understanding of the human intelligence (cf. Section 7) among several alternative classifications of human intelligence (Dunderfelt 1998, pp. 26–29).

This structure of the human intelligence is accompanied with the descriptions of the human centres from mental or spiritual heritage or knowledge (Figure 12.). No connection between these descriptions is shown. They are controversial within science, or excluded from scientific contexts, except for Frager (1994 in Dunderfelt 1998, p. 28). They are shown in Figure 12. as a reminder of the efforts on the structural presentations of the human instinct or intuition, that is to say, the invisible mental body. Such presentations or definitions exist many (Dunderfelt 1998, pp. 26–28). They are often described with colours as well as other human qualifications such as the temperament for example (cf. Dunderfelt 1998, pp. 47–58). The colours and their meaning in the context of environmental psychology is the nearest connection of the building science to the colours of those centres.

The following are some notes relevant to this work about the human intelligence from Dr. Tuomi's phenomenological analysis of the theory of intelligent organisations (Tuomi 1999, pp. 105–191):

- *"Bergson's central point was that human beings do not only use existing tools, but also create tools using their intelligence* (p. 114).

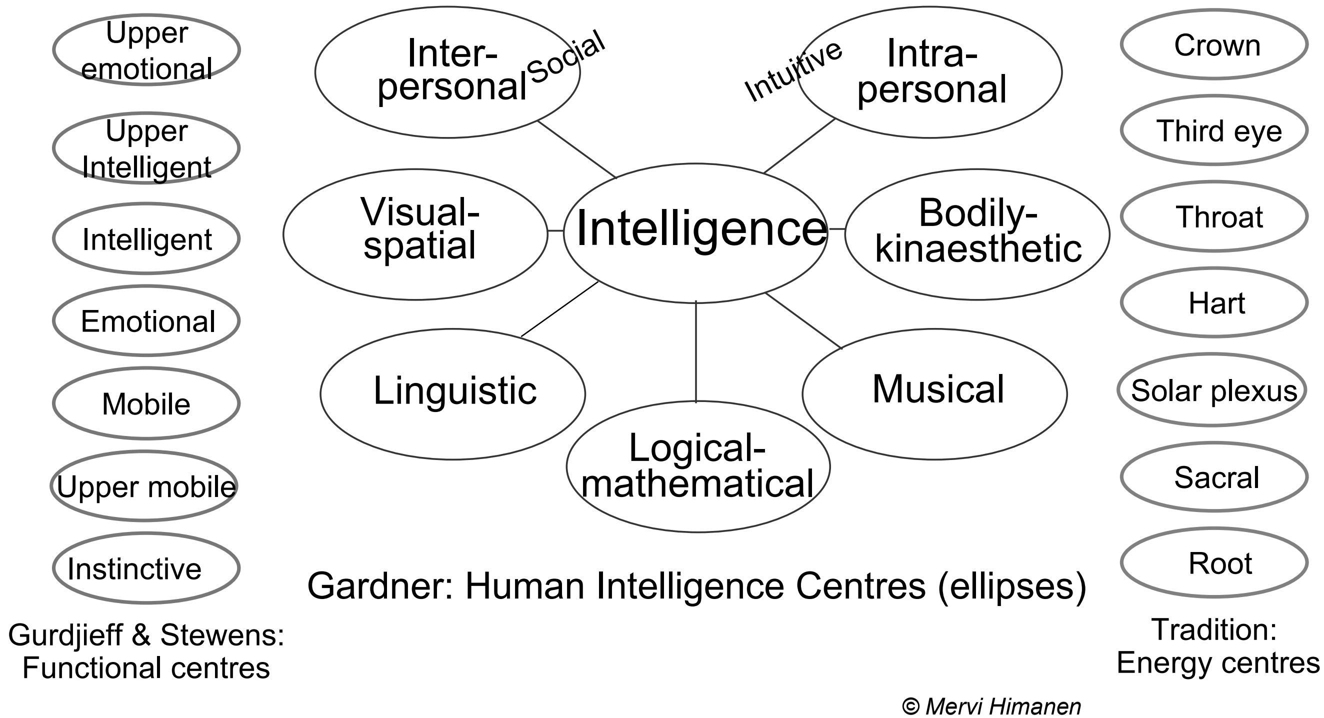



*Figure 12. The forms of human intelligence (Gardner 1983 in Dryden & Vos 1996, pp. 120–123, Gardner 1991 in Dryden & Vos 1996 pp. 345–352, Gardner 1993 in Tuomi 1999, pp. 107–110, Gardner (1993) in Dunderfelt 1998, p. 28, Stevens 1995, Stevens & Warwick-Smith 1995).*

- *Vygotsky was the first to analyze the interplay with tools and thinking, arguing that human being are able to create cognitive tools that can become integrated parts of our thinking* (p. 114).

- *Gregory has noted ... human-made artefacts ... served as models of world, and of guided scientific and philosophical thought ... "We live off intelligence stored in artefacts designed by our ancestors."* ( p. 114).

- *In contract to the action-oriented, ecological, and social views intelligence has traditionally been understood in the context of problem solving and abstract thinking* (p. 119).

- *Bergson's observation was that the distinctive characteristic of living being is their capability to perceive those aspects of their environment that they can act on* (p. 119).

- *... [T]o view intelligence within the context of the process where meaning emerge and become available for further processing ... leads us to discuss intelligence as the generator of effective selective action.* (p. 110).

- *... [I]ntelligence is possible only for living systems.* (p. 127).

- *... [I]ntelligence is a generator of selective behaviour.* (p. 121)

- *In Bergson's view, intelligence ... looks upon all matter as if it were carvable at will. It makes us consider every actual form of things ... artifial and provisional ... indifferent from form ... it also creates a space ... lending itself to any mode of decomposition whatsoever ... Objects, as extended things in an undifferentiated space, symbolize this tendency of human intelligence to fabrication.* (p. 131).

- *... [I]n Bergson's sense, ... instinct and intelligence ... imply two radically different kinds of knowledge... "this knowledge is rather acted and unconscious in the case of instinct, thought and conscious in the case of intelligence" ... instinct is reflected outwardly in exact movements, instead of being reflected inwardly in consciousness ...* (p. 128)

- *According to Bergson ... instinct is not within the domain of intelligence, it is not situated beyond the limits of mind. ... We can access instinct through* *feeling, in unreflecting sympathy. We can live knowledge, instead of representing it.* (p. 134)

- *... Polanyi's terminology ... intuition is the capability to use and access the tacit components of meaning and knowledge. But according to Bergson, the push for this transcendence comes from intelligence. Without intelligence, intuition would have remained in the form of instinct ...* (p. 135).

- *According to Bergson ... The two faculties of the consciousness are the intelligence and the intuition* ( p. 135).

- *The consciousness explained by Dennett does not exist as a separate unit in human being.* (p.112).

- *... [L]iving systems are not static. ... Intelligence is a product of history and development, and it is a relational concept. ... Gardner points out that his list is only a 'fist cut' and that there probably is no final list of intelligence.* (p. 112)."

All these notes will be used in the argumentation of the nature of the intelligent building concept and the building intelligence.

Unlike many of the writers to whom he refers in his work about intelligent organisations, Tuomi (1999) argues that intelligence is possible only for living systems. He also looks at the higher-level processes in his research on intelligence.

One concept is that the ability for conscious thinking differentiates human from machine (Hautamäki 1993, cf. also Tuomi 1999, p. 113, note 32). Another principle within the artificial intelligence research at the beginning of 1990's was to understand as intelligence only the activity of the mind and brain (Linnainmaa 1993). Within artificial intelligence research this matter of machines' ability for intelligence is under constant examination. Serious attempts to build a conscious, intelligent machine exist (Haikonen 1999).

This study is based on the idea that humans have the ability to lend human intelligence to a machine, building or any other non-living system. This fact has been argued several times in the above listed notes. The idea of a building as a man-made product has been placed first, although it is true that the raw materials used for the product may not all – or in many cases none – be intelligent. **The author's understanding does not exclude any form of intelligence, but it is not necessary to discuss this in any more detail in this context.**

Bergson has been using the words artefact and carve in the description of the role of intelligence. I have preferred using the words: product and manufacture in the same meaning (cf. Section 8.3.4).

Within the scope of the IBs Survey (Section 5.1), the psychological, mental and social approach is very limited although the author saw its inevitable importance for the IB concept already in the planning phase of the IBs Survey (in 1992).

It is possible on the basis of a careful analysis to criticise various explanations of the intelligence, as for example Tuomi has done in his work on intelligent organisations, and among others also on Gardner's classification of intelligence (cf. Tuomi 1999, pp. 108–114). Instead of a critically analytic type of approach, which to my understanding Tuomi is using for the purpose of his task, I have tried to be open to various ideas and points of view, and to understand the various truths about intelligence. Rather, I consider these different points of view as different perspectives on the same phenomenon. Instead of criticism, I respect every effort for clarification of the nature of intelligence, human or artificial, and I try to make a synthesis of those facts, which are common in each of them.

The selection of the Gardner's classification of human intelligence as a metaphor for the building intelligence was based mostly upon its validity in spatial terms. This doesn't mean that I am placing the emphasis on the spatial factors in my thinking of intelligence, but rather on the building intelligence. Several other concepts are important for my understanding of intelligence. Time is one. The existence of unknown dimensions – similar to those of space and time- is challenging for a human standing in space on the earth. So is the unknown essence of the consciousness, or the questionable existence of intelligence in everywhere in a subject, not only in the head and mind, but in all living tissues and in organic and even inorganic material.

#### 4.3.3.2 Concept of ba

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

Tacit knowledge is according to Nonaka and Takeuchi (in Tuomi 1999, p. 323), personal, context-specific, and therefore hard to formalise and communicate. Explicit knowledge, in contrast, refers to knowledge that is transmittable in formal, systematic language. Tacit knowledge includes cognitive and technical elements. These cognitive elements include mental models, such as schemata, paradigms, perspectives, beliefs, and viewpoints, and they help individuals to perceive and define their world. The technical elements include concrete know-how, crafts and skills. The central idea of the concept of ba is that new knowledge is created in the articulation of tacit mental models, when the tacit knowledge is converted into explicit form.

The transformation of knowledge happens in a cycle. The tacit transforms to explicit, which in its turn transforms to tacit. There are four possible types of knowledge conversation modes (Nonaka & Takeuchi in Tuomi 1999, pp. 324–326):

> *"[T]acit knowledge transforms to tacit knowledge through socialisation (sympathised knowledge); tacit knowledge transforms to explicit knowledge through externalisation (conceptual knowledge); explicit knowledge is converted to explicit knowledge through combination (systemic knowledge); explicit knowledge transforms to tacit knowledge through internalisation (operational knowledge)."*

These form a flow in cycle in the presented order. The last mentioned operational knowledge turns into tacit knowledge, etc.

If studied in the context of the IB concept, the spatial instinct (cf. e.g. Skalsky 1992, Suikki 1987) could turn out to be consisting of similar elements as the concept of ba.

An important ability for competence in knowledge work is to express things, matters and one's personality in a correct way (Korvajärvi & Lehto A.-M. 2000, p. 192), i.e. to use correct explicit knowledge in the knowledge management of the knowledge work. This fact is parallel or a metaphor for the importance of intelligence based on explicit knowledge in the knowledge management of the knowledge design according to the IB concept.

#### 4.3.3.3 Access to New Knowledge

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 go on.

The caps between scientific information and the information needs of the industries and other businesses have long been the main concern in the dissemination of the research results. Consulting activities have been a solution. The role of the designers has long been as that of the suppliers of construction information, and further on that of an intermediary, who through design supply the clients with the information based on construction science. Also, the seamless co-operations among scientists and industrial partners have given good results.

Far quicker than earlier, the results of basic research are nowadays employed by industries, and new products based on resent research reach the markets in a relatively short time period. This is the case, for example, in the information and communication industry and biotechnology. Despite of the fact that the construction industry is being characterised as conservative, it could follow the other industries' example of quick adoption of recent scientific results. This type of progress has been typical in the ICT of construction. For example, in building automation fuzzy algorithms can turn Proportional Integral Derivative (PID) control with digital technology into optimised cycling with good control and fewer cycles.

#### 4.3.3.4 Communication and Comprehension

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 real, in the face to face contacts, as well as when technical means are used for information and communication. Tuomi (1999, p. 100) has given the levels of the articulation of knowledge as follows:

| *Level of articulation* | *Characteristics* |
|---|---|
| Tacit | Unorganized and dynamic meaning relations |
| Focal | Conscious organized patterns of meaning relations |
| Articulated | Meaning relations sedimented in produced artifacts or expressions |
| Verbal | Meaning relations sedimented within a system of concepts |
| Socially legitimized | Socially shared conceptual knowledge |

Tuomi (1999, pp. 99–100) explains:

- *"... [M]any current authors contrast tacit knowledge with explicit and articulated knowledge ... when tacit knowledge becomes focal, it is still in most cases unarticulated. A key difference between tacit and focal knowledge is that when focal knowledge emerges, the complexity of tacit meaning structure becomes simplified in an object of consciousness.*

- *... [I]ts (an object of consciousness) interpretation as an object of the world ... may be understood as a structure or configuration of meaning relations that is held together by the active processing of meanings by the individual cognition.*

- *When focal knowledge emerges ... it becomes possible to articulate it ... through activity. Thought is converted into artifacts or expressive behaviour. Artifacts can ... for example drawings, tools, and models. Expressing can be unintended or intended, and in latter case we call it communication ...*

- *... [A]dvanced form of articulation – and one that requires considerable stocks of sociocultural knowledge and cognitive efforts – is conceptual and verbal articulation.*

- *When knowledge is articulated, it can become interpersonal and socially shared."*

Comprehension, as well as information retrieval, is also confusing, because of the various types of information (Figure 13.) (cf. Keskinen 1999, p. 42).

In choosing between computer aided means and manual ones, the type of information is relevant, because it has great influence on the status of human understanding (Lehto & Himanen 2001, Himanen et al. 2000a). Theoretically, it seems obvious that routine tasks can more easily be substituted with the ICT aided tasks than the non-routine ones.

Information exchange is enhancing, because information intensive work is based on teamwork, co-operation and networking (Keskinen 1999, Tuomi 1999). It is not any more possible to manage with superior knowledge and skills. Instead managing is the skill to collect experts together, and persuade them to work for common targets. Teams do not necessary work at the same spot, although connectivity and trust on workmates are very important. Constantly changing teams can benefit out of the sophisticated spatial solutions, if construction industry can follow the progress of its clients – the source of the clients' needs.

The possibilities for computers to communicate in the human manner are limited, despite of their superiority in memory management, and their tirelessness in repetition of same message, calculation, etc. The ICT cannot provide the end-user with the information in a manner typical for human communication, and it cannot solve the human problems of communication. A computer can repeat the fact from its memory in different combinations, but its possibilities for writing creative ideas or code is limited.

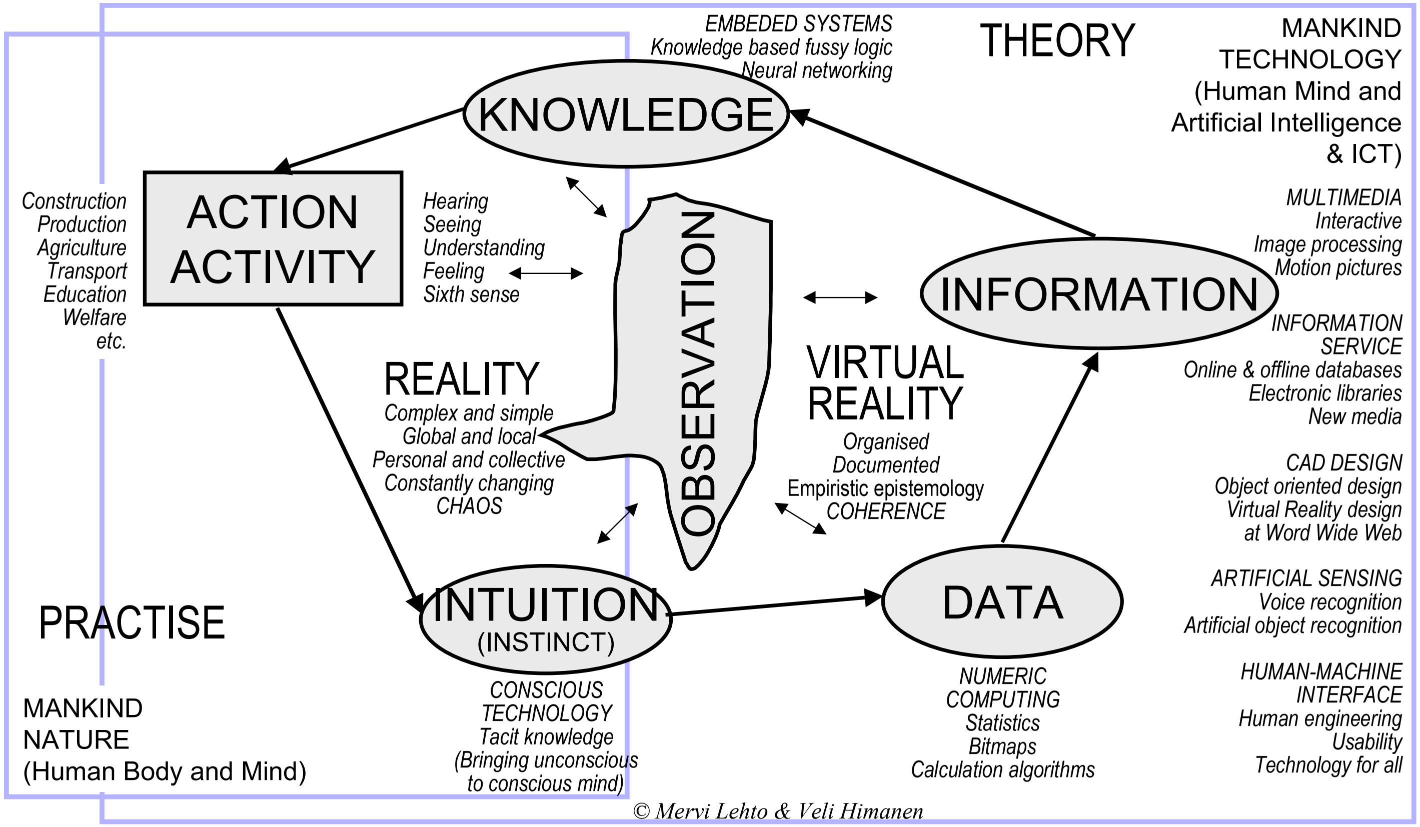



*Figure 13. Transformation of information types and their expressions in the data processing systems (Himanen et al. 2000a, Lehto 2000b, Lehto & Himanen 2002a).*

### 4.3.3.5 Intelligence and Wisdom

Tuomi (1999, p. 109) notes:

> *"... [I]ntelligence, ability, knowledge, and practice are different sides of the same conceptual package, and therefore it is not always clear what people are talking about when they talk about intelligence ..."*

V. Himanen has made the concept of intelligence (Himanen 1990) more clear by looking the difference between intelligence and wisdom. Intelligence and wisdom are separate phenomena. He clarifies the phenomena with the level of intelligence and that of wisdom. Intelligence and wisdom are operating in different dimensions (Figure 14.). When the level of intelligence of a person is low considered to an intellectual one the level of intelligence may result in stupidity. Madness or foolishness can be the consequence of low level of wisdom. Thus, a mad person can be intellectual, and even a wise human stupid.

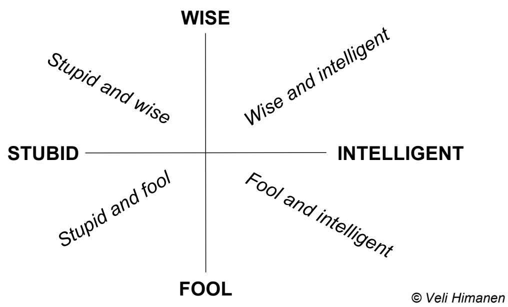



*Figure 14. Wisdom and intelligence operate in different dimensions (Himanen 1990).*

But is the problem clearer now, as it is known that for example in medicine science it is difficult to define the madness? In any case, the idea of considering intelligence and wisdom as being in various dimensions has made V. Himanen also keep wisdom and intelligence as phenomena, which are different from knowledge, information and data (Figure 13.). The author would like to add action and intuition in to the line of thought. They all are on their own level or in their own edge of this human ability. Intelligence and wisdom are operators, while action, intuition, knowledge, information and data are reflections (Figure 15.).

An intelligent person has good capacities for actions, intuition and information processing. A wise person uses these capacities for fulfilling her or his needs in harmony with her or his environment. With good wisdom and intelligence human beings are capable of coping with the packages of life, which emerge as action, intuition, knowledge, information and data reflections and can be called conceptual packages of life as Tuomi (1999) has done. Vice versa, with madness or foolishness and stupidity humans have difficulties with and they cause difficulties with of action, intuition, knowledge, information and data reflections. Wisdom and intelligence are not for problem solving and abstract thinking only, but something people use, live off: the generator of effective selective action as noted in section 4.3.3.1.

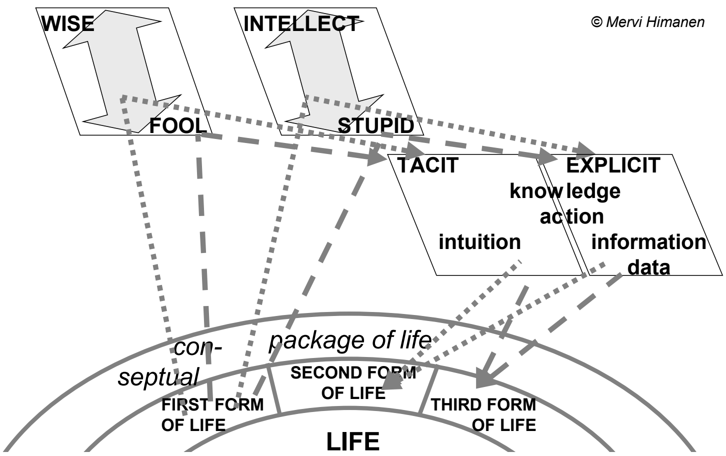



*Figure 15. Wisdom and intelligence or foolishness and stupidity reflect the conceptual package of life in action, intuition, knowledge, information and data causing the new versions of forms of life.*

### 4.3.4 Artificial Intelligence

In Finland the Finnish Artificial Intelligence Society has actively organised seminars and conferences and published reports and books on artificial intelligence from the 1980's onwards.

The intelligent building is, or at least could be, a part of the artificial intelligence phenomenon. A study subject of building intelligence can be included in the paradigm of artificial intelligence. The context of artificial intelligence has focused only on the products and production methods of the intelligent manufacturing of certain industrial fields. The same problem lies on the behalf of the intelligent building paradigm with the phenomenon of information society. Intelligent building is the scene of venue for the information society activities, but it is in various connections not included in the context of the information society.

Despite of this possibility to include the building intelligence into the artificial intelligence paradigm, during the analysis process of the results of the IBs Survey, it soon became clear that it is better to study the IB concept as a metaphor between human and building intelligence directly. This is because the comparison between man and machine is included within the artificial intelligence paradigms. It will be of more use to study this dependency directly between human and building intelligence than indirectly between artificial and building intelligence.

Furthermore, the idea of intelligence being concentrated into the head, brain or mind is not as suitable for the research of intelligent buildings, as is the idea that the intelligence exists in the whole body, e.g. in muscles able to remember, etc. The latter seemed a more promising baseline for the intelligent building concept with active structures, spatial flexibility, etc.

Due to the final choice of the starting point of the IBs Survey to be in the human intelligence (cf. Hautamäki, Linnainmaa and Haikonen in Section 4.3.3.1), the paradigm of the artificial intelligence is not included in the background of this thesis. It will not be discussed further in this context, despite of the potential importance and validity of the subject on behalf of the research of intelligent buildings.

### 4.3.5 Industrial Economics

The paradigms of the industrial economics (or the industrial engineering and management) has been a starting point for the IBs Survey. This is due to the expertise of the leader of the project and the fact that the property and facilities management phenomenon was not very well and widely known in the Finnish construction science in the beginning of 1990's.

In fact, the author of this thesis was developing the thinking of the property and facilities management in the beginning of the 1990's by applying it to the building phenomena without knowledge of the property and facilities management. During the analysis of the IBs Survey contacts to the Finnish science society of the property and facilities management were made and the work has since then based on their paradigms.

Still, this thesis is based on both theories; the applications of the industrial economics to the building phenomenon and the theories of property and facilities management. The building economics is a tool to study the buildings of the IBs Survey, but it has not been in focus of this thesis. A reason for that has been the relatively late introduction of the customer and end-user oriented building paradigm, which was not available at the start of the IBs Survey.

#### 4.3.5.1 Market Pull

The real consumer mass markets have developed after the consumers demanded more than whatever was available. The enterprises are trying to find out which kinds of products will be interesting enough for people who already have "several pairs of shoes". It is obvious that there exists a great need for services and time (Marzano 1999, Anon. 2000b). People spend time and effort in driving, shopping, cooking, cleaning, and washing. In that way they form the working class not only during the office and working hours, but also in their spare time and at home. Variation of products is possible even in mass production thanks to the ICT controlled production and distribution. The technology-for-all concept is adding even more products, which so far has been tailor-made for certain group into the realm of mass production (Hyppönen 1999).

The building industry cannot be described as having been a business of consumer mass markets. Rather, offices have several interoffice systems, which are tailored to the building. Although a house bargain is not an everyday act, the housing sector is the one building sector, which best resembles consumer markets. Consequently, the many housing products, especially those of the smart housing technology belong to that category. The same is the case with the energy efficient technology products, such as heat pumps or high performance windows for one-family housing (Lehto 2001b).

Kostiainen has pointed out that it is as important for the companies, which are competing for the ICT workforce to take account how well the community can serve them as it is important to serve them within the company (Kostiainen 2002). These services include as well the good variety daily groceries as the decent housing. Thus the connection between consumer market and the building industry, is more close than sometimes had been thought.

Consumer markets can be found to be very dependent on the opinion of the end-user. However, the same end-user is operating in the office as well. Accordingly, the office worker has been the target in many post-occupancy studies. No research for the future needs of the office worker similar to that of the SMART Technology Programme of Tekes, which had a part scanning the future needs of the manufacturing industry customer, has been found (Meristö 2001). The lack of services and time seems obvious on the basis of the research done in the consumer electronics and home appliance sector (Marzano 1999).

Emergence, a project of the Information Society Technologies Programme of the European Commission (IST), is an example of economic research on the information society. It is going to study the information business opportunities in the following manner (Anon. 2001d):

> *"The introduction of new information and communications technologies has been accompanied by major shifts in the European regions, and globally. These developments are leading to a new industrial geography, with increasing regional specialisation in certain types of information processing activities (e.g. call centres, data processing and software development). However, such developments are poorly mapped and documented. In particular, no evidence has been collected on the types of information processing activities which are likely to be outsourced or relocated, the extent of such relocation, or the criteria used in the selection of remote locations. Such information will, however, be of critical importance to policy-makers at regional, national, EU and international levels, in predicting future employment trends, ensuring the competitiveness of*

*industries, combating unemployment, and developing policies for a socially inclusive information society."*

It is important to study the influence of the existing solutions and the use of ICT for various businesses, but it is also good to ask what are the future forms of use of ICT and how the content production will appear in the future.

#### 4.3.5.2 Demand Driven Construction

Customer orientation is well known in business economics meaning the market pull and the technology push approach together. In addition to the prising, the Maslow's Hierarhy of Needs – or to be more precise, a simplified version of it – has been used as a basis for the product variation in economics. It is a human approach to production, which turns the human opinion into material form. Maslow's Hierarchy of Needs is one of the foundations used in psychology and in social science, and a term one can see in marketing, or advertising (Huitt 1998). Dr. Abraham Maslow was studying, in addition to motivation and personality, human mentality, values, etc., which have become and are becoming more important in modern economy. Understanding Maslow is especially important in global marketing, in order to decide, which level of human needs are appropriate in another country and culture.

Usually, the word "customer" within the building industry means the representatives of clients' companies. The consumer is the actual end-user, who buys the manufactured products or mass production products. Not so often, but also within the construction industry, the term customer can mean the real end-user or the words tenant or occupant, are used. In some cases end-users are seen as the customers' customers. The end-user orientation is very important in the IB concept implementation (cf. Section 2.1.2).

While the company representatives' orientation to the production can be different from that of the end-user, it is good to be careful with the terms of customer oriented and (end) user oriented building industry. Demand driven building industry covers them both, as well as the term occupant, which covers various end-user groups. Actually Brill (1985, p. 289) is pointing out that:

*"The office workers certainly know more about their work than facility managers and designers, and probably more than their supervisors. They should be the primary source of information about work tasks, methods, activities and products. In this they are expert, and any analysis of work during programming and design should utilize their expertise."*

#### 4.3.5.3 Stakeholder Activities

The perspective towards the IB in general and in this study, is from end-user's point of view. The end-user is a stakeholder of the IB concept (cf. Section 2.1).

The realisation of an intelligent building requires the participation of representatives from a number of different fields. Building developers and users must have a say in the development of construction. In addition to the office workers, the stakeholders of an office building can be an occupant company, building managers, service personnel, those who provide facilities management services, designers, the building owner, building purchasers and speculators, the contractor, real estate developers and providers, authorities, local and global community.

The field of stakeholders can be organised along four main groups by a modification of the model of professor José Viegas (Himanen et al. 2000b, p. 60) (Figure 16.):

a) subject agents, i.e. those who are active in the system's planning, provision, management and service,

b) object agents, i.e. those who benefit or use the system, such as customers and end-users,

c) catalysts, i.e. those who affect the system but do not take part in the actions on the systems,

d) passive indicators, i.e. those who are directly affected by the system (positively or negatively).

The providers and the clients have both been named as agents because of their interaction. The passive indicators are a system outside group, but they are not totally separate, because of the affection of the system on them. The indicators can feel – willingly or unwillingly – the consequences (advantages or disadvantages) of the system, and thus they measure it.

Customer's position as an agent is more active than that of the end-user, while they often are in the position of the paying operator – a position of a strong decision maker. The end-users in the building sector have been in a passive role. In the end, they too are in the position of a paying customer, but for example in the office they hold this position in such an indirect manner, that they can be easily left without proper attention in decision making. The occupant's productivity is becoming a more important factor also in the building sector and thus the end-user’s position improves accordingly. Still, in some cases in this connection client or customer is meant with the occupant.

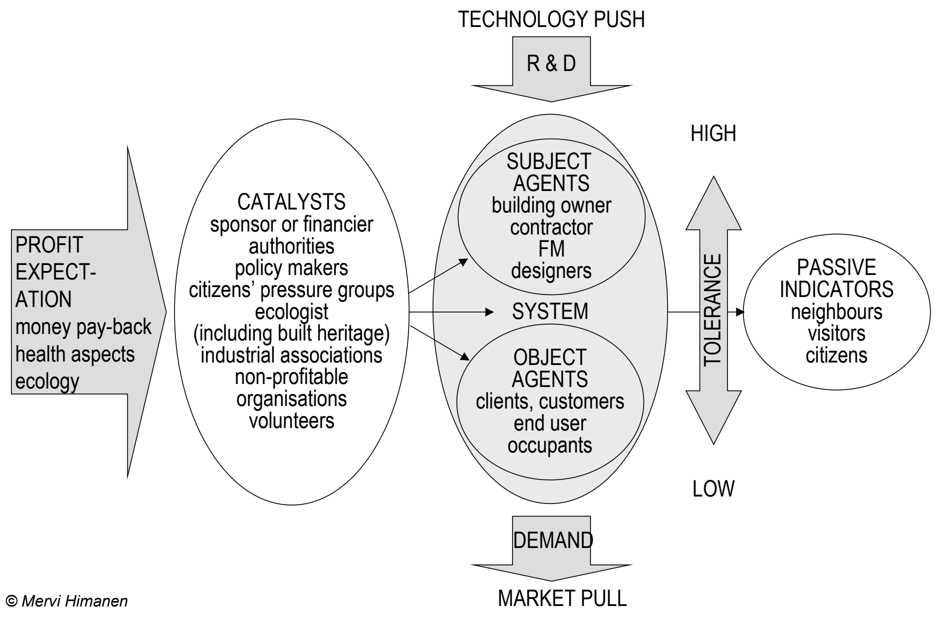



*Figure 16. Classification of stakeholders into groups of catalysts, subject agents, object agents and passive indicators.*

In the private housing sector, the user and the customer are in most cases the same person. In commercial building the customer and the end-user are often separate stakeholders. That is the case with the offices as well.

The building providers' position confused because of the changing occupants or the obscurity of the occupant in the beginning of the project.

#### 4.3.5.4 Demand Driven Construction Embedded in the Sciences

The multidisciplinary approach to the intelligent building system generated from the collection of sciences (Figure 10.) can be applied to the concept of demand-oriented construction, which can be composed of a slightly different collection of sciences than that of the intelligent building system (Figure 17.). In demand driven construction are included such sciences, as use either mental, psychological or physiological human parameters. Most of them have been characterised in section 2.4. References to semiotics are given in section 7.3.7.

Within the European Commission's Fifth Framework Programme the integrated approach to research projects from the technical, economical and social science points of view has been promoted. This kind of starting point for all projects funded by the European Commission has its effect on the future research results. More information about the social factors in the context of construction science and industry can be expected.

#### 4.3.5.5 Technical Turning Points

The traditional approach to the R&D work has been that of technology push. The first technical turning point within industrial time has been the invention of the steam engine, which caused the replacement of the manual work with machinery and started the railways. At the same time, telegraph and cinematoscope were invented. Combustion engines, electrical engineering, chemistry and metallurgy made the industrial mass production (by the side of the assembly line) possible and the car (in various forms: buses, lorries, etc.) appeared (Castells in Himanen et al. 2000a), increasing mobility and changing gradually even the structure of town planning. Telephone, telex, radio and television were the communication tools of the time. Now, the information and communication technology is causing the third technical revolution, which is said to make the freedom of time and space available. At time being, computing, multimedia and mobile communicators are the keys to the global information networks (cf. Himanen & Lehto 2001) as well as those of the integrated buildings and media homes.

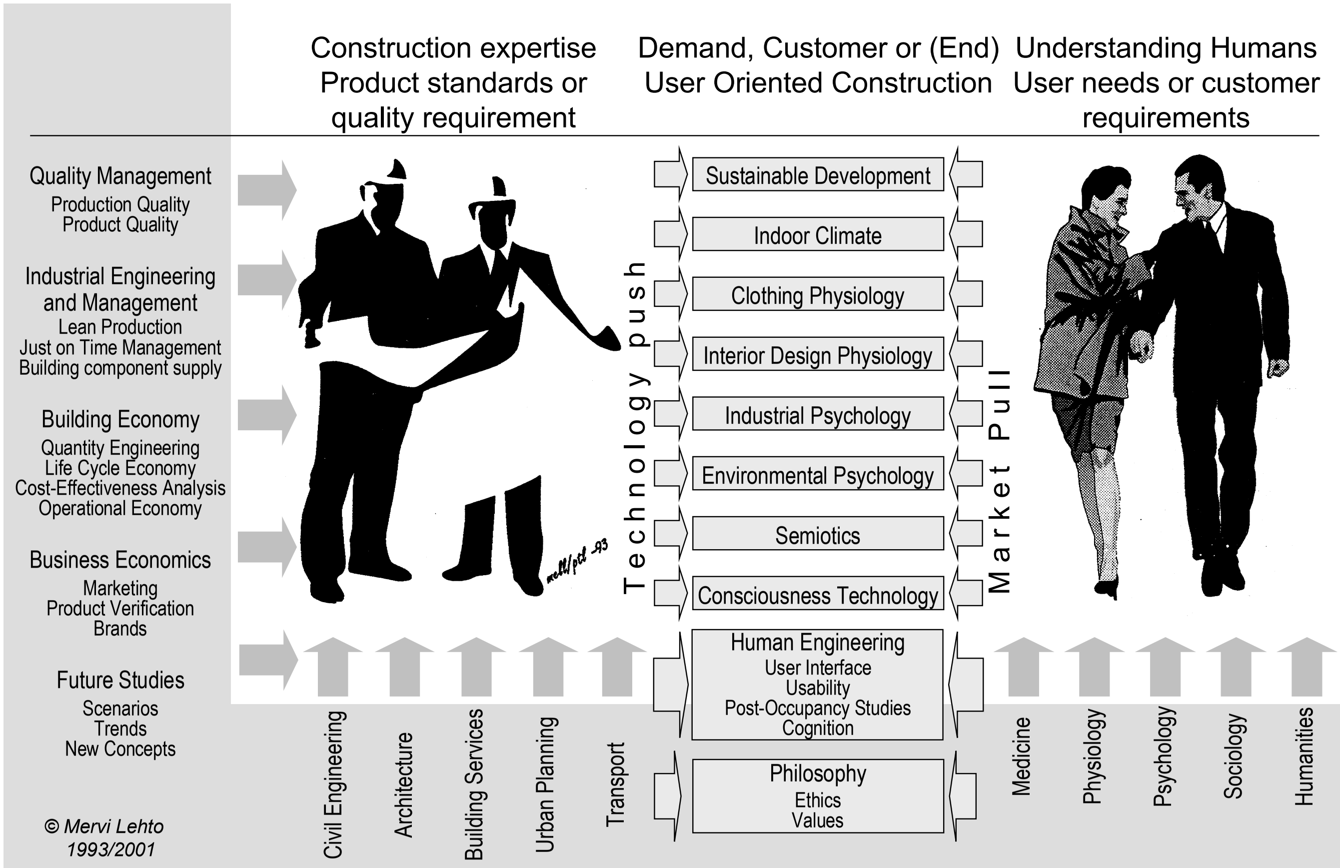



*Figure 17. The user oriented construction industry generated from the collections of sciences.*

The first Finnish computer was built in the 50's at HUT (Helsinki University of Technology). The need for computing capacity was estimated too small at that time. Till the end of 20th century, computing has spread gradually from the offices in the 60's, to half of the Finnish working tasks according to the Finnish Ministry of Labour, starting from technical calculations, various bookkeeping tasks and word processing. The development of the Finnish information society can be traced by the steps of the implementation of the computer-aided systems (cf. Keskinen 1999, pp. 94–110). What comes to the use of computing, the Finnish society is without any doubt an information society (Hienonen & Lehtinen 1995, Hienonen 1997a, Hienonen 1997b, Pekkola & Ylöstalo 1996). Another dimension in the Finnish information society is the ICT industry. Finns are not only using computers, but also earning part of their living from ICT – to be more accurate, at time being (2001) mainly from the ICT hardware, in some extent from software, but not yet much from content industry.

#### 4.3.5.6 Information as a Production Factor

The use of computing is not regarded the only measure of the advancement of the information society. The essence of the information is a wider concept (Figure 13.), which actually has as much to do with human qualifications, information content and software as with the hardware, which at the time being is the common tool for the ICT and the IB solutions. Computing is an aid for end-users in office work, as well as the information intensive office work is a mean of making business and earning a living in the information society. This meaning of the information society is well defined in the literature of the intelligent organisations, such as Tuomi's book about Corporate Knowledge (cf. Tuomi 1999, pp. 77–86). Here the word information is used for the various forms of the human expertise (Figure 13.), unless specified more accurately.

Information handling and communication are similar to other interlinking activities: transport, trade and financing or banking (Figure 18.). They work independently as a part of the society and business, but because of their nature of linkage they cannot exits without the other parties of the activities in society. Vice versa, all the other activities are applying interlinking activities into their functions. The changes caused by the introduction of the information society led to the creation of the intelligent working environment.

An intelligent building is a spatial strategy taking into consideration modern equipment for information exchange, structural and spatial changes resulted from the installation of new equipment (cf. Section 2.1) and new working methods, such as a desire to have ad hoc meetings standing or walking, hot desking, part week distant working, etc. (cf. Section 2.4.8). The increase in information intensive work might increase the need for office space, and rank or challenge office environment qualities or set up new standards.

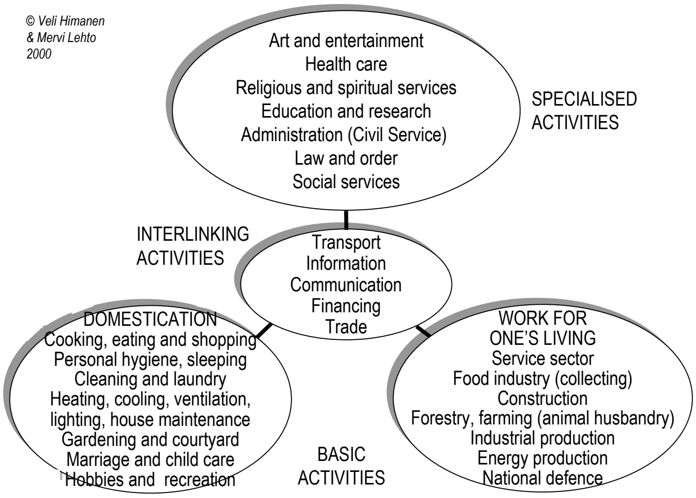



*Figure 18. Human activities (Himanen et al. 2000a.).*

Even so, during the information age the trust on the constant need for goods remains. However, the value of the business is added to by ICT – the fourth production factor (Figure 19.). 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 businesses in the information age arise from the synergy of the development of the construction processes and that of information services (Figure 19., Figure 11.). The intelligent building concept is taking the construction industry's share out of the economy and RTD of the information society. It is becoming a production factor of the information age, one of the "information intensive production factors". Using the information as a fourth production factor introduced the workspace as a part of the total production system in the light of a new means for carrying out the production, not just as a condition of work.

However, workspace can become a part of the total production system, not just as a condition of work, but as a means of carrying it out. Workspace is a similar resource for production as other factors of production: capital, manpower, tools and machinery. It is worth careful planning, when other parts of the production have to be changed according to the needs of changes in the production and customer needs. The nature of the productivity of a building can be identified by examining current industrial and business practices and by developing diagnostic tools for workspace audits. Besides providing detailed descriptions and evaluations of the workspace design, the questions crucial to enterprises' decision processes are to be defined. This thesis is about the latter approach to the R&D of buildings in the context of the information society (cf. Figure 19.).

The ability of the enterprises to respond to technological changes will be significantly enhanced by enabling them to develop optimal workspace strategies. The intelligent office space belongs either to the category of the necessary needs for information intensive work, or the IB is considered as a concept for creating spatial end-user requirements for the needs of the information intensive work (cf. Section 2.1.2). The workspace strategy of the provider of the intelligent workspace and the client of it can be seen from a different angle and perspective, but the phenomenon is the same (cf. Section 2.3).

Within the business of architecture, civil engineering and construction, and 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. The use of ICT in construction and the IB concept might bring with it the change from the local to internationalised construction industry. If the international intelligent construction industry is not exporting whole houses in the first place, it can manufacture intelligent building products, and it can serve with computing and software products world wide as well as with consulting engineering of intelligent building expert knowledge.

The RTD of construction information management projects help parties in construction projects to form networks and share project data even on-line real

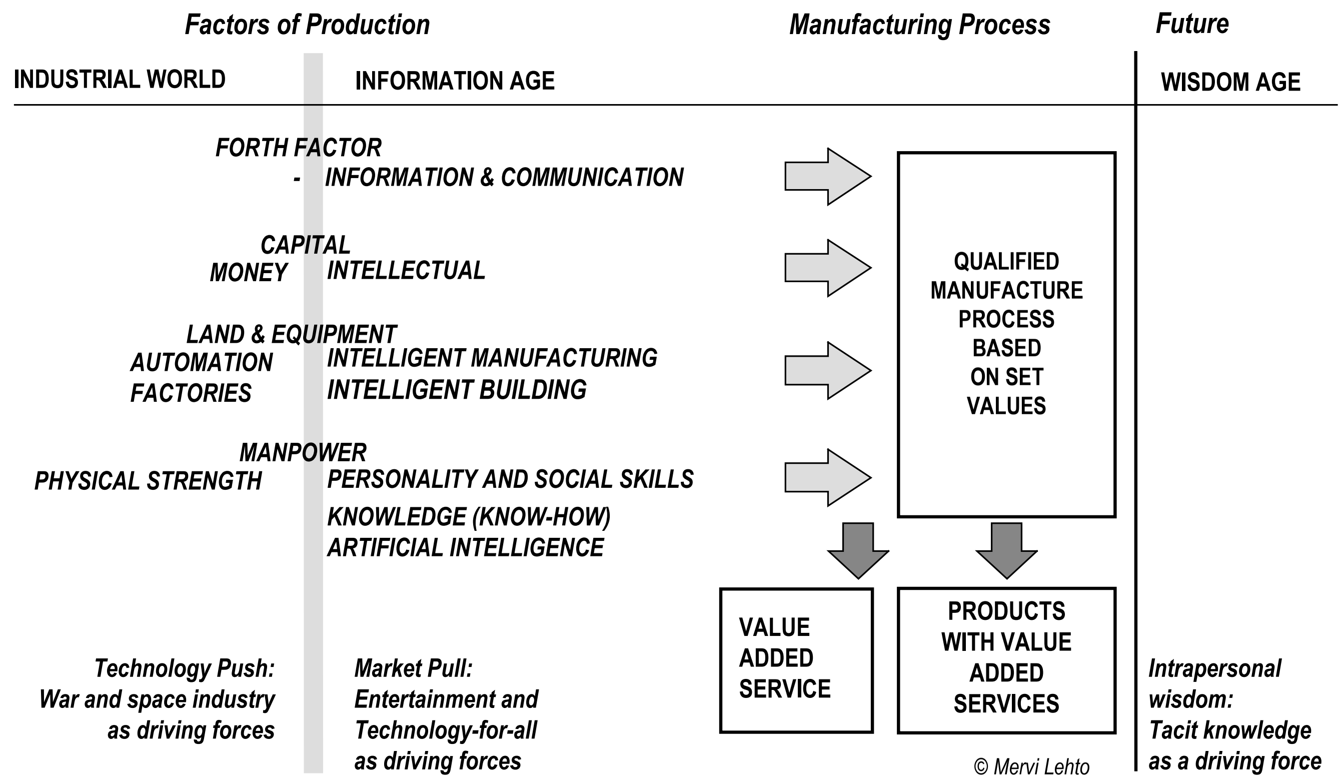



*Figure 19. Making money in the information era. Manufacturing of products with value added services by knowledge of quality engineering, awareness of company values and the fourth factor of production, e.g. information.*

time, instead of sharing it only on paper by revised versions of design drawings. The VR construction information projects support internationalisation of construction industry, while the virtual office possibility makes it possible to work with design databases in the word wide web, which actually form the VR office for the designers who in reality are located in different places, even in different countries.

#### 4.3.5.7 Indirect Financial Gain

Money is the most commonly used measure for the benefits in the Western economy. Money is also an active factor in the economy; for example, money can be made by money. In any case, being the tool for exchange is the main task of money.

All measures can be expressed monetarily. The primary aim of using monetary terms for measuring everything gives the possibility to have an equal measure for all, and thus the values of different items are comparable. However, the problem of quantitative comparison – despite of the measurement – lies in the value setting. The same item is worth more for one partner and less for another.

Due to the transparency of the information age, values are becoming more visible. Easy access to information makes activities vulnerable and vital at the same time. Work efficiency grows, but temptation to software crimes appears. Co-operation becomes close but competition ever more rough. Trust – on co-workers, clients, agreements, functionality and workability of the legal system – has become important in business. It has become obvious, how essential soft values are for existence. Transparency and visibility together with turbulent and fast progress make it easier to learn out of one's experiences during one's lifetime. Individuals start to trust their own vision of life, which is reflected in the user requirements of buildings among other things. The building quality is not only the sum of the quality of the building properties, but a parameter of the (end) users' or user groups' experience and opinion of the use of space, structures and equipment.

Benefits can be gained directly after the construction investment, or indirectly. The ICT investments are typically inputs with indirect gains. The investment on the IBs is similar. The IB, as well as the ICT, is a tool, and the core business idea lies somewhere else (cf. Figure 19.). This is true even in the real estate business. In the customers point of view, intelligence can mean for example inexpensive high quality solutions. The developer or property management (or contractor) of the IBs is actually gaining the investment back by providing the building with technology beneficial for the clients business, not from the investment itself, which might work or might not. The risk can be shared or be the burden of one partner.

#### 4.3.5.8 Building Performance

Performance is a factor of the building feasibility. The four e's of performance are economy, efficiency, effectiveness and efficacy (Akhlaghi 1996, p. 27, Carder year unknown) (Figure 20.). Economy means doing things for low cost. Efficiency and effectiveness take into account the outcome of the input, instead of only minimising the input. Efficiency is doing things right, i.e. using resources well. Effectiveness is doing right things, it is, taking into account the market demand. Efficacy means the relevance of the outcome. Effectiveness means satisfying the market in qualities, efficacy means qualitative market saturation. All these factors are taken into account in successful business.

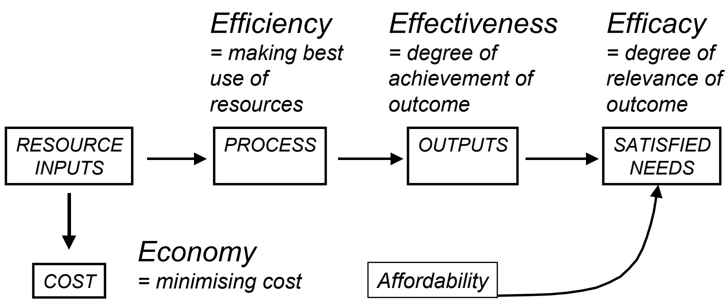



*Figure 20. The four E's (economy, efficiency, effectiveness, efficacy) of performance (Carder year unknown).*

In the IBs Survey, the office workers' work performance, the working efficiency and effectiveness, is a main indicator. The respondents of the questionnaire study within the IBs Survey were not asked to make any difference between efficiency and effectiveness, when they were asked to evaluate the quality of the building properties on the behalf of their effect on their working performance.

The workers’ productivity was not connected to the companies' productivity, which is the consequence of the efficiency or effectiveness of the input of workers.

The end-user evaluation of the building properties was based on their effect on working efficiency or effectiveness. The work performance is a reflection of the end-user satisfaction in the building. As well as the building quality, the IB concepts' quality will be described within the IBs Survey as an efficacy of the building or the building management.

The effectiveness of the building is measured in this study by the additional indicators (Section 5.4). The economical study included in the IBs Survey was studying the building economy from the cost effectiveness perspective. It was also measuring the effectiveness of the outcome. The effectiveness of the end-user evaluation results of building properties and the possible savings, such as in reducing travelling or savings in space costs and in energy consumption, were taken into account (Pulakka in Lehto et al. 1997, pp. 226–243). The savings of the spatial costs have not included into the analysis of this study.

The subject of work-related trips is included under the concept of efficacy of the intelligent buildings (cf. Figure 21.), because the method of gathering data of work-related trips was based on the working efficiency or effectiveness of the office worker, as all parameters in the questionnaire.

A second feasible approach to the building performance for the IB research is looking at the four generic trails of the facility resource management; the financial resource trail (business), the human resource trail (people), the physical resource trail (property) and the knowledge resource trail (information) (Nutt 2000). All these factors were included into this study. The examination of them is not in line with the progress, which has taken place in this study. That is why it is not easy to apply this very valuable approach to this data.

Still, continuing with the four factors, productivity depends on four cardinal aspects: personal, social, organisational and environmental (Clements-Croome 2000, p. 11). Clements-Croome continues:

*"Although it is difficult to collect hard data which would give a precise relationship between the various individual environmental factors and productivity, there is sufficient evidence to show that there are preferred environmental settings that decrease people's complains and absenteeism, thus indirectly enhancing productivity."*

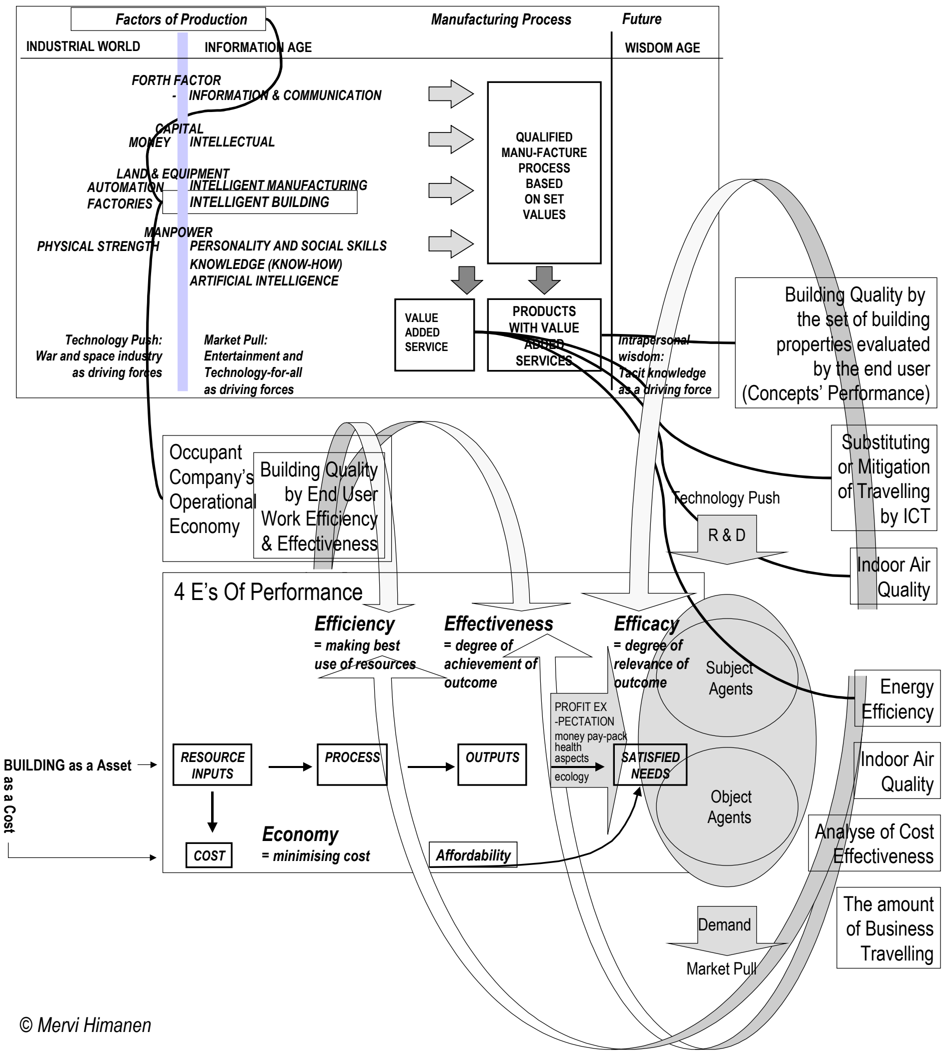



*Figure 21. The performance of intelligent buildings by the indicators of the IBs Survey.*

This is actually the case in the IBs Survey. The connectivity of the grades of end-user evaluation and the sense of environment quality have been combined together by asking office workers to evaluate their environment's influence on the working efficiency or effectiveness. In the IBs Survey 'environmental' means the physical building properties and the technology. The co-influence of personal, social and organisational factors on the evaluation of the environmental quality for the working efficiency of the office worker has been measured, at least to certain extent (cf. Section 8.2.1). The high grade indicates good environmental settings. The separation of the personal, social, organisational and environmental factors has been possible only by studying the socio-economical factors and their effect on the end-user evaluation results.

Finally, in the CBPD at Carnegie Mellon University the total building performance is measured by four metrics: user satisfaction; organisational flexibility; technological adaptability; and environmental and energy effectiveness (Hartkopf & Hemphill in Clements-Croome 2000, p. 272). User satisfaction, technological adaptability and the energy effectiveness are included in the IBs Survey, but the measurements of organisational flexibility are missing.

#### 4.3.5.9 Quality Engineering

The quality engineering is defined by ISO 9000 standards. How it has been used in this study in the formulation of the questions of the questionnaire is described in sections 4.2 and 5.3.4, and in Figure 19. Many questions ask the respondent to pick the most valuable alternative for his or her working efficiency's sake out of several options, which can be considered as the subsystems of the system, of which the question is set. The quality is built on the quality of subsystems or quality features. The quality of a system is the summary of the qualities of subsystems or the qualities of the features of it.

# 5. The Intelligent Buildings Survey

The comparison between qualities of the two types of office building products, the intelligent office buildings and the reference buildings, is based on the possibility to find with the IBs Survey building features, which might have an influence on the differences between those two above mentioned office building types. The IBs Survey is a case study of twelve office buildings.

The influence of the organisational matters has not been studied. The line of business and business opportunities of the company seem to have an influence on the selection of the location of the company, if it is located in an IB or in some other type of a high quality office building. The separation of the physical, organisational, personal and business parameters of the building quality evaluations of the post-occupancy studies is an interesting scientific task for the future. So far surveys have managed without it.

The IBs Survey has had several phases. The information gathering had two phases. First it took place in three buildings. After that the rest of them were studied. The analysis has also two phases. First at the end of the IBs Survey project the results were reported to those companies, who were clients of the project, for their needs. Secondly the scientific analyses have followed. In this chapter the progress of the IBs Survey and the research methods are given. The results of the IBs Survey are reported in chapter 7 (Sections 7.1, 7.2 and 7.4).

## 5.1 Goal and Scope

The primary aim of the end-user evaluation of the office working environment is in profitable office work, the quality of the buildings has been evaluated using the workspaces’ influence on the office workers’ work performance as a main indicator. It has been measured by a post-occupancy study, which was carried out as a questionnaire study. The parameters of the questionnaire are the variables of the building properties (cf. Section 4.2).

To verify the result – the difference in the two types of buildings' influence on the office workers' work performance – additional indicators of the building quality have been studied. Such elements of the property management as indoor air quality, energy efficiency, analysis of space cost effectiveness and possibilities for saving in business travelling have been used as completing indicators. The spatial costs have not been reported in this study.

The IBs Survey was made to fulfil the needs of a small number of Finnish private companies and with the support of Tekes. The focus of the study was to find out, whether the information and communication technology of the office buildings built according to the intelligent building concept is significantly different from that of the other types of office buildings. Simultaneously, the feasibility of the intelligent building concept was studied in it's wider meaning, including also the intelligence of architecture, structures and building services in the studied case buildings.

Firstly, the analysis of the study was based on the comparison of two sets of office buildings: the intelligent ones and the other high quality office buildings or reference buildings. Secondly, six office worker groups were compared: female and male executives (supervisors), professionals (experts) and clerical personnel. In this study the office workers have been only group of end-users or stakeholders of the office buildings (cf. Section 4.3.5.3).

The questionnaire measured the building features with an end-user evaluation of the suitability of the building characteristics for the working efficiency of the office workers. On the other hand other questions were measuring whether a certain building feature was needed or not, because of its effect on the working efficiency of the office workers. Furthermore, some questions in the IBs Survey were asking about the current situation as well as the need or wish for the future quality of the building features. In most cases the questions asked about the influence of the building feature and its quality to the workers personal working efficiency. Also, the importance of the building feature and its quality to the occupant company was included. This latter factor has remained unanalysed and is not reported in this thesis. On the behalf of the equipment, it was also asked, whether the person used the equipment or not, and if the worker would want to use the equipment in the future.

In the first place, the results from the indoor air measurements and the gathered empirical cost and energy consumption data were tabulated carefully, and the results of the questionnaire study were analysed statistically. Project reports of the results were written. Afterwards the collected data has been mirrored against the scientific literature, and more throughout analyses have been carried out, and conference and scientific papers have been written of the results. This work will be continued.

## 5.2 Approach and Touch

Often scientific studies make progress in a sequential order from the hypothesis via several well-planned parts of further research to the final conclusion. The scientific papers follow this logical order of research. After careful planning of the data gathering and the questionnaire, the analysis of the IBs Survey followed the random access approach instead of the sequential. The studies and reporting of the results from the survey data follow this type of approach accordingly (Figure 22.). The project reports revealed a general view of the most important factors. The conference and scientific papers written after that have studied certain aspects of the gathered research data and material, but the building is considered as a solid complex. Consequently, they also reveal the building properties' quality to a greater extent study after study. These studies are based also on the random access approach to the multidisciplinary study problem.

The primary aim of the IBs Survey was to gather empirical information about the buildings built according to intelligent building concept, in order to be able to judge if it is worthwhile to continue building in accordance with this. At the same time, the empirical data was gathered with a wide range of various research methods, in order to draw an overall picture of the intelligent building properties for judging which factors, if any, are relevant for the IB concept. The approach to the data gathering of the sample can be described also as taking the random access approach rather than the sequential one (Figure 22.).

The intelligent building concept is a concept of several disciplines (cf. Section 4.2). The reporting of the IBs Survey highlights the data from a certain angle: IB concept, indoor air, healthy building, energy consumption, quality of equipment, spatial requirements, business trips (Figure 8.). Each of these adds new information to the overview and makes the picture clearer. They also make the previous information more understandable. A clear picture will appear gradually.

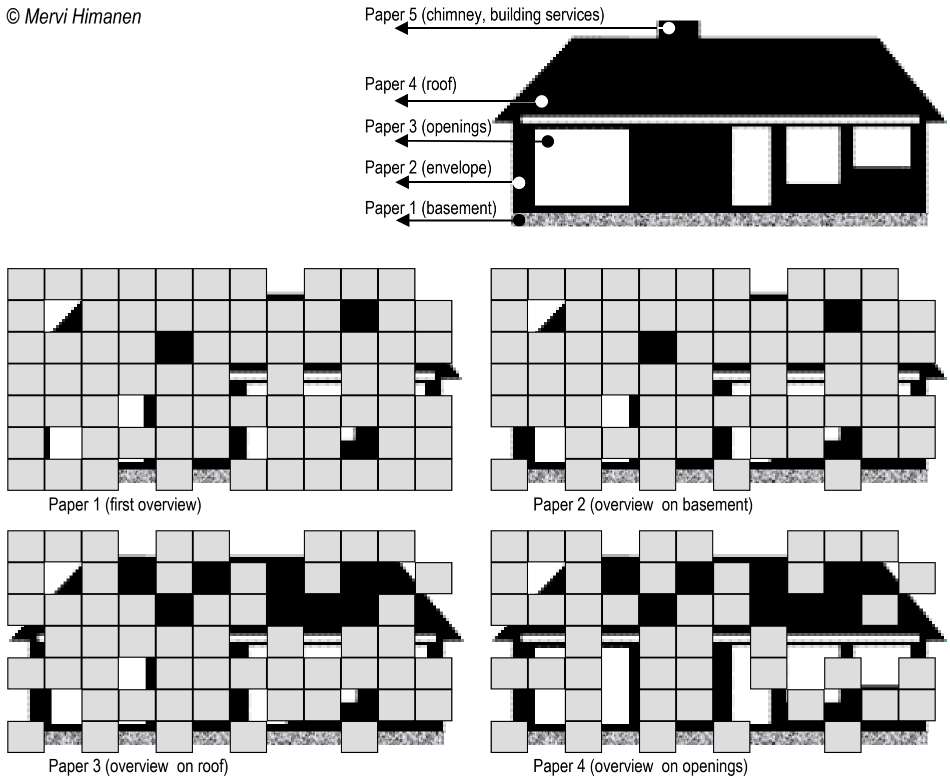



*Figure 22. The sequential (upper picture) and the random access approach to the research.*

It is hard to cover all of the IB factors in a study, which has natural limited resources. A thorough analysis of all the data gathered during the IBs Survey on the sectors of the IB concept parameters is not covered in this doctoral thesis, but the most important ones have been fully examined. The author's wish is to be able to continue, in following studies, the work on the analyses of such subjects as [1)] the interplay of the energy consumption and indoor air quality, and [2)] that of the clothing and the indoor air quality, and [3)] that of cleaning and indoor air quality; or [4)] the telework phenomenon and its importance compared to the influence of the ICT technology to business trips, [5)] the illumination and voice environment in different office buildings, [6)] the influence on the end-user evaluation of the possibility to influence on one's work environment's design. This is just to mention some of the considerations, which are possible on the basis of the gathered material (cf. Section 8.2.7).

## 5.3 Questionnaire

The post-occupancy study which was carried out with the questionnaire is the primary measuring tool for the hypothesis of the IBs Survey. The additional indicators verify the result of the questionnaire as shown previously in Figure 2. The effect of energy efficiency and space cost economy were surveyed separately.

For finding out the indoor air quality field tests with measuring equipment were carried out. The indoor air was tested also by the post-occupancy study. When the results of the indoor air quality measured by the post-occupancy study are indicted, the terms indoor air quality or indoor air quality evaluation have been used. When the field test result is concerned, the term indoor air measurements has been used. Thus, the factor of indoor air is included in both the questionnaire measuring the end-user evaluation and in the additional indicators, which measure the building quality by other means than end-user response. As a matter of fact, they have been measured either by expert knowledge based on the gathered facts or by the field tests of the physical properties.

The questionnaire is a research method for studying the end-user opinion of the experienced possibilities of saving in business travelling by using ICT, which is one of the additional indicators. With the questionnaire information on the number of the trips, that of the modes, destinations, commuting, etc was gathered. This information is relevant for the additional indicators.

The indoor air is included in the description of the questionnaire (Section 5.3.5.2) and in that of additional indicators (Section 5.4.3). The difference of the two methods has been indicated by the use of two different terms as mentioned above. The business travelling is also included in the description of the questionnaire (Section 5.3.5.4), and in that of the additional indicators (Section 5.4.4). In the post-occupancy study is included the correlation of the use of ICT and the number of business trips. In the additional indicators are included the facts of the experiences of business trips. In sections 7.1 and 7.2 the results of the IBs Survey are reported accordingly. The results of the indoor air (Sections 7.1.1.10 and 7.2.1.2) and the business trips (Sections 7.1.3.3 and 7.2.1.4) are reported in two connections.

### 5.3.1 Two Phases of Data Gathering

Data was gathered by a questionnaire with 417 parameters that was circulated among workers in the twelve office buildings, of whom 534 answered (Lehto 1996c, Lehto 1997a, Lehto 1999e, Lehto 1999f, Lehto & Himanen 2002b, Lehto & Karjalainen 1997, Lehto 1998d, Lehto 1999c, Lehto 2000c, Lehto et al. 1997, pp. 71–72). In the first phase of data gathering 38.5 per cent answered, and during the second phase 28.5 per cent.

The data gathering with the questionnaire took place in two phases. In the first phase, in spring 1994 (in March) two intelligent buildings and one non-intelligent building were studied. The questions had been tested among some professionals, but the first phase of the data gathering was at the same time a full scale test of the questions.

After that, the questionnaire was changed. Some questions were rewritten. They were set in a more accurate way. In the end of 1994 and in the very beginning of 1995 (in December and in January 1995), a new questionnaire was used for studying additional three intelligent and six non-intelligent office buildings (cf. Section 5.3.3.2).

### 5.3.2 The Timing

The main part of the information was collected in 1994. The economical recession began in 1990 and the bottom was reached in 1993. Even so, during 1994 it was not yet clear in which direction the economical progress would swing. At the same time, the 1990s were a period of constant change in working life. These two elements caused some uncertainty in working life at the time. Those who had not lost jobs, were at that time in a good position compared with those, who were unemployed, which at that time in Finland was possible despite of good education, work performance, etc. On the other hand, for those who had work, the work was exceptionally demanding during the recession. Thus, it can be presumed that the judgement of the working environment has been based on the needs of the work. Still, the reflection of the surrounding conditions can not be undervalued.

### 5.3.3 Samples

The end-user evaluation was done by the building tenants, who in this case were office workers. The number of buildings was twelve in all, of which five were intelligent office buildings and the remaining seven high quality office buildings. The number of respondents, 534 office workers, was relatively high and they represent very well the average Finnish office workers.

The number of intelligent office buildings in Finland in the beginning of the 1990's was not very big. Their number has not been calculated, but the situation can be described roughly by stating that it could have been possible to name and calculate them relatively easily, because their number most probably was less than 50. In the end of SAMBA (Smart and Modular Building Automation) Technology Programme of Tekes in 1999 the number of office buildings with LON-technology (Local Operating Network) in Finland was about 800. They represent the integrated office buildings rather than intelligent ones. However, the interest in the RTD of the LON-technology in Finland has been relatively active not only among those who have developed the building automation networks, but also among those companies who produce intelligent hardware, which can be operated by the building automation networks. That is why the number of office buildings with LON-technology tells also about the existence of intelligent office building projects.

Compared to the situation in the North America (Anon. 1999) the number of buildings with integrated building features in Finland is not high, if not very low either, because it is not very high in the USA either, being around 12 per cent on the behalf of the most intelligent features (Section 2.5.3).

In Finland, the volume of finished office building projects was about 0.66 milj.$m^3$ per year (150 projects) in 1994, while it was in 2001 2.4 milj. $m^3$ per year (246 projects) (Riihimäki 2002). To be precise, there were planning permissions of 0.52 milj. $m^3$ per year (173 projects) and 0.66 milj. $m^3$ per year (152 projects) were began to be build in 1994. Corresponding figures in 2001 were 2.24 milj. $m^3$ per year (251 projects) and 2.08 milj. $m^3$ per year (210 projects). The volume of the studied IBs was 0.34 milj. $m^3$. Although they were not at all the only Finnish IBs at that time, their volume in the exceptionally low office building volume built in the 1994 was remarkable, and even in comparison to the high office building volume of the 2001, they represent 15 per cent of the yearly built office building volume.

The intelligent building features were not at all a standard in the Finnish office building projects at that time when the IBs Survey was carried out. The steering committee members of the IBs Survey chose the buildings for study carefully from among relatively big building projects. Three out of five were occupied by several companies. The buildings were located in various parts of the Helsinki metropolitan area. They were building projects, which were the flagships either of the owner company or that of the building provider and they were also given a similar status from the real estate company.

The sample of the buildings did not include buildings with hot desking or other new office layouts although there were such a buildings available for the study. This was the decision of the steering committee of the IBs Survey, which was in cahrge of the selection of the buildings for the study. The sample of the end-users was limited to the office workers and the service personnel, FM people, etc. were excluded.

#### 5.3.3.1 Office Workers

The demography of the office workers in this sample resembles the Finnish office workers in general in 1994 (Lehto, Flink & Karjalainen in Lehto et al. 1997, p. 82, Kaartovaara 1995 in Lehto et al. 1997, Kaartovaara & Sauli 1994 in Lehto et al. 1997, Koivisto 1994). The officer workers' demographic factors were different in each building. The differences per two office building types can be summarised as follows: those who answered were younger, more often men (58 per cent) and married or living in a partnership (82 per cent ($n$=158/193)) in the IBs than in the reference buildings (45 per cent men, and 68 per cent married or living in a partnership ($n$=109/160)) (cf. Lehto 1996c, Lehto 1997a, Lehto 1998d). In the IBs (24 per cent ($n$=70/290)) workers were also more often executives than in the other offices (13 per cent ($n$=23/176)) (Lehto 1999f).

In the IBs the mean age of the respondents was 37.4 years ($n$=120) and in the reference buildings 39.9 years ($n$=166). The difference is a statistically significant one ($p$= .016945). The difference in the numbers of workers of different genders is also statistically significant (Pearson Chi-square $p$= .00331 and M-L Chi-square $p$= .00329, when $n_{women}$= 234 and $n_{men}$= 265.).

The frequency of *the statuses of the workers* among those who answered proved Goleman's theory of the derivation of the diamond organisation (1993) to be true in 1994 in Finnish office work organisations, especially in those ones located in the IBs. In the IBs the amount of executives was 24 per cent, professionals 47 per cent, and that of the clerks 22 per cent. Corresponding figures in the reference buildings were 13 per cent, 55 per cent, and 26 per cent. **It can be argued that in the working organisations of the IBs, the knowledge organisation qualifications seems to be highlighted on the basis of the working organisation's diamond structure.**

Over half of the office workers in this sample had an university degree; 10 per cent had a lower academic degree, 36 per cent had a higher academic degree, and 6 per cent a doctors' degree (Lehto, Flink & Karjalainen in Lehto et al. 1997, p. 89). Only 6 per cent had received only a basic education.

The workers in the IBs were better *educated* than those in other offices: 9 per cent had a lower academic degree in the IBs, while the same figure in the other office buildings was 11 per cent, 40 per cent had a higher academic degree in the IBs, while the same figure in the other office buildings was 31 per cent, and 9 per cent had a doctors' degree in the IBs, while the same figure in the other office buildings was only 3 per cent (Lehto, Flink & Karjalainen in Lehto et al. 1997, p. 89).

Finnish office workers are better educated than for example those in the American office (Brill 1985 in Lehto et al. 1997, pp. 90 –91). For example, 83 per cent of the executives in a Finnish office at the time had at least a lower academic degree, when the same figure in USA was 61 per cent. The time of the data gathering can influence this matter. Ten years difference can influence the educational level of the office worker sample. On the other hand, Finland is known as an education oriented society.

Female executives and professionals were better educated in general than men (81 per cent of female executives has higher academic degree, 55 per cent of male ones), while the male clerks were better educated than the female clerical staff (27 per cent of male clerks has higher academic degree, 7 per cent of female clerks). Interestingly, however, the doctor's degree was more common among male executives (11 per cent), and actually there were no female executives with a doctor's degree. Accordingly, the doctor's degree was more common among female professionals (10 per cent) than male professionals (7 per cent). **It can be argued that although a good education is a necessity for a woman for getting any position in the knowledge intensive industries, it is no guarantee of a senior work position.**

Furthermore, in the working organisations of the IBs these differences may be emphasised. In the work organisations of the IBs more often than in the office organisations of other types of office buildings, the doctors' degree leads to an executives' position for men than for women.

*Table 1. Working with the computer according to the office building types, genders and the statuses of the workers.*

| *The sample of the second phase of the IBs Survey*<br><br>*Percentages of the respondents (%)* | All together *(n= 386)* | IBs[1] *(n= 201)* | Non-IBs1 *(n= 162)* | Men *(n= 186)* | Women *(n= 155)* | Executives[2] *(n= 49)* | Professionals[2] *(n= 170)* | Clerk[2] *(n= 87)* | Other[2] *(n= 26)* |
|---|---|---|---|---|---|---|---|---|---|
| Hardly at all | 6 | 1* | 10* | 7 | 5 | 13* | 3 | 4 | 7 |
| 1–2 hours per day | 15 | 13 | 17 | 17 | 12 | 33* | 13 | 11 | 15 |
| Less than half of working time | 17 | 14* | 19* | 15 | 20 | 17 | 18 | 16 | 15 |
| Over half of working time | 31 | 35* | 26* | 31 | 30 | 23* | 30 | 35 | 26 |
| Almost all the time | 32 | 35* | 27* | 31 | 33 | 15* | 36 | – | 37 |

* ≡ a statistically significant difference, $p < .05$, [1] ≡ p= .00057 (Pearson Chi-square) and p= .00036 (M-L Chi-square), [2] ≡ p= .00855 (Pearson Chi-square) and p= .01890 (M-L Chi-square).

The analysis of the effect of education on the status of the worker according to gender is lacking in this phase of the study. That is why nothing precise about the professionals' education can be stated. However, it is known that, in the first place, the education level is higher in the IBs, and secondly, that the education level is higher among female professionals and executives than the male ones, in the whole sample. Hence, the education level of the female professionals and executives in the IBs is expected to be higher than that of the male professionals and executives. Still, it is impossible to say if it is higher among female executives or professionals, or both, without statistics from the sample (cf. Section 8.2.7.12).

The use of computers has been considered as *one signal of information intensive work,* although it does not describe the information intensive work in full. On the basis of the data which is gathered in the second phase of the Survey, only 6 per cent of the respondents did not use the computer at all (Table 1.).

*Table 2. Participation to meetings via ICT according to the office building types.*

| *The sample of the second phase of the IBs Survey. Percentages of the respondents.* | Conference call (by phone) | | | Video-conference call[1] | | | Attendance of video-conference | | | Computer conference[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All[5] | IB[3] | Non-IB[4] | All[5] | IB[3] | Non-IB[4] | All[5] | IB[3] | Non-IB[4] | All[5] | IB[3] | Non-IB[4] |
| Altogether | 25 | 27 | 23 | 5 | 7* | 1* | 3 | 3 | 2 | 8 | 11* | 4* |
| Daily | 9 | 9 | 10 | 0 | – | – | | | | 2 | 4 | 0.5 |
| Weekly | 3 | 3 | 4 | 1 | 1 | 0 | | | | 2 | 2 | 2 |
| Monthly | 5 | 5 | 4 | 0 | 0 | 0 | | | | 1 | 1 | 1 |
| Yearly | 8 | 10 | 4 | 4 | 6 | 1 | 3 | 3 | 2 | 2 | 4 | 0.5 |

[1] ≡ p= .04113 (Pearson Chi-square) and p= .01691 (M-L Chi-square), [2] ≡ p= .08126 (Pearson Chi-square) and p= .04662 (M-L Chi-square); [3] ≡ n=218; [4] ≡ n=168; [5] ≡ n=386

Two thirds of the workers worked half of their working time with computer. There are no big differences between genders in the use of computers, but the differences between workers in general of the two different office building types are statistically significant, as well as those of the three worker groups of different working status. Those who work in the IBs use computers more and the executives use computers less than the other groups of workers.

The difference of the numbers of conference calls was not statistically significant between the intelligent and the other offices in 1994 (Table 2.). Video-conference calls or participation in a video conference, as well as computer-conferencing was not common. Those who worked in the IBs had video-conference calls more often than those who worked in other types of offices.

More men had participated in video-conference calls (32 per cent) than women (19 per cent). This is the only variable, which shows a statistically significant difference between men and women in participation to meetings via ICT ($p$= .05381 (Pearson Chi-square) and $p$= .04635 (M-L Chi-square)). The working status played no role in the comparison of these factors of participation in the ICT aided meetings.

#### 5.3.3.2 Buildings

The steering committee members of the IBs Survey (Section 1.3) *selected* the set of buildings for the IBs Survey (Table 3. and Table 4.). The intelligent office buildings were picked out from those office buildings, which were designed and built according to the intelligent building concept. When selecting the buildings for comparison purposes, the experts of the steering committee kept in mind the qualities of the intelligent office buildings and tried to find as similar buildings as possible. The selected buildings were built at the same time as the IBs, they were located in the same areas as the IBs, the number of occupant companies was close to that of the IBs, and their building standards were of high quality and their purpose of use varied accordingly to that of the IBs.

During the analyses the researchers made *an exception from the selection* principle of the buildings. One building, which was selected for the study as a reference building is analysed among the intelligent buildings (the IB number

2.), because in the researchers' mind its design, structures and spaces resembled more those of the IBs than those of the reference buildings (Table 3. and Table 4.).

A study was done (on the basis of the summarising statistics of all evaluative questions of the second phase of the IBs Survey about spaces and equipment (cf. Section 5.3.6)) to see, if moving this building from one group to another would have an influence on the result or not. No difference was found. When comparing the differences of the end-user evaluations of equipment no difference at all was found. The total end-user evaluation grade of equipment with the IB number 2. was 7.59 ($n$=175), and without the IB number 2. it was 7.60 ($n$=153). On the behalf of spaces the IB number 2. reduced the total end-user evaluation grade of the IBs. Without it the total end-user evaluation grade of the IB spaces was a little better (7.81 ($n$=172)) than with it (7.74 ($n$=195)). The correct way of handling the situation would have been to leave it out of the comparisons based on the two office building types. Because of the relatively small number of buildings in the sample and because of the result of this test the IB number 2. was included in the analyses. However, it was known that this decision made the differences between the IBs and the reference buildings less significant (Table 9.). On the other hand, it made the result of the differences between the IBs and the reference buildings more reliable.

According to the final study of the differences between buildings, which was based on all summarising statistics of all evaluative spatial questions of both phases of the IBs Survey (cf. Section 5.3.6), the spatial quality of the IB number 2. was not very good either (the least of the twelve buildings). On the other hand the IB number 5., which was studied in the first phase of the IBs Survey was evaluated as a very good building (the second best of all twelve buildings). It was not included in the study on the effect of the end-user evaluation results of the IB number 2. on the result of the summaries of the end-user evaluations of the second phase of the IBs Survey. A very critical scientific approach necessitates leaving out the best and the worst values or cases. In this case on the basis of the spatial quality, it would mean leaving from the analyses the IBs numbers 2. and 5. Because of the relatively small number of buildings in the sample and because of the result of this test the IBs number 2. and 5. were included in the analyses. It was known that they were not influencing the analyses of the spatial quality of the buildings.

*Table 3. The summary of the properties of the IBs of the* IBs Survey.

| Building type | Year of construction Size m³ | Office bldng type Number of occupants[4] | Bldng Autom. & Safety | LAN | Personal Cooling Units | Stand by Energy Supply | Bldng man- ager | Recep- tionist | As- sembly Floor | Move- able Walls | Glass Roofed Lobby | Out Rented Spaces | Personal workspace area [2,3] | Office type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IB 1 | 1991 110 000 | office hotel 508 | + | + | + | | + | + | + | + | + | + | 2.9 | open space[1] |
| IB 2 | 1993 35 370 | governmental 185 | + | + | | | + | + | | | + | | 2.8 | rooms |
| IB 3 | 1993 86 161 | head office 249 | + | + | + | + | + | + | + | + | + | + | 2.6 | open space[1] |
| IB 4 | 1991 20 300 | office hotel 70 | + | + | + | | | + | + | + | + | + | 2.4 | open space[1] |
| IB 5 | 1988 84 500 | sales office 340 | + | + | | + | + | | | | + | | 2.2 | rooms (open area) |
| Average | 67 300 | 270 | | | | | | | | | | | 2.6 | |

[1] ≡ Open space available, firms use it either for rooms or as open area; [2] ≡ An index from 1to 4: 1≡ less than 5 $m^2$, 2≡ 5–9 $m^2$, 3≡ 9–13 $m^2$, 4≡ over 14 $m^2$; [3] ≡ informed by the office workers (the IBs Survey); [4] ≡ the current number of office workers of the occupant companies excluded service, maintenance and FM personnel.

*Table 4. The summary of the properties of the reference buildings of the* IBs Survey.

| Building type | Year of construction Size m³ | Office bldng type Number of occupants[3] | Bldng Autom. & Safety | LAN | Personal Cooling Units | Stand by Energy Supply | Bldng manager | Receptionist | Assembly Floor | Moveable Walls | Glass Roofed Lobby | Out Rented Spaces | Personal workspace area [1,2] | *Office type* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non-IB 1 | 1987 40 200 | two users' office 65+90 | + | + | | | | + | | | + | | 2.9 | rooms |
| Non-IB 2 | 1987 49 500 | head office 100 | + | + | | + | | + | | | + | | 2.9 | rooms |
| Non-IB 3 | 1978/92 (123 000) | office 70 | + | + | + | + | | + | | | | | 3.3 | open area |
| Non-IB 4 | 1989 8 350 | municipal office 100 | + | | | | | + | | | | | 3.1 | rooms (customer service) |
| Non-IB 5 | 1989 46 630 | head office 250 | + | + | | | | | | + | | + | 2.8 | rooms open area |
| Non-IB 6 | 1992 49 440 | office hotel 117 | + | + | + | | | + | | + | + | | 2.3 | rooms |
| Non-IB 7 | 1991 15 500 | office hotel 70 | + | + | | | | | | | | | 3.1 | rooms |
| Average | 35 000 | 123 | | | | | | | | | | | 2.9 | |

[1] ≡ An index form 1 to 4: 1≡ less than 5 $m^2$, 2≡ 5–9 $m^2$, 3≡ 9–13 $m^2$, 4≡ over 14 $m^2$; [2] ≡ informed by the office workers (the IBs Survey) ;
[3] ≡ the current number of office workers of the occupant companies excluded service, maintenance and FM personnel.

However, the previously mentioned comparison between the IB number 5. and other IBs was not done on the end-user evaluation results on the behalf of the equipment. The IB number 5. seems to have relatively good quality of the equipment, because the final result of the test of the quality of the equipment of all the IBs shows significant statistical difference between the equipment of IBs and that of the reference buildings (Table 10.), which was not the case according to the first comparing study with the four other IBs and the reference buildings based on the second phase of the IBs Survey (Table 9.). The number of employees in the IB number 5. is also relatively high (340 employees) and in the first phase of data gathering 38.5 per cent answered, while the answering percentage was lower (28.5 per cent) in the second phase. However, the analyses of the results took into account the number of responses from each building, when calculating the final grades of the buildings.

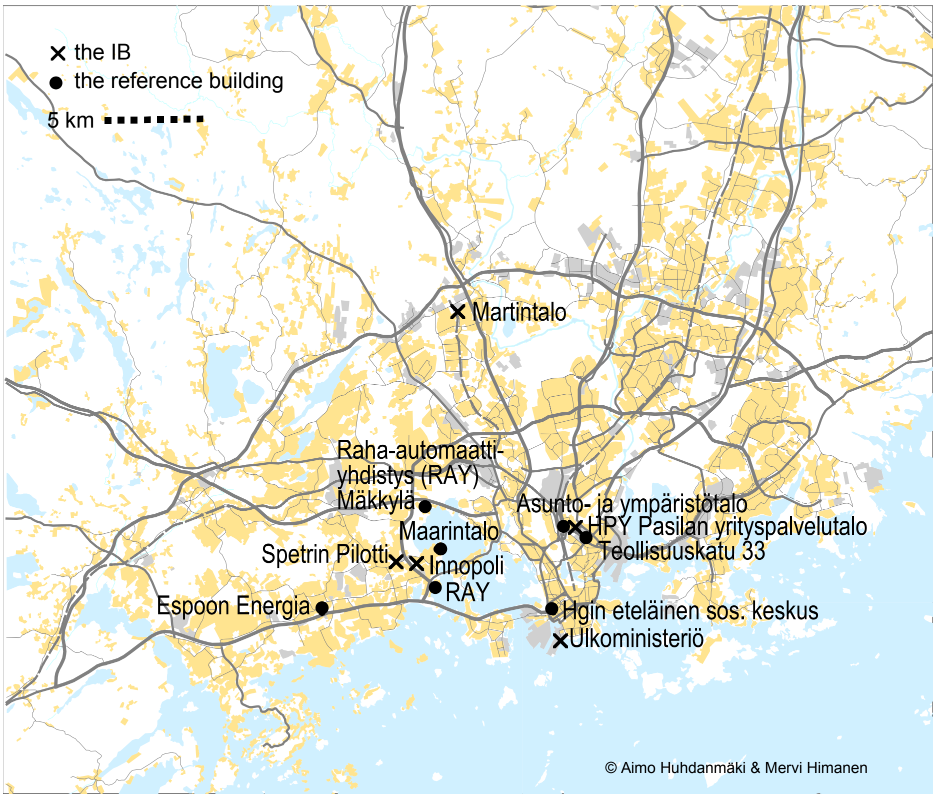



*Figure 23. Location of the buildings of the IBs Survey.*

The *locations* of the studied office buildings were all in the Helsinki metropolitan area. Most of them are in the city centre of Helsinki, or in the technology parks and in suburban areas of the City of Espoo (Figure 23.). One of them (Martintalo) is located in the City of Vantaa. No buildings were located in the fourth small city in the Helsinki metropolitan area, Kauniainen.The location of the buildings is being studied in more detail and a paper has been written on the subject (Lehto 1999e, cf. also Lehto et al. 1997, pp. 108 and 111).

The IBs are some what *newer and bigger in size* than the reference buildings (Lehto et al. 1997, pp. 22–23, Lehto 1996c, Lehto 1999f, Lehto & Karjalainen 1997, Lehto 1999c). The average age of the IBs is 3.8 years and the average size 67 300 $m^3$ or 14 613 $m^2$ with 270 occupants. The average age of the reference buildings is 5.4 years and size 35 000 $m^3$ or 10 998 $m^2$ with 123 occupants. The IBs are newer, because after the new concept was adopted, the high quality office buildings were built in great extent according to it and it was not possible to find high quality buildings for reference buildings among the very new.

The average occupancies of the two office building types show the spatial efficiency of the IBs: the occupancy in the IBs is 54 $m^2$ (249 $m^3$) per worker, and in the reference buildings 62 $m^2$ (278 $m^3$) per worker. The occupancies have calculated from the number of the office workers of the occupant companies excluding the service, maintenance and FM personnel. The average occupancies are relative large, because in 1994 due to the recession the office spaces were not fully occupied. In the IBs the spatial effectiveness is based on the compact workspace size, while the shared spaces per worker are bigger than those in the other high quality office buildings (Lehto 1996c, Lehto 1997a, Lehto 1999f). This is a fact in general in the Finnish IBs, which have been built in the end of the 1980's and the beginning of the 1990's (Lehto et al. 1993).

*The structural and technical differences* of the two different office building types were surveyed (Lehto 1996c, Lehto 1999f, Lehto 1999c, Himanen et al. 1996a, p. 83). In general, some IB features appear in both office building types, but the total number of the IB features in the IBs is greater than that of the reference buildings (Table 27., Table 28., Lehto 1999f).

Common properties of the studied IBs are (cf. Table 27., Table 28., Lehto 1996c, Lehto 1999f, Lehto & Karjalainen 1997, Lehto 1999c, Lehto et al. 1993):

- The existence of a glass roofed lobby.
- Interoffice restaurant and show-rooms next to the lobby.
- Spaces for customer occasions (including a sauna bath section) on the roof.
- Innovations in the facades, pillars and floors (bearing structures) to make spatial flexibility possible, and to guarantee the functionality of the building service installations.
- Personal flexibility of the work space by the building automation, and new heating and ventilation design.
- Sharing the shared spaces with several users coming from inside and outside of the building.
- Spaces reserved for recreation.
- The high quality of building services, and that of automation and communication installations.
- Parking and technical space in the basement.

The shares of the *various room types* of the total building room area were studied (Table 5.). The workspace is a room area for the office workers' own use. It can be in a private room, in a shared room, in an open area office or the workspaces can be organised on the basis of so called hot desking (or multisite) principle, which means that the worker does not have a desk of her or his own, but can reach all her or his files from the nearest desktop. In the studied buildings of the IBs Survey the hot desking did not appear. The popularity of room office and that of the open area office workspace was studied.

All the workers use shared spaces. These are the lobby, staircase and elevators and escalators, meeting rooms, auditorium and class rooms, dining room (restaurants), show-rooms, library, hobby halls and fitness centre. The space for common office services includes such spaces as corridors, spaces for peripheral office automation devices, such as copiers, printers and fax machines, spaces for temporary group work and rest areas, rest rooms and storage rooms. Defining a space to be included in either the shared spaces or the common office service

*Table 5. The share of various types of spaces in the studied buildings.*

| *Percentages of the total room area.* | Work spaces | Space for common office service | Shared spaces | Other |
|---|---|---|---|---|
| IB1[5] | 30 | 30 | 25 | 5 |
| IB 2 | 35 | 35 | 20 | 15 |
| IB 3[4] | 35 | 35 | 30 | 15 |
| IB 4[2] | 40 | 40 | 30 | 10 |
| IB 5[1] | 25 | 25 | 30 | 30 |
| Average | 33 | 25 | 27 | 15 |
| Non-IB 1 | 45 | 45 | 20 | 15 |
| Non-IB 2 | – | – | | |
| Non-IB 3 | – | – | | |
| Non-IB 4 | 60 | 60 | 10 | 10 |
| Non-IB 5 | – | – | | |
| Non-IB 6 | 50 | 50 | 10 | 15 |
| Non-IB 7[3] | 45 | 45 | 10 | 5 |
| Average | 50 | 26.25 | 12.50 | 11.25 |

[1] ≡ Other spaces includes a shop, two flats, a kitchen and technical space for air conditioning

[2] ≡ Other spaces includes a kitchen; shared spaces include an education centre and a sauna bath department for entertaining.

[3] ≡ Common office services includes capacious cleaning equipment storage rooms; work spaces include also a class room with computers and a printing room

[4] ≡ Shared spaces include a glass gallery, an auditorium, an education centre and a sauna bath department for entertaining; other spaces include main frame computer rooms, storage rooms and a kitchen

[5] ≡ Shared spaces include an auditorium and a sauna bath department for entertaining; other spaces include a kitchen; common office service spaces include office rooms without natural lighting

– ≡ means no drawings available; Non-IB means reference buildings, which are not built according to the IB concept.

spaces was made case by case. Usually, the common office service space is in the same level of the building as the workspaces of those workers who use it.

The areas for the common office services and for other spaces are quite similar in both office building types. The share of the total room area of the building used for the work spaces and the shared spaces is different in the IBs than in the reference buildings.

##### 5.3.3.3 Lines of Business of the Occupant Companies

The standard industrial classification from the Statistics of Finland was used for the classification of lines of business of the companies located in the studied buildings. The percentages of the occurrences per building were calculated on the basis of the number of workers in each company (Lehto 1999c).

In the IBs the category of Technical and commercial services (including among others civil engineering, ADP, management, law and marketing, 35 per cent), and the category of Communication technology (post and telecommunication, 30 per cent) are dominant in the sample. The categories of Public administration and national defence (15 per cent), and Education and research (13 per cent) follow these.

In the other offices two categories of the businesses were dominant: Energy and water supply (22 per cent), and as in the IBs, Technical and commercial services (22 per cent). They were followed by Public administration and national defence (17 per cent) similarly to the IBs and by Health and social services (11 per cent), Financing and insurance (9 per cent), and Recreation and culture services (9 per cent). The diversity of the lines of businesses is wider in the case of the companies located in the other office buildings (Lehto 1999c).

It can be concluded that the businesses in all buildings are either from the service sector or from lines of knowledge work or that of knowledge oriented work. Further, it can be concluded that both office building types share the importance of the category of Technical and commercial services. In the IBs the category of Communication technology is emphasised, while in the other offices the categories of Energy and water supply, and Health and social services, are emphasised.

The executives and the professionals working both in the intelligent and reference office buildings can be presumed to belong to the group of workers with knowledge work. As mentioned, there were more executives in the IBs than in the reference buildings.

**It can be concluded that the sample of the IB office workers resembles the work force of the information sector (ICT-workers) more than that of the reference buildings, although several different fields of businesses are presented also among the IB office workers.**

According to the Office Tenant Survey of the BOMA and the ULI a higher proportion of tenants in insurance, high-tech businesses, and government are located in office buildings with intelligent building features (Anon. 1999, p. 44). The groups that have the lowest proportion of tenants in such buildings are retailers, medical services, legal services, consulting firms, and accounting firms. This seems to be quite true also in the IBs of the IBs Survey. However, a insurance company appeared in a reference building of this sample, and there were no medical services, but companies of the pharmaceutical industry were present in the IBs.

Intelligent building features are much more prevalent in owner-occupied buildings (Anon. 1999, p. 50) in North America. This factor has not been studied in Finland. In any case, the IBs of the IBs Survey were representing both concepts of ownership; that of owners and that of lessees quite equally. It has been suggested by the Office Tenant Survey of the BOMA and the ULI that building owners and managers need to be careful before retrofitting their buildings with any intelligent building feature to make sure their tenants really want or need it (Anon. 1999, p. 49). In the owner-occupied building this can be done more easily than in lessees-occupied real estate projects, when the tenants will be known relatively late. In Finland, however, it has been the tendency to provide the building with technology which allows the possibility of providing intelligent features according to needs of the occupants.

A far greater number of the largest tenants (in terms of numbers of employees and square footage of office space) are located in buildings with intelligent features (Anon. 1999, p. 49) in the North America. This seems to not to be true within the companies located in the IBs of the IBs Survey, although the IBs are relatively large and occupied by larger number of people than the other types of high quality office buildings. Among the buildings of the IBs Survey was, for example, a business park with many spin off companies and a business hotel with several small companies.

### 5.3.4 Composition of the questions

The questionnaire was based on ideas taken from some of the documented empirical office studies and books about post-occupancy evaluation carried out before 1992, when the final empiristic arrangement was set up (Kell 1989, Orr 1989, Atkin 1987, Mill et al. 1987, Duffy 1983, Brill 1985, Vilkki et al. 1987, Lindholm et al. 1987, Preiser et al. 1987, Junnila 1988, Anttila 1992).

The IBs Survey project group and experts mentioned below lent their expertise to the composition of the questionnaire (Figure 10.). Questions from the several different disciplines were originated with the help of Professor Liisa Halonen at Helsinki University of Technology for illumination, Dr. Veli Himanen and Ms. Tuuli Järvi-Nykänen (MSc. in Engineering) at VTT Urban Planning and Transport, Mr. Markku Norvasuo (MSc. in Engineering and Architecture) at VTT Building Technology on the image of the building, Ms. Ulla Tuononen (MSc. in Architecture) at Rakennushallitus (current Senate Properties) in interior design, Professor Kari Lindström and Mr. Vesa Viljanen (M.Sc. in Physics) both at Finnish Institute of Occupation Health for the voice environment, Mr. Finn Eriksson (MSc. in Interior Architecture) and Mr. Tomi Salonen (MSc. in Political Science) both at Tandem-konsultit Oy in the occupant psychology.

The questions were measuring the physical working environment with the EWE. It simply meant that every question was asking how the office worker find the influence of the device, space, surface, etc. on her or his working efficiency.

The ideas of the systems thinking (Section 4.2), and quality engineering (Section 4.3.5.9) were followed during the work on the creation of the questionnaire. This meant that the focus was in all influencing factors of the phenomenon not that much in the scale, etc. Also, the general ideas of the substances of intelligent building phenomenon were kept in mind (Sections 2.1 and 2.6).

In addition to the system analyses, the second starting point for the composition of the IBs Survey questionnaire, that is, the quality engineering, looks at the total quality of a building as a summary of the quality of the subsystems or building properties, which either alone or together influence the building quality in total. That is why the questions not only asked if the evaluator considered the quality of each property of the building as good or bad or something in between, but the evaluators were also asked to pick from among the alternative factors those, which in their opinion either did or did not influence the total work environment quality.

### 5.3.5 The Subjects

The main topics of the questionnaire were: moving, premises and the image of the building, availability of amenities, technical services and equipment, spaces (worker's personal workplace and shared spaces, including interior design and furniture), working hours spent in the various office spaces, indoor air, illumination, voice environment, clothing, health symptoms, housing, commuting and business trips, job description and education (including salary), and other socio-economic and demographic factors.

Sets of questions will be described in the following sections, but for example the parameters for such subjects as Integration (Section 7.1.2.8), Illumination (Section 8.2.7.2), Nature of Work (Sections 8.2.7.8, and 8.2.7.10), Environment for Knowledge Work (Section 8.2.7.4), Voice Environment (Section 8.2.7.3), and Demographics and Socio-economic Factors (Section 8.2.7.12) have been dealt only in other parts of this thesis, as notified in the parentheses.

In this thesis, the analysis of the features of the office buildings (Section 7.1.1.3) is based on the expert analysis of the buildings (Section 5.3.3.2), which was done during the IBs Survey. However, the questionnaire of the second phase of the IBs Survey included also questions about building features and their usefulness. The need of such parameters as assembly floor, glass roofed space, children's corner, adjustable walls, multifunctional spaces, automatic doors, video-conference room, smart cards, video monitoring, meeting room reservation service on a personal computer, etc. The need and quality of these features remains unanalysed.

#### 5.3.5.1 Spaces – Office and Building Automation – ICT

The questions about the spaces, about office and building automation and about the ICT form the backbone of the IBs Survey and also of this study. The parameters of the end-user evaluations of the spaces and equipment are shown in Table 6 (Section 5.3.6). How much various spaces and apparatus are used was studied. The presence of each worker in various spaces during the working day and the time spent on using certain apparatus was asked in addition to the end-user evaluation of building properties' influence on the working efficiency of the office worker. The operational aspects of the workspace, apparatus and furniture, and some questions on the organisation of work, were included in the questionnaire in order to be able to reflect the importance of the relationship between a physical environment and organisational activities (Section 5.3.5).

The end-user evaluations of all shared spaces were included in the study, as well as evaluations of the different properties of the worker's personal workplace and of the furniture (cf. Section 5.3.5.11). Also additional questions on the possibilities to influence one's work environment (cf. Section 5.3.5.7), participation in the design and satisfaction with it (Section 7.1.3.9), semiotics (Section 8.2.7.5), and a question on occupational psychology (Section 7.1.4.4) were included.

The attitudes towards the use of technology (and computer-aided services) and the ways of learning to use new equipment, as well as the need for advice and support were studied. Also, the office workers opinion on the popularity of various technical services as opposed by human aid instead was asked.

In the section on automation in the questionnaire were included such parameters as: 1) how to learn to use equipment, 2) the amount of hours spent in using a computer, 3) the frequency of teleconference participation, 4) difficulties in the use of ICT devices and the means of recovery from false operations, 5) the end-user evaluation of office automation and interoffice services (facilities management services), 6) additional services (building amenities), 7) intelligent building features, and 8) special devices in the office building, 9) the popularity (attitude towards) of the manual vs. ICT aided services, and finally 10) some claims about effects of the ICT on office work performance.

The possibility of influencing one's work environment has been claimed to be one of the most important factors of the workspace design. It has been considered to be more important than any other of workspace property. A second one can be the feeling that things are taken care of, with some changes, repair, etc. The first one could be included in the IBs Survey, the second one not.

#### 5.3.5.2 Indoor Air Quality

The questions on the indoor air were taken from previous studies (cf. Vilkki et al. 1987, Lindholm et al. 1987) for referring purposes. Questions on indoor air control possibilities, as well as those on the quality of cleaning were included into the question set.

#### 5.3.5.3 Clothing Physiology

Questions of clothing physiology were included in the IBs Survey, because of the importance of the subject to the office work environment (Sections 2.4.7, and 2.4.7.2) and because of the possibility to understand the possible failures of the indoor air quality caused by clothing. The importance of the gender in the indoor air quality research was a reason for including clothing into the questionnaire.

#### 5.3.5.4 The Correlation of the Work-Related Trips and the Use of ICT

Work-related trips were included in the study, because it was presumed that by means of ICT, business trips could be substituted or mitigated. Thus, the questions about the work-related trips were accompanied with questions about the use of ICT, and their relationship was studied. Also, data on commuting and the possibility of teleworking was gathered (Section 8.2.7.10).

#### 5.3.5.5 Image of the Building

The building can through its architecture and materials reflect various values such as advanced progressive development, keeping up with traditions, trustworthiness, user-friendliness and so on. In the image of the building were also included the attractiveness of the building and its accessibility, as well as interoffice signs and orientation. In the questionnaire, there was a question about the image of the building which asked, whether the details of the building reflect the business idea of the company or the values of the respondent, or the atmosphere of the organisation.

#### 5.3.5.6 Interaction and Communication

The questions on interaction and communication were included under various topics of the questionnaire: 1) in the image of the building (the interaction between companies), 2) in the office and building automation, 3) in work-related trips, and 4) in personal workplace. The purpose was to find out if the various spatial arrangements influence the possibilities for interaction and communication, and how or if the ICT tools can help in communication and in concentration in one's work in the IB environment.

#### 5.3.5.7 Personal Control

Such subjects of the IBs Survey as personal control over illumination, indoor air and office equipment, spatial flexibility, and participation in the design of the workspace are factors with which the workers can influence their work environment.

Questions on the possibilities to influence one's work environment were asked in different connections. In addition to the spatial flexibility, questions about the possibilities for controlling the environment with the help of building automation and ICT were in focus among questions about illumination and indoor climate (cf. Section 5.4.3).

The earlier mentioned claims about the effects of the ICT on the office work included questions about the usability of the new technology in the office, as well as questions about interaction and communication mentioned in the previous section (Section 5.3.5.2). They included also questions which concern the office work effectiveness (8.1.4.5).

#### 5.3.5.8 Spatial Flexibility

While flexibility was a striking key word of the IB concepts, a section of the questionnaire was about moving from building to another and interoffice moving. In several other connections, the possibilities to move furniture, apparatus and to switch office space area were studied. Also, a question on the possibilities to move inside one's personal workplace was included, because modern ergonomics encourages changing working positions during the day. The parameters of that question are shown from Table 57. to Table 60.

#### 5.3.5.9 Need for Building Amenities

The need for additional services in the office building was a design criterion for the Finnish intelligent offices (Section 4.3.3.1, cf. also Section 2.4.9.4), and questions concerning these services were included in the questionnaire. The question concerning additional services and building amenities consists of following primary parameters: secretarial services, conference spaces and services, reception, travel office, information service, building management, ICT management and support, and shared services of several companies located in the same building. The secondary ones were: food and drink vending machine, cash dispenser (ATM), kiosk or grocery, child-care facility, health care services, hairdresser or barber, nature cure or healing, car wash and car service station. These parameters are similar to those of the Office Tenant Survey of the BOMA and the ULI (Anon. 1999, p. 83).

#### 5.3.5.10 Participation in Design

The possibilities for participation in the design and satisfaction with the new design were, in the first place, asked in order to learn more about the need for interaction between designers and occupants. However, it turned out to be important to use this parameter also in the connection of the possibilities in influencing one's work environment (Section 7.1.3.9).

#### 5.3.5.11 Occupational and Environmental Psychology

Occupational psychology was among the interests of the IBs Survey researchers, but only few questions about work satisfaction and attitudes had been included, and additionally the office workers were asked to draw the layout of their personal workplace. Thorough analyses of these have still to be undertaken. The drawings of the workspace were asked for in order to verify the furniture layout, some factors of the illumination, and the orientation of the workspace according to cardinal points.

The aim for including questions on occupational psychology was to be able to separate the emotional reactions from those opinions, which were more based on the respondents' reasoned judgement of the effect of the building qualities on work performance.

The use of environmental psychology could serve best of all psychological approaches in the search for the quality of building properties. The Finnish expertise for that was not available when the questionnaire was under preparation. Farshchi and Fisher claim that no unified theory of environment and behaviour has as yet been formulated (Farshchi and Fisher in Clements-Croome 2000, p. 60). Thus a comparison between the two office building types could have been possible, but not a comparison against results from other studies.

### 5.3.6 The Analysis

The results of the questionnaire were analysed statistically from the beginning of the first phase of the IBs Survey (Lehto 1996c, Lehto 1997a, Lehto 1999e, Lehto 1999f, Lehto & Himanen 2002b, Lehto & Karjalainen 1997, Lehto 1998d, Lehto 1999c, Lehto 2000c), and also the possibility to use neural networks for the analysis was tested (cf. Section 8.1.1).

In the questionnaire there are two types of questions, which needed a statistical analysis. Firstly, there are questions, to which the respondents have answered by giving the grade of their evaluation of building properties' influence on the working efficiency of the office worker. They have answered by giving the number of an index from 4 to 10 (with 10 as the best). This index was selected, because it has been used in the Finnish primary schools and it is therefore familiar to all, which makes the answering faster (cf. Section 5.3.7). To the questions about indoor air indexes from 1 to 5 and from 1 to 7 were used, as they have been used in other indoor air studies. Secondly, there were questions, to which the respondents picked one or more of the given alternatives. The numbers and percentages of answers fallen to different categories have been calculated.

The SPSS-program has been used for statistical analyses. The percentages and the mean grades of the marks (from 4 to 10 [with 10 as the best] or from 1 to 5) given to the building qualities have been calculated. The analysis of variance (F-test) has been used for comparison of the mean values and for testing the difference of each pair of the end-user evaluations. In some cases, the use of the Tukey test has been necessary, if the comparison has included more than two values. Because the IBs Survey is a case study and no wide scale generalisations have been made, no calculations of relative standard error have been done.

In the first place the analysis was based on the results of the first phase of the IBs Survey. After that, the result of the second phase was analysed similarly. Several differences between the two office building types were found. Some differences showed statistically significant difference. Many of those results have been reported in earlier documents on the IBs Survey (Lehto et al. 1997, Lehto 1996c, Lehto 1997a, Lehto 1999e, Lehto 1999f, Lehto & Himanen 2002b, Lehto & Karjalainen 1997, Lehto 1998d, Lehto 1999c, Lehto 2000c) and they are shortly referred also in this thesis (8.1.4).

Some of their results have been referred to in chapter 8 of this thesis, where they are relevant to the results of this study (Section 8.1.4). This thesis is based on the detailed analysis of such variables which have turned out to measure significant differences either between the two office building types, or between the evaluations of the various worker groups and genders.

The final study of the differences between the buildings was done on the basis of all summarised statistics from all evaluative questions of both phases on spaces and equipment (Table 6.). The systematic comparison of the result of the IBs Survey to the other post-occupancy studies have failed either because of the different timing of the data gathering or the difference in the data gathering method, i.e. most often in the set of questions used to ask for the end-user opinion. However, it has been possible to compare the results of some details to the results which have been found from the literature of comparable studies.

### 5.3.7 Trust in the End-user Opinion

Because of some doubts about the validity of the end-user opinion as a study method, some tests were made. The comparison between the measured indoor air quality and the result of indoor air quality evaluation by the interview with the questionnaire was made. It showed that with both methods similar results were gained.

*Table 6. The parameters of equipment and spaces of the questionnaire of the IBs Survey, which were used for the final test of the use of the IB concept.*

| EQUIPMENT $x_1 \ldots x_{20}$ | WORKSPACES $x_{21} \ldots x_{40}$ | SHARED SPACES $x_{41} \ldots x_{53}$ |
|---|---|---|
| A telephone | Adjustment of furniture | Car parking, a garage |
| A mobile phone | Adjusting furniture | Staircase and corridor |
| Multifunctional telephone exchange | Change of computer position | Lobby |
| An answering machine | Change of cabinet volume | Show-rooms |
| Email | Room temperature and air-conditioning control | Meeting rooms |
| Paging | Control of illumination | Dining room |
| E-banking | Change of working position (standing, etc.) | Auditorium and class rooms |
| Security (locking, alarms, etc.) | Rearrangement of furniture | Spaces for temporary group work |
| Access control | To see outdoors (to different scenery) | Rest areas (spaces for breaks) |
| Work time monitoring | Lock oneself in privacy | Hobby halls |
| A personal computer | To form a temporary group working area | Library and a reading room |
| A portable computer | Functionality | Sport and fitness halls |
| A dictation machine | Comfort or amenity | Rest rooms |
| A printer on your desk | Change of the room size | |
| A shared printer | Possibility to move the location of doors | |
| A colour printer | Durability of the materials and furniture | |
| Video, digital camera, other image processing | Creation of needed visual or oral contact | |
| A shared telefax | Beauty | |
| A telefax service via your computer | Relaxing and moving around | |
| A telefax on your desk | Representativeness | |

Examples can clarify the various situations. In a building, where the indoor air temperature was too high the end-user evaluation result also revealed the fact. Also, in a building where the odour panel found the indoor air smelling of tobacco smoke, the problem had come out during the start-up inspection. Further, for instance, in one building the users had complained of the bad indoor air, because there were grey spots in the ceiling near by the air inlets, which were caused by the incoming fresh air. However, the indoor air measurements proved the indoor air quality good, and so did the end-user evaluation based on the questionnaire.

There are cases where too much important information remains undiscovered when information is gathered by interviews (cf. Davis in Clements-Croome 2000, pp. 240–241). Nevertheless, despite of the doubts about the end-user opinion as a measuring method, it proved its workability during the IBs Survey.

The target of the IBs Survey was mainly to sketch an overall view of the feasibility of the IBs. This type of general target setting is not as demanding as for instance a post-occupancy study for a particular building project.

The doubts of the end-user surveys have been based on the concept of superior expert knowledge over the ignorance of the end-user, who however has expert knowledge on the use of the product, if not on its design and R&D. Secondly, doubts have been based on the claim that the end-user cannot imagine new situations and judge them. This seems a universal problem, because several technical innovations have never reached a wide range of users. There may be many reasons for this, among which can also be the inability of the designer to imagine the future customer needs of the product.

A third problem is that the end-users do not act in accordance with the answers they give during interviews. It can be asked, if they really have the chance to do so afterwards, because technology has changed accordingly, and the design has not been implemented as such without any modification before implementation.

Because the end-user evaluation index in the questionnaire was the same, which is in use in Finnish primary schools for the school grades, there was doubt that the women might evaluate everything in general with better grades, because girls usually get good marks at school, better than boys do. It cannot be said if this effect is at work or not, but the results show in several cases that women are more critical than men.

## 5.4 Additional Indicators

Documents of the building data of the additional indicators (drawings and specifications, construction costs, energy consumption) were gathered from the designers and building owners (Lehto & Karjalainen 1997, Pulakka in Lehto et al. 1997, p. 226).

### 5.4.1 Energy Efficiency

The building managers were asked to provide the researchers with the energy consumption figures, which they obtained from the building automation reporting. The reports contained information about the total energy consumption and the shares of the electricity and heating energy consumption. The reference energy consumption was taken from the statistics.

### 5.4.2 Building Economy

The economy of the buildings under study was looked at carefully during the IBs Survey (Pulakka in Lehto et al. 1997, pp. 226–248, cf. also Section 5.3). The analysis of the cost effectiveness was carried out for various intelligent building features (cf. Sections 5.3.3.2, and 7.1.1.3), and also the influence of the end-user evaluation was taken into account in the economical analysis.

The economic study measured the building quality with monetary examination of the end-user evaluations. It took into account the building costs and benefits out of the quality standard, which is concerned. A study was made on the expected estimations of output from the IB features, such as [1)] the existence of the restaurant and exhibition space in the same building as workspace and meeting rooms, [2)] the investment on the glass roofed lobby and its probable effect on work productivity of the office workers, [3)] the cost benefit ratio of a video-conference room, or [4)] that of the indoor air quality, etc. Only some of the results of the economical analyses of the buildings are included in and discussed in this thesis.

### 5.4.3 Indoor Air Measurements

Indoor Air measurements were carried out in four buildings using two methods: IAQ Audit and using the odour panel (Lehto 1996c, Lehto & Karjalainen 1997, Kovanen in Lehto et al. 1997, pp. 192, 194, 196, and 202). The IAQ-Audit method is elaborated in the EU JOULE II -project and was carried out in eleven European countries in 1992–1994. The indoor air rate and temperatures, pollution (TVOC, CO2) and particles were measured.

In this thesis the focus is on the results of the questionnaire study. Indoor air measurements by IAQ Audit or by the odour panel are dealt with only as far as it is necessary for understanding, whether the results of the interview are convincing or not.

### 5.4.4 Business Travelling and Commuting

The number of business trips, their destinations, the mode of travel, the nature of the trips and the need and the willingness to travel was included in the questions of the questionnaire. Also questions about commuting were included. The length of the work trip, its mode of travel and the reason for using a certain mode were included.

## 5.5 The Factors of Intelligent Building Concepts

The factors of the IB concepts and their descriptions have been listed in section 2.1.6 and in Table 7. These factors of the IB concepts can be described as (Equation 5.):

$$IB_{concepts} = f\,(z_1 \ldots z_n)$$

where n is 23 according to the inventory of the IB concepts based on the inventory of this study.

There is no scientific definition available for the factors of the IB concepts. They are keywords, which describe common knowledge about intelligent building. The IBs Survey included, at least to some extent, the following factors the IB concepts in the questionnaire: end-user need orientation, level of integration, space flexibility and utilisation, movable space elements and equipment, comfort, convenience, working efficiency, image of high technology, and information intensity, interaction, service-orientation, ability of promoting health (therapeutic), and adaptability.

*Table 7. The building capabilities according to the factors of the IB concepts.*

| | | | |
|---|---|---|---|
| $z_1$ | End-user need orientation | $z_{13}$ | Construction process and structure |
| $z_2$ | Level of integration | $z_{14}$ | Long term flexibility |
| $z_3$ | Environmental friendliness | $z_{15}$ | Marketability |
| $z_4$ | Space flexibility and utilisation | $z_{16}$ | Information intensity |
| $z_5$ | Movable space elements and equipment | $z_{17}$ | Interaction |
| $z_6$ | Life cycle costing | $z_{18}$ | Service-orientation |
| $z_7$ | Comfort | $z_{19}$ | Ability of promoting health (therapeutic) |
| $z_8$ | Convenience | $z_{20}$ | Adaptability |
| $z_9$ | Safety and security | $z_{21}$ | Reliability (stabile sand accurate) |
| $z_{10}$ | Working efficiency | $z_{22}$ | Productivity (profitability) |
| $z_{11}$ | Image of high technology | $z_{23}$ | Correctness of basic technical solutions |
| $z_{12}$ | Culture | | |

In the case of the questionnaire of the IBs Survey project the Equation 5. receives the form:

$$\textit{Equation 11. } BQ_{\textit{IBs of the IBs Survey Questionnaire}} = f\,(z_1, z_2, z_4, z_5, z_7, z_8, z_{10}, z_{11}, z_{16}, z_{17}, z_{18}, z_{19}, z_{20})$$

where n is 13.

The economical study included factors about life cycle costing ($z_6$) and marketability ($z_{15}$). The additional indicators (energy efficiency and savings in travelling costs) included in the category of productivity (profitability) ($z_{22}$).

In the case of the IBs Survey project in all the Equation 5. receives the form:

$$\textit{Equation 12. } BQ_{\textit{IBs of the IBs Survey}} = f\,(z_1, z_2, z_4, z_5, z_6, z_7, z_8, z_{10}, z_{11}, z_{15}, z_{16}, z_{17}, z_{18}, z_{19}, z_{20}, z_{22})$$

where n is 16.

The following factors were not included in the IBs Survey: environmental friendliness ($z_3$), safety and security ($z_9$), culture ($z_{12}$), construction process and structure ($z_{13}$), long term flexibility ($z_{14}$), reliability (stabile sand accurate) ($z_{21}$), and correctness of basic technical solutions ($z_{23}$). The focus of the IBs Survey was in end-user study. Many of these factors which are not included in are not end-user related. Safety and security were left out, because in the beginning of the 1990's they were not considered very important in Finland, but the situation changed rapidly that after. Especially in some office building, where the service spaces are located the personnel was afraid of violent customers.

The correspondence of the factors of the IB concepts and those of the IBs Survey is shown in Table 8. The end-user need orientation and working efficiency are factors of the IB concepts which were included into the IBs Survey through the information gathering method, which was done among the end-users and where they were asked to judge the quality of the building or building subsystems for their working efficiency.

The socio-economic data has also a relation to the end-user orientation. Service-orientation is a factor of the IB concepts which is included among the factors of the FM of the IBs Survey. Service orientation is related also to personal control.

*Table 8. The correspondence of the parameters of the intelligent building concepts from the literature of intelligent buildings and those studied in the IBs Survey.*

| | PARAMETERS OF THE IB CONCEPTS FROM LITERATURE | PARAMETERS OF THE IB CONCEPT STUDIED IN THE IBS SURVEY |
|---|---|---|
| $z_1$ | End-user need orientation | End-user need orientation |
| $z_2$ | Level of integration | System integration |
| $z_4$ | Space flexibility and utilisation[1] | Spatial flexibility |
| $z_5$ | Movable space elements and equipment | Moving |
| $z_7$ | Comfort | Indoor air quality |
| $z_8$ | Convenience | Concentration on work<br>(Work satisfaction) |
| $z_{10}$ | Working efficiency | Working efficiency<br>Paperless office, Flexi-work |
| $z_{11}$ | Image of high technology | Image of the building (values and types of buildings), Space selection criteria |
| $z_{16}$ | Information intensity | Control and regulation (HVAC)<br>Office automation |
| $z_{17}$ | Interaction | Among occupant companies, Communication, Awareness of the use of ICT, Participation in design |
| $z_{18}$ | Service-orientation | Building amenities<br>User interface (man or machine) |
| $z_{19}$ | Ability of promoting health (therapeutic) | Health symptoms |
| $z_{20}$ | Adaptability | Adaptability (Adjustable) |

[1] ≡ Included also in the parameters of the questionnaire, such as occupancy and room size.

# 6. Method

The author has found the IB concept definitions and descriptions and the essence of the intelligence as interesting research subjects. Human intelligence and the possibilities of man-made items or other inorganic entities to be able to use intelligence has kept the author occupied. Studies on these subjects have been based on theoretical literature, participation in scientific seminars on futures sciences and artificial intelligence.

However, it was a challenging task to compose the questionnaire for the post-occupancy survey on the behalf of the IB concepts without any scientific definitions and related subjects. This difficulty was repeated in the analysis of the results of the IBs Survey, which made the author rethink the essence of the building intelligence. The intuitive hypotheses on the building intelligence were confirmed by the theoretical knowledge of the literature of intelligence, and by the search for presumable answers for the inexplicable results of the IBs Survey.

The interest in human intelligence has brought with it also an interest in the author's own behaviour, as well as that of the groups of people who share this interest in human mental abilities. The consequence of this has been the interest in not only the intelligence of workspace but also in the sense of workplace within the social space paradigm.

## 6.1 Composition of the Building Intelligence Framework

The problem setting of the IBs Survey included the uncertainties of the definitions in the IB concept (Section 4.2). During the analysis of the IBs Survey it became clear that clarification of the intelligent building concept was needed also in some cases for explaining the results of the IBs Survey, which at first seemed partially inconsistent. A simple scientific method of searching the existing literature for the possible reasoning for the results – a part of which is already introduced in chapter 4 – and embedding new findings into the old paradigms was used to clarify the IB concept by drawing conclusion from the results found in the literature and the empirical evidence from the IBs Survey.

The understanding of the difference between building intelligence and the intelligent building concepts was the key to the clear definition of the building intelligence derided from the definitions of human intelligence.

The next step after this study of conclusions from the empirical post-occupancy study and previous literature could be to find out more and discuss further the definition of building intelligence (the BI) and the BIF or the content of IB concepts, or to try to identify buildings according to the BIF by empirical survey. It could be done in accordance with the IBs Survey, which measured the buildings with feasibility. Also, the IBI defined by So could be feasible and worth using in further research. With BIF it could be possible to measure intelligent buildings more accurately by performance of intelligence.

## 6.2 Measurements of Intelligent Buildings and Intelligent Building Features

The presumed benefits of the IB construction were: good building profitability or successful real estate and building management business, occupant productivity or end-user empowerment, energy efficiency, savings in travel costs of the occupants, and sustainability, i.e. both environmental friendliness and human social and mental welfare (Figure 24., cf. also Figure 43.). The benefits are a consequence of the total building quality. The building quality consist of the building properties' quality. The measures or indicators for the building quality are the selection of the building properties or components. The benefits are measurements for building properties such as the rate of the indoor air quality, the quality of architecture and interior design (new floor plans, flexibility, active structures, new materials, colour sets supporting information intensive work, etc.), that of acoustics or illumination, etc.

In this thesis, the existence of the IB features in the studied office buildings has been examined (Figure 25.). As a measurement tool for the building quality is used the EWE, which is got from the questions of the questionnaire asking the respondent to evaluate the device, space, structure or any building property on the behalf of its influence on the working efficiency. The variables of studied building components are the 417 parameters of the questionnaire of the post-occupancy study. **From now on, in this report of the end-user evaluation of**

**building properties' influence on the working efficiency of the office worker will be used only the term the end-user evaluation or the acronym of EWE.**

Because the effect of the building properties and the IB features was measured by their influence on the work performance the IBs Survey is a reflection of the building quality, which influences the occupant productivity or end-user empowerment. In some cases only the existence of this benefit has been studied. In other cases the end-user evaluation is given with a scale. The level of the end-user evaluation of a building property might indicate the level of the benefit. The primary aim of the study is in finding a set of properties defined by an index, which have influence on the benefit. The nature of this case study allows no more detailed or quantitative analyses, although some results seem very relevant when they are compared to the results found in the literature.

The comparison of the building properties of the two types of buildings, will prove if such a building concept as an intelligent building does exist (second hypothesis, cf. Section 3.2). Furthermore, it will prove, which properties will have effect on the building quality difference between the two building types. Finally, the difference will prove the power of the IB concept in creation of a profitable work environment for the occupant. In other words, this difference will prove the efficacy of the intelligent buildings (cf. Figure 21.).

The other benefits of the use of IB concepts, besides occupant productivity or end-user empowerment, have been studied as additional indicators for the aim of this study – for the proof of the difference between intelligent and other office buildings. They have been energy efficiency and savings in travel costs of the occupant companies. The indoor air measurements have had also the status of an additional indicators within this study. Such benefits as good building profitability or successful real estate business and sustainability have not been included in this study.

The most common IB features from the IB concepts (Sections 2.1, 2.6, and 4.2) and the IB building features of the already built buildings (Section 5.3.3.2) were used as the basis for composition of the questionnaire (Section 5.3.4), in other words, as the basis of the end-user evaluation (efficacy) of the building quality (effectiveness). The additional indicators either do or do not confirm the efficacy of the intelligent buildings.

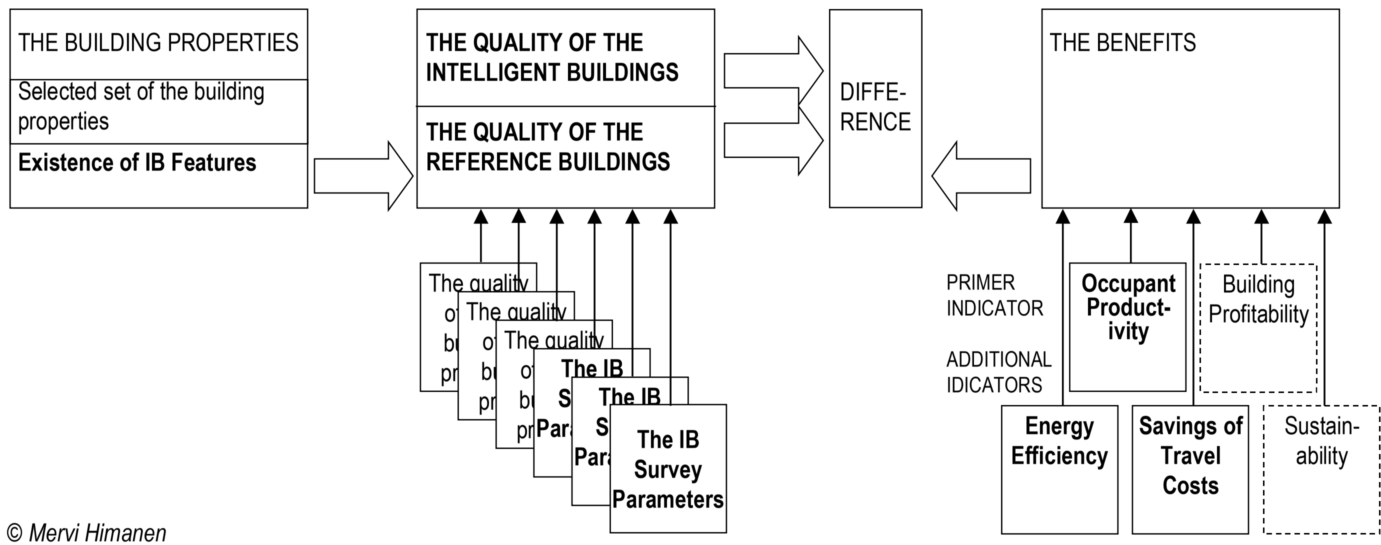



*Figure 24. From building properties to benefits of the buildings.*

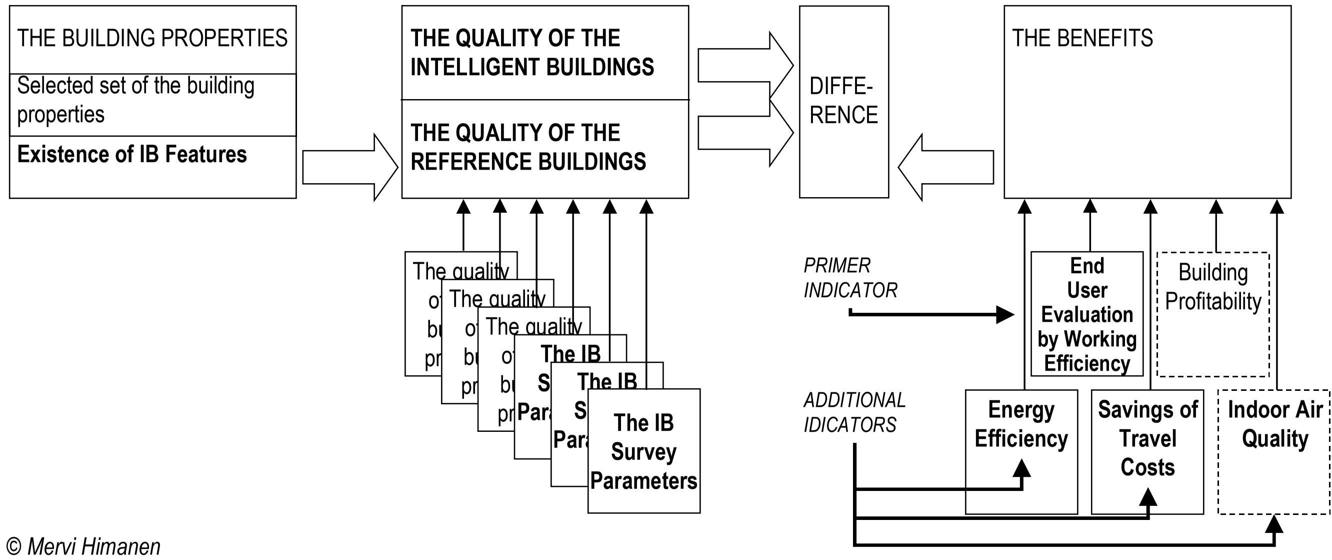



*Figure 25.To the proof of existence of the IB concept from the IB features of the IBs Survey.*

**As notified in the Introduction, on the behalf of this thesis the IBs Survey serves as material for this study.** The IBs Survey was one of the first tries to indicate intelligent building features' power in construction and in occupants' productivity (Figure 26.). Due to the uncertainties and the amount of tacit knowledge in the beginning of (cf. Section 4.2) and during the work process of the IBs Survey (cf. Section 5.2), it is rather a feasibility study by nature than a systematic study on building performance, although it can identify to some extent the building performance by the effectiveness of the end-user evaluation of the building features, which is the efficacy of the IB features.

## 6.3 Existence of Intelligent Building Concept

The IBs Survey was based both on the knowledge of the IB concepts and descriptions, which were relevant in the beginning of the 1990's, and on the knowledge of the relevant factors of the office design of the 1990's. They both have been described in chapter 2. The summary of the factors of the IB concepts is in section 2.1.6. Equation 5. defines the factors of the IB concepts, which were general knowledge during the IBs Survey. However, all of them have not been part of the IBs Survey (Section 5.5).

It can be claimed that the attestation of the hypothesis 2. by the IBs Survey is not complete, since all factors of the IB concepts are not a part of its basis. On the other hand, the IB concepts are not accurate definitions of the IBs. Furthermore, the selection of the IBs for the IBs Survey was based on the use of the IB concept as a design criterion for them. The existence of a certain selection of IB features was not the basis for the choice. The IB concept has been applied differently for their design. The IBs Survey is a case study of twelve buildings, of which five are intelligent.

In these circumstances, the difference of the all end-user evaluations of spaces and equipment has pinpointed the primary evidence for the difference of the two office building types. The summary of all end-user evaluations includes both factors of the IB concepts and those of the office design of the 1990's in general (Table 6. cf. also Lehto 1999f). The end-user evaluations were made of the

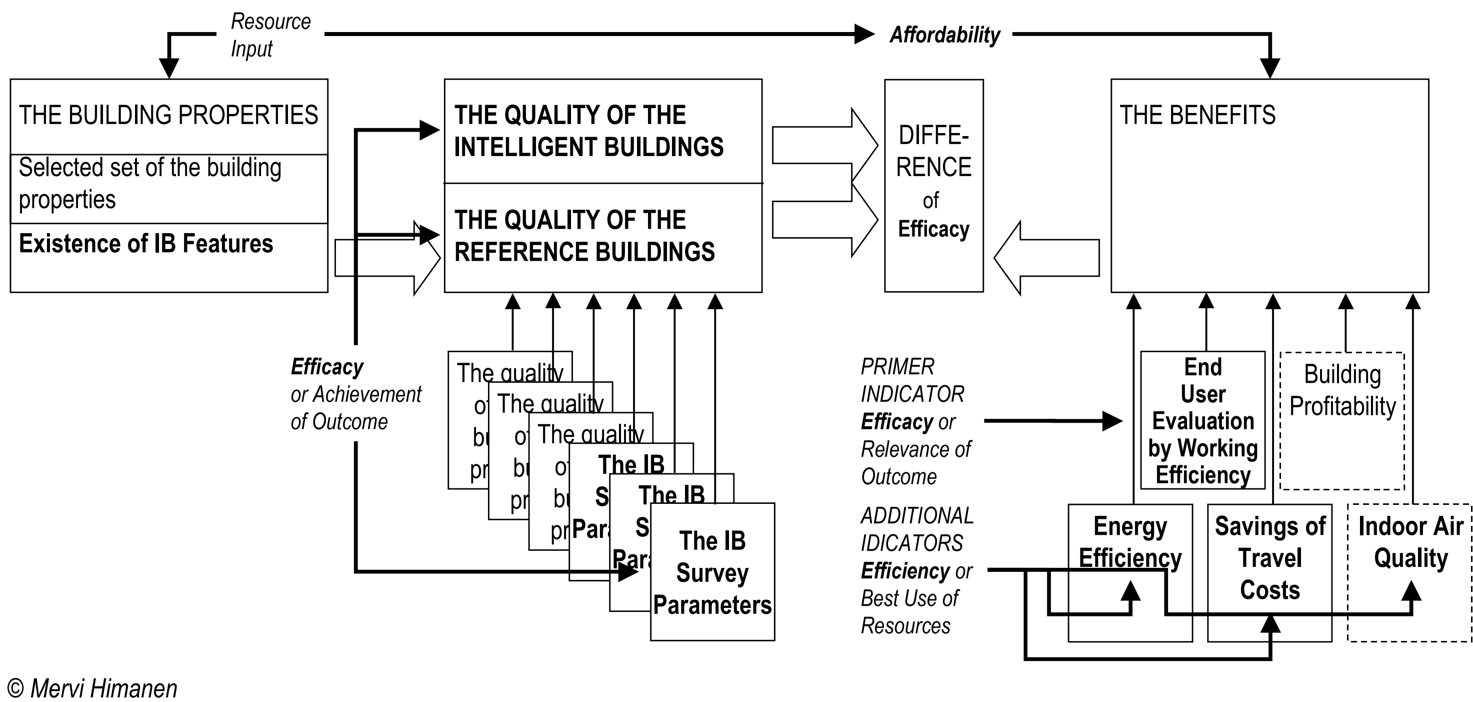



*Figure 26. The correspondence between the IBs Survey and the four E's.*

quality of equipment and spaces, which includes both shared spaces and the workspaces. There are end-user evaluations on building services and building amenities, but they have been left out from the final analysis so far (cf. Section 8.2.7).

The separation of the IBs from other office buildings will follow on the basis of the list of parameters shown in the Table 6. They were found to be the important parameters of building quality against the results of the preliminary analysis of the data of the second phase of the IBs Survey. The test of qualities of the two different building types (Section 7.1.1.1) was made according to the Equation 4.:

*Equation 13.* $BQ_{Difference} = f\,(x_1 \ldots x_{53})$

where $x_1 \ldots x_{53}$ can be found in the Table 6.

The Equation 4. can be written also as follows:

*Equation 14.* $BQ_{Difference} = (BQ_{EQUIPM}, BQ_{SPATIAL})$

where according to the Table 6.:

*Equation 15.* $BQ_{EQUIPM} = f\,(x_1 \ldots x_{20})$

and

*Equation 16.* $BQ_{SPATIAL} = f\,(x_{21} \ldots x_{53})$.

$BQ_{EQUIPM}$ is the quality of available equipment in the office building, $x_1 \ldots x_{20}$ are the parameters of quality of the equipment, and $BQ_{SPATIAL}$ is the spatial quality of the office building and $x_{21} \ldots x_{53}$ are the parameters of spatial quality.

These parameters of the IBs Survey are related to following factors of the IB concepts (Section 5.5): the level of integration ($z_2$), space flexibility and utilisation ($z_4$), movable space elements and equipment ($z_5$), the image of high technology ($z_{11}$), adaptability ($z_{20}$), information intensity ($z_{16}$), interaction ($z_{17}$), comfort ($z_7$), convenience ($z_8$), service-orientation ($z_{18}$), and the ability to promoting health (therapeutic) ($z_{19}$). Such factors of the IB concepts as end-user need orientation and working efficiency are included in the research approach of this study.

During the research of the evidence for the hypothesis 2. results which concern property and facilities management, were attained. They are the consequence of the use of the post-occupancy study as a study method. More over, the additional indicators, which are used to prove the hypothesis, are related to efficiency, effectiveness or efficacy. The results of the IBs Survey in all can be summarised by using the theory of the four e's as a criterion for the efficacy of the results (Figure 20.), which are the end-user evaluation of the outcome.

Although the post-occupancy study is not classified as an examination of a "value-of-money-audits" type, many factors used in monetary context are relevant or in actual fact valid in this context for grouping the results of the IBs Survey. When the quality of the building properties is measured by the end-user evaluation, the evaluation result is the relevance of the outcome of the building process (Figure 26. and cf. Figure 20.).

## 6.4 Interplay between the Building Intelligence Framework and the Intelligent Buildings Survey

The basic problem of the IBs Survey was the lack of an universal definition for the IB concept. This problem has been solved by the creation of the BIF during the scientific work of this doctor's thesis. The creation of the BIF is based both on the empirical results of the IBs Survey and the literature review, which is referred to chapter 4.

The BIF defines the building intelligence. The IB concepts define the intelligent buildings. The intelligent buildings are the outcome of the application of the intelligent building concepts. They are the implementation of the building intelligence into the building. As far as the building intelligence has been undefined this implementation of it has occurred only in the level of tacit knowledge. The intelligent building concepts have been left as they are. They serve their purpose in building intelligent buildings, although the intelligence itself has been tacit knowledge, which is not articulated in the IB concepts.

The BIF is used for the criterion of the relevance of the results of the IBs Survey. If the difference of the two office building types occurs in such factors, which are relevant for the BIF, the existence of the IB concept could be proved on the basis of the building intelligence. In this study the BIF has been used to double check the result of the existence of the use of IB concept in the buildings of the IBs Survey.

# 7. Results

On the whole, the two results of this thesis are based on the results gained from the use of several research methods. The theoretical search after the definition of the IB concept lead to the definition of the building intelligence. The results of this study are in the latter part of this chapter. It includes also the correlation between the BIF and the IB concepts (Section 7.4).

The questionnaire circulated among the office workers was a wide part of the Survey and that is why its results are in the focus of the IBs Survey. This post-occupancy study made with the questionnaire either promotes the use of the IB concepts in building or advises against it. The end-user feedback is used as the measurement of the qualities of the buildings (Sections 7.1 and 7.2). The results are also including facts of the measuring instrument (Section 7.1.4).

The preliminary analyses of the IBs Survey done before the study of this thesis and based mainly on the results of the second phase of the IBs Survey questionnaire, are reported in chapter 8 (Sections 8.1.4 and 8.2.7). They have been the criteria for selection of the topics for the deeper studies made for this thesis, which are based on the analyses of the data of both phases of the IBs Survey questionnaire and reported in this chapter 7 (Sections 7.1 and 7.2). The analyses are based on the IB features, which are taken from the literature of the descriptions of the IB concepts, and which have been summarised previously in this study (Sections 2.1.6 and 5.5). The analyses are based also on the office building features, which were common in the office buildings of the early 1990's and which have been described in chapter 2 (Sections from 2.3 to 2.6).

Additional indicators were used for fully understanding the use of the IB concepts. These additional indicators are either promoting the use of the IB concepts in building or advises against it. At the same time, the results of the additional indicators either prove or disprove the findings of the questionnaire.

After the results of the IBs Survey have proved or disproved the existence of the use of IB concept in the IBs, and the BIF has been introduced the correlation between the results of the IBs Survey and the BIF are presented (Section 7.3). Double checking the results of the feasibility of the IB features against the BIF is done.

## 7.1 The Existence of Intelligent Office Buildings

Tests of the difference of the two office building types, the intelligent and the reference office buildings, were made on the end-user evaluations of the various variables of the IBs Survey, which will be shown in the following sections (cf. Section 5.3.4). Test results of the differences between the two office building types are based either on the evaluation grade of the quality of a particular building feature or on variables indicating the percentages of the respondents of the whole sample, who like or dislike a certain building property (Section 7.1).

In order to find out, if and how certainly the whole building quality indicates the difference of the two office building types, a test on the grand total of all end-user evaluation variables indicating the quality of spaces and equipment was made (Section 7.1.1). The results of the preliminary studies done on the basis of the second phase of the IBs Survey (Section 8.1.4) have been used as a criterion for the selection of the interesting further analysis of the differences between two office building types based now on the end-user evaluations of the data from the whole sample of the questionnaire (Figure 22.). These tests form the basis of the studies of this doctors' thesis (Sections from 7.1.1.1 to 7.1.1.10.). All of the parameters of the IBs Survey have not been included in this analysis (cf. Section 5.3.5). The unfinished analyses have been listed in section 8.2.7.

The role of the factors of the IB concepts in the difference of the two office building types is studied (Section 7.1.2), as well as the role of the FM related factors (Section 7.1.3). The IB features of the examined buildings, and their size and age, as well as the status of the worker and gender of the occupants (evaluators) were taken into account in the analysis. The possibility to influence one's working environment turns out to have an important role in the end-user evaluations (Section 8.2.4), as well as the influence of the socio-economic of the respondents (Section 7.1.4).

The difference of the all end-user evaluations has selected the primary evidence for the difference of the two office building types. As secondary evidence for the existence of the IB concept the results of some other subjects of the IBs Survey have been used. After the results of the end-user evaluations are presented in section 7.1, the results of the additional indicators are presented in section 7.2.

It is worth while to continue to test with the summarised data the importance of each individual property of the buildings for the difference between the quality of the two office building types. Summarised evaluating variables of the spaces, structures and apparatus have been tested.

### 7.1.1 The Intelligent Office Building Properties

The aforementioned difference in all end-user evaluations has been selected as the primary evidence for the difference of the two office building types, which is the proof of the existence of the IB concept. The summary of all end-user evaluations includes both factors of the IB concepts and those of the office design of the 1990's in general such as factors of FM (Table 6. and cf. Lehto 1999f). The end-user evaluations are made of the quality of equipment and spaces, which includes both shared spaces and the personal workspaces.

#### 7.1.1.1 Spaces and Equipment

In the first place, the difference of the building quality between the IBs and the reference buildings was surveyed based on the results of the first phase of the post-occupancy study. The need for improvements in the study method was found, and a new version of the questionnaire was made.

The second study of the difference was based on the analyses of the data of the second phase of the IBs Survey (Table 9.). Several differing factors were found (Section 8.1.4, Lehto 1996c, Lehto 1997a, Lehto & Himanen 2002b, Lehto & Karjalainen 1997, Lehto 1998d, Lehto et al. 1997). Also statistically significant differences were found.

The final tests (so far) were made on the basis of the results of the whole sample (Equation 4.). The gathered information from both phases of data collection was used (Table 10., Lehto 1999e, Lehto 1999f, Lehto 2000c). The tests were based on summarising statistics of all evaluative questions (Table 6.). In some cases, the alternatives of the questions of the two phases were co-ordinated for the test.

The difference of the qualities of the IBs and the reference buildings is true according to statistical tests (F-test).

*Table 9. The mean grades of the end-user evaluation of the quality of the spaces and equipment according to the office building types.*

| *The sample of the second phase of the IBs Survey (n=356)* | All spaces[1] | Equipment[1] |
|---|---|---|
| IB *(n=193)* | 7.7 | 7.6 |
| Non-IB *(n=162)* | 7.2 | 7.5 |

[1] ≡ An index from 4 to 10 (the best); Non-IB means reference buildings, which are not built according to the IB concept.

*Table 10. The test (F-test) of mean grades of the end-user evaluation of the quality of spaces and equipment according to the office building types.*

| *Samples of 1. & 2. phases (n=534)* | All spaces[1,2] | Personal[1] workspace | Equipment[1,3] |
|---|---|---|---|
| IB | 7.8* *(n=303)* | 7.1 *(n=306)* | 7.9* *(n=286)* |
| Non-IB | 7.3* *(n=192)* | 7.1 *(n=177)* | 7.5* *(n=182)* |

* ≡ a statistically significant difference ($p < .05$); [1] ≡ An index from 4 to 10 (the best); [2)] ≡ p= .000000, [3)] ≡ p= .000121; Non-IB means reference buildings, which are not built according to the IB concept.

The IB concept exists according to the Equation 3., because $BQ_{IB} \neq BQ_{Non\text{-}IB}$. and the fact that $BQ_{IB} \neq BQ_{Non\text{-}IB}$, is based on the fact, that according to Equation 14.

*Equation 17.* $$(BQ_{EQUIPM} + BQ_{SPATIAL})_{IB} \neq (BQ_{EQUIPM} + BQ_{SPATIAL})_{Non\text{-}IB}$$

where the quality of the IBs, i.e. $BQ_{IB}$ is the summary of the spatial quality ($BQ_{SPATIAL}$) and the quality of equipment ($BQ_{EQUIPM}$) of the IBs, and the quality of the reference buildings, i.e. $BQ_{Non\text{-}IB}$ is the summary of the spatial quality ($BQ_{SPATIAL}$) and the quality of equipment ($BQ_{EQUIPM}$) of the reference buildings.

**The final test for proving the existence of the difference between of the two office building types showed a statistically significant difference between the**

**total qualities of spaces and equipment of the IBs and those of the reference buildings in terms of the workers' productivity, i.e. the working efficiency of the office workers. The efficacy of the IBs is better in comparison to that of the other types of high quality office buildings in terms of end-users' working efficiency.**

#### 7.1.1.2 Status of the Worker and Gender of the Respondent

**The status of the worker and gender have an effect on the end-user evaluation of the buildings** (Table 11. and Table 13.). Executives evaluate the spaces and equipment best. Men like the spaces better than women, and women prefer the equipment better than men.

The opinion of the professionals and of the clerical personnel on the spaces is quite similar. Executives share the good EWE of the equipment with the clerical personnel, while the professionals find the effect of the equipment on their working efficiency worse compared to all other worker groups.

The co-effect of the status of the worker and gender on the mean evaluations based on the summary of all parameters of the evaluative questions of spaces and equipment is shown in Table 12. Analyses of the background information is shown as well. The test of the influence of the background information has been carried out (Table 14.).

*Table 11. The test (F-test) of mean grades of the end-user evaluation of spaces' and equipment's quality according to the statuses of the workers.*

| *Samples of 1. & 2. phases, n=534 (smallest n for any variable 468)* | All spaces[1,2] | Personal[1] workspace | Equipment[1,3] |
|---|---|---|---|
| Executives | 7.8* *(n=89)* | 7.6* *(n=86)* | 7.9* *(n=85)* |
| Professionals | 7.5* *(n=226)* | 7.0[4] *(n=224)* | 7.6* *(n=209)* |
| Clerks | 7.4* *(n=103)* | 6.7[5] *(n=104)* | 7.8* *(n=98)* |

* ≡ a statistically significant difference ($p < .05$); [1] ≡ An index from 4 to 10 (the best); [2)] ≡ p= .002159, [3)] ≡ p= .025484; Turkey test: [4)] ≡ p= .000941, [5)] ≡ p= .000022.

*Table 12. The mean grades of the end-user evaluation of spaces' and equipment's quality and some background information according to the statuses of the workers and genders.*

| | | Executives | | | | Professionals | | | | Clerks | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Men | | Women | | Men | | Women | | Men | | Women | |
| *Samples of first and second phases of the IBs Survey (n=534)* | Mean | IB | Non-IB | IB | Non-IB | IB | Non-IB | IB | Non-IB | IB | Non-IB | IB | Non-IB |
| *n* | | *51-54* | *9-14* | *10-14* | *4-9* | *53-86* | *29-52* | *32-47* | *13-44* | *7-13* | *5-10* | *25-47* | *19-35* |
| All spaces $(4–10)^1$ *(n=447)* | 7.6 | 8.0 | 7.7 | 7.9 | 7.1 | 7.8 | 7.5 | 7.6 | 7.2 | 7.4 | 7.0 | 7.7 | 7.1 |
| Equipment $(4–10)^1$ *(n=419)* | 7.7 | 8.1 | 7.1 | **8.4** | 7.4 | 7.7 | 7.2 | 7.9 | 7.7 | **7.1** | 7.4 | 8.0 | 7.8 |
| Room size $(1–4)^2$ *(n=428)* | 2.7 | 3.0 | 3.4 | 3.1 | 3.6 | 2.5 | 3.1 | 2.1 | 2.6 | 2.2 | 2.8 | 2.5 | 2.8 |
| Symptoms (number per year) *(n=463)* | 2.9 | 1.8 | 1.1 | 2.2 | 1.9 | 2.3 | 1.8 | **3.7** | **3.8** | 2.6 | 3.2 | **4.0** | **4.3** |
| Work-satisfaction[1] *(n=471)* | 8.1 | 8.4 | 8.4 | 8.3 | 7.9 | 8.1 | 8.0 | 8.2 | 8.2 | 8.0 | 7.5 | 7.7 | 7.8 |
| Participation in design of space[3] *(n=407)* | – | 44 | 43 | **62** | 25 | 45 | 36 | 51 | 17 | 33 | 20 | **63** | 35 |
| Realisation of the design ideas[3] *(n=240)* | – | 100 | **56** | 90 | 75 | 72 | 76 | 72 | **54** | 71 | **40** | 76 | 63 |
| Presence in ones workspace (min) *(n=365)* | 327 | 290 | 293 | 310 | 292 | 322 | 322 | **330** | 315 | **378** | **340** | **390** | **347** |
| Working out of office (min) *(n=365)* | 74 | **139** | 93 | **132** | 83 | 69 | 97 | 80 | 50 | 39 | 18 | 19 | 28 |
| *The sample of the second phase of the IBs Survey (n=38).* | | | | | | | | | | | | | |
| Sick leave (days/a) *(n=336)* | | 0.5 | 0 | 0 | 0 | 0.7 | 0.9 | **3.8** | 1.8 | 0.4 | 1.7 | 0.8 | **3.6** |
| Salary (FIM[4]/month) *(n=325)* | | 22432 | 20654 | 20375 | 18500 | 15091 | 15357 | 12130 | 13129 | 10750 | 8650 | 9257 | 8672 |

[1] ≡ An index from 4 to 10 (the best) ; [2] ≡ An index from 1 to 4 as follows: 1≡less than 5 $m^2$, 2≡5–9 $m^2$, 3≡9–13 $m^2$, 4≡over 13; [3] ≡ The per cent of the responses ; [4] ≡ The Finnish currency before Euro (2002), 1 € is about 6 FIM; The bold text is for the best or biggest values. The underlined text is for the smallest values. Non-IB means reference buildings, which are not built according to the IB concept.

*Table 13. The test (F-test) of mean grades of the end-user evaluation of spaces' and equipment's quality according to genders.*

| *Samples of 1. & 2. phases, n=534 (smallest n for any variable 468).* | All spaces[1,2] | Personal workspace[1,4] | Equipment[3] |
|---|---|---|---|
| Men | 7.7* *(n=260)* | 7.3* *(n=257)* | 7.6* *(n=248)* |
| Women | 7.5* *(n=221)* | 6.9* *(n=213)* | 7.9* *(n=202)* |

* ≡ a statistically significant difference (p< .05); [1] ≡ An index from 4 to 10 (the best); [2)] ≡ p= .011164, [3)] ≡ p= .000254, [4)] ≡ p= .000033.

The *work-satisfaction* and the *number of health symptoms* of the evaluator seem to have no influence on the differences between the end-user evaluation results of the IBs and the reference buildings. Absence from work was also tested on the behalf of the sample of the both phases finding out whether workers had been on sick leave or not, and if so to what extent. No (statistically significant) difference between the two office building types was found (22 per cent of respondents of the IBs and 21 per cent of respondents of the reference buildings had been out of office during the year *(n= 339, p = ,79919)*).

However, there seems to be a great difference in how much time the evaluator is spending out of the office in the IBs when compared with the reference buildings (Table 27., cf. also Section 7.1.4.6). The office workers seem to spend quite a similar amount of time in their personal workplace in both office types (Table 12., Section 7.1.1.8). Under these circumstances, the workers of the offices in the IBs work longer hours than those in the reference buildings. The difference is 34 minutes per working day, which is 12.5 hours per month. The larger work load originates from the work done outside the office building. Thus, this difference is not directly due to the building quality. The indirect influences of overtime work on the evaluation results is in this phase of the analysis unknown (cf. Section 8.2.7.9). The overtime work is typical for all academic workers in Finland, but this result of the existence of overtime in the IBs has also a correlation with the conclusion of the overtime work among knowledge workers (cf. Section 2.4.9.2).

The evaluation result has a correlation with the possibility of the evaluator to *participate in the design* of the work environment (Table 14., cf. also Section 7.1.3.9). In the IBs this possibility has been better and the workers' ideas have been realised well. This has been true especially in the case of female executives and clerical personnel of the IBs. They also evaluate the equipment good for their work performance (Table 12.).

*Table 14. The test (F-test) of the difference of the background information of the evaluators according to the office building types.*

| *Samples of the first and second phases of the IBs Survey (n=53)* | IB | Non-IB |
|---|---|---|
| Health symptoms (number per year) *(n= 534, p= .171485)* | 2.6 *(n=336)* | 2.9 *(n=198)* |
| Presence in personal workplace (min) *(n= 432, p= .430795)* | 329 *(n=262)* | 319 *(n=170)* |
| Working out of office (min) *(n= 432, p= .035984)* | 86* *(n=262)* | 62* *(n=170)* |
| Work-satisfaction [1] *(n= 471, p= .203861)* | 8.1 *(n=287)* | 8.0 *(n=184)* |
| Participation in design of space [2] *(n= 480, p= .00371)* | 45* *(n=297)* | 30* *(n=183)* |
| Realisation of the design ideas [2] *(n= 280, p= .09208)* | 78 *(n=185)* | 68 *(n=95)* |

[1] ≡ An index from 4 to 10 (the best) ; [2] ≡ percentages of the respondents;

Non-IB means reference buildings, which are not built according to the IB concept.

The evaluation result was dependent on the *working status;* the higher status of the worker the better the evaluation result on the spaces (Table 24.). Similarly, the higher the status the greater the work-satisfaction, the smaller the number of health symptoms, the shorter time is spent in the personal workplace and the longer time is spent out of office (Table 15.).

On the behalf of the space quality the status of the worker rather than the type of building correlates with work-satisfaction, the number of health symptoms, and to the time which is spent in ones personal workplace. The working hours which need to be spent out of office concern especially the executives.

*Table 15. The test (F-test) of the difference of the background information of the evaluators according to the statuses of the workers.*

| *Samples of the first and second phases of the IBs Survey, n=534.* | Executives | Professionals | Clerks |
|---|---|---|---|
| Health symptoms (number per year) *(n= 434)* | 1.8 *(n=93)* | 2.8 *(n=232)* | 3.8 *(n=109)* |
| Presence in personal workplace (min) *(n= 368)* | 294 *(n=85)* | 323 *(n=193)* | 369 *(n=90)* |
| Working out of office (min) *(n=368)* | 126 *(n=85)* | 73 *(n=193)* | 24 *(n=90)* |
| Work-satisfaction [1] *(n=406)* | 8.4 *(n=85)* | 8.1 *(n=219)* | 7.7 *(n=102)* |

[1] ≡ An index from 4 to 10 (the best).

Everything what is said above about the correlation of the working status of the worker and the spatial quality of the building is true also concerning the equipment, when the comparison between the evaluations of the executives and the professionals is done. However, it is not true when the clerical personnel is concerned. Even the high number of health symptoms among the clerical personnel does not make them evaluate the equipment poorly. Neither they dislike their equipment because of their poor work-satisfaction. The influence of possible other background factors have an effect on the good evaluation of the equipment by the clerical staff, as well.

The evaluation result is dependent on the *gender*; men like the spaces and women the equipment (Table 13.). Work-satisfaction has no correlation with the differences of the evaluations of the genders (Table 16.).

Women spend more time in their personal work space than men and they work outside the office only half of the time which men do. As a whole their working time is the same as that of men. Women have 1.7 times more health symptoms than men. The long working hours in the building and the big number of health symptoms correlate to the critical female opinion of the quality of the space.

The number of health symptoms was also high in the reference buildings as a whole (Table 14.), and their spatial quality was not as high as that of the IBs.

The number of women in the reference buildings was also higher than that of the IBs (Section 5.3.3.1). There is a correlation between the large number of women and the large number of health symptoms. There is a correlation between both the large number of women and the health symptoms, and the reference buildings as well as the poor end-user evaluation of spaces.

*Table 16. The test (F-test) of the difference of the background information of the evaluators according to genders.*

| *Samples of the first and second phases of the IBs Survey, n=534.* | Women | Men |
|---|---|---|
| Health symptoms (number per year) *(n= 499)* | 3.6 *(n=234)* | 2.1 *(n=265)* |
| Presence in personal workplace (min) *(n= 424)* | 346 *(n=196)* | 308 *(n=228)* |
| Working out of office (min) *(n=424)* | 49 *(n=196)* | 99 *(n=228)* |
| Work-satisfaction [1] *(n=468)* | 8.0 *(n=219)* | 8.2 *(n=249)* |

[1] ≡ An index from 4 to 10 (the best).

There is a correlation between the long working hours and the IBs (Table 14.). The working hours were long in the IBs as a whole, but the executives working out of office increase those hours in particular. The long working hours of women at ones personal workplace correlate to the poor spatial end-user evaluation. The same concerns the long working hours and the status of the worker (Table 15.). The long working hours at their personal workplace correlates with the poor spatial end-user evaluation more generally than only among the women. The good spatial quality of the IBs seems to correlate with the male executive status and the possibility to work outside the office in addition to long hours at the office.

It can be concluded from the Table 11. and Table 13. and seen from Table 12. that it is the female executives and female clerical personnel of the IBs who evaluated their equipment best of all worker groups for their work. In other words, they get most out of the equipment in their work. This result correlates with relatively long working hours at ones personal workplace and the large number of health symptoms. It can make sense if the health symptoms are a consequence of the long working hours working with interoffice equipment, which seemed to be true on the basis of the second phase of the study (Lehto 1997a). The female professionals of the IBs evaluate the equipment also quite high, but not as high as their executive and clerical colleagues. They work long hours at their personal desk and have a large number of health symptoms, but in addition to the female executives and clerks in the IBs the professionals there have lots of sick leaves.

The diamond structure of the knowledge work organisation highlights the need of professionals for the modern office work. The work load in offices rests on the shoulders of the professionals. The heavy work load of the professionals might reflect from the evaluations of the quality of the space and equipment. The importance of their quality for female office workers is more critical than to men because female office workers are the heavy users of office space and equipment. Similarly men will turn out to be critical of the quality of the portable office equipment because it is important for their work performance, while they work outside the office.

The fact that women work less hours outside the office than men explains also the fact, which was found during the analysis of the results of the second phase, that the women do not evaluate the mobile phones and portable computers as highly as men do from the working efficiency point of view (Table 52.). It seems that they simply do not need them as much as the men do, who work more out of the office. However, they prefer paging devices, which are an interoffice device, more than men do. It was found that those, who use the equipment evaluate, its quality as better than those who do not use the device do (Section 8.1.4.3.).

However, it was also found that the female executives are the heavy travellers among the office workers, although the male office workers travel more in general than their female colleagues do (Lehto & Himanen 2002b). Thus, it seems that it is more typical for women to work at their personal workplace with the interoffice equipment than it is for men, who work (likely with mobile phones and portable computers) out of office more than women and travel as a whole more than women in general, if the female executives are not counted in. Especially female executives and clerical personnel are satisfied with the equipment. The female executives work effectively with the equipment at the office and travel a lot for business.

The poor evaluation grades given to the equipment by men is due to the end-user evaluation of the equipment quality in the reference buildings (Table 12.). However, the male clerks in the IBs are the exception to the rule. They work outside office more than the other worker groups and it could be the cause of the poor end-user evaluation of equipment, because the fact of poor male evaluation of the male clerks of the IBs does not correlate with either the poor work satisfaction or the big number of health symptoms. It is not known or studied in detail within this study, but even so it seems that if they use portable equipment, the quality of it is not good enough in their mind (cf. Section 8.1.4.3). (A reason for this fact can also be the unavailability of such equipment.)

Are the female executives who work effectively with the equipment at office and travel a lot for business, or the male clerks who might need more feasible portable office equipment the weak signals of the future of the office work? Will the women and men work similarly or use different strategies in future knowledge work as they have done according to the result of the IBs Survey?

#### 7.1.1.3 Intelligent Building Features

In the IBs, there are on average 3.75 special installations of equipment per building and 3.50 spatial specialities (Table 17. and Table 18.). The corresponding numbers for the reference buildings are 2.43 and 0.86. The number of equipment installations does not differ between the building types as much as the number of the spatial specialities. These numbers correlate to the end-user evaluation results shown in Table 10.

The IBs differ from the other offices most on the basis of the spatial solutions (Table 17. and Table 18.). **It can be concluded that in order to give effective result the design of the IBs requires careful and qualified spatial planning, and extra installations of equipment and structural innovations.**

This emphasis on good spatial intelligence of this sample of Finnish IBs, instead of that on the differences in the quality of the equipment seems to prove that So is correct in saying that the European intelligent building definition is more on the user's requirements than merely on the technologies (So 2001, p. 5). **Regardless, it can be concluded that the end-user evaluation of the equipment favours also the technical installations of the IBs in comparison to the reference office buildings.**

In examining the installations of equipment, structures and spaces of an individual building, which are not composed of several IB features, and comparing the set of solutions in it to the end-user evaluation results, it can be found that good results can also be gained with a stripped-down solution (Lehto 1999f, Lehto 1999c).

**It can be concluded that innovative new technology, and new structural and spatial solutions can make the IB concept work. However, this is not the fact vice versa, good results can also be gained with a stripped-down solution.**

According to this sample the LAN and building automation were a standard in any office building in the late 1980's and in the beginning of the 1990's in Finland and the most important technical speciality is a personal cooling unit (Lehto 1999f). Neither the building automation nor the local area network installation differentiates the IBs from the reference buildings within this sample. There is only one reference building without LAN. Despite of that, the equipment of this building has been evaluated as good (average grade of 8), but spaces as poor (6.4).

According to the comparison of the installations of equipment and structures of two different groups of buildings, intelligent and other high quality buildings, it can be concluded that the good end-user evaluation results of the intelligent buildings was rather based on good engineering practice and thinking of the design of the spaces and building services according to the intelligent building concept (Sections 2.4.2, 2.6, 4.2, 4.3.3.1, Lehto 1996c, Lehto 1999f, Lehto 2000c) than on the electrical systems, which had been installed in every studied office building (Section 8.1.4.3).

Among the reference buildings, there were no assembly floors. There was an assembly floor in three out of five IBs. One of those IBs without an assembly

*Table 17. The IB features and the technical qualifications of the IBs.*

| *Samples of 1. and 2. phases of the IBs Survey*[5] | Building Automation & Safety | LAN | Personal Cooling Units | Stand by Energy Supply | Mean Grade[1] Equipment | Building Manager | Receptionist | Grade[2] Services | Assembly Floor | Moveable Walls | Glass Roofed Lobby | Out Rented Spaces | Personal worskpace area[2,3] | Mean Grade[1] Shared Spaces |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IB 1 | + | + | + | | 7.6 | + | + | 7.5 | + | + | + | + | 2.9 | 7.7 |
| IB 2 | + | + | | | 7.5 | + | + | 7.9 | | | + | | 2.8 | 7.2 |
| IB 3 | + | + | + | + | 7.6 | + | + | 7.3 | + | + | + | + | 2.6 | 8.0 |
| IB 4 | + | + | + | | 7.6 | | | – | + | + | + | + | 2.4 | 7.6 |
| IB 5 | + | + | | + | 8.1 | + | + | – | | | + | | 2.2 | 7.9 |
| Together | | | | | 7.9[4] | | | – | | | | | 2.6 | 7.8[4] |

[1] ≡ An index from 4 to 10 (the best) ; [2] ≡ An index from 1 to 4 where 1≡less 5 $m^2$, 2≡5–9 $m^2$, 3≡9–13 $m^2$, 4≡over 13 $m^2$; [3] ≡ informed by the office workers (the IBs Survey); [4]≡ the mean average of the weighted averages of each parameter; [5] n=534.

*Table 18. The IB features and the technical qualifications of the reference buildings.*

| *Samples of 1. and 2. phases of the IBs Survey* | Building Automation & Safety | LAN | Personal Cooling Units | Stand by Energy Supply | Mean Grade[1] Equipment | Building Manager | Receptionist | Grade[1] Services | Assembly Floor | Moveable Walls | Glass Roofed Lobby | Out Rented Spaces | Personal worskpace area [2,3] | Mean Grade[1] Shared Spaces |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non-IB 1 | + | + | | | 7.4 | | + | 7.2 | | | + | | 2.9 | 7.4 |
| Non-IB 2 | + | + | | + | 7.7 | | + | 7.5 | | | + | | 2.9 | 8.1 |
| Non-IB 3 | + | + | + | + | 7.5 | | | 7.1 | | | | | 3.3 | 7.9 |
| Non-IB 4 | + | | | | 8.0 | | + | 7.3 | | | | | 3.1 | **6.4** |
| Non-IB 5 | + | + | | | 7.5 | | + | 7.4 | | + | | + | 2.8 | 7.2 |
| Non-IB 6 | + | + | + | | 7.5 | | + | 7.4 | | + | + | | 2.3 | **6.8** |
| Non-IB 7 | + | + | | | 7.5 | | | – | | | | | 3.1 | 7.4 |
| Together | | | | | 7.5[4] | | | – | | | | | 2.9 | 7.3[4] |

[1] ≡ An index from 4 to 10 (the best) ; [2] ≡ An index from 1 to 4 where 1≡less 5 $m^2$, 2≡5–9 $m^2$, 3≡9–13 $m^2$, 4≡over 13 $m^2$; Non-IB means reference buildings, which are not built according to the IB concept; [3] ≡ informed by the office workers (the IBs Survey); [4] ≡ the mean average of the weighted averages of each parameter; [5] n=534.

floor has still been evaluated as good (equipment 8.1 and spaces 7.9), and the other as of average in quality (equipment 7.5 and spaces 7.2). An assembly floor seems to have positive correlation with the good end-user evaluation result in the quality of the IBs, but these two examples out of five prove that good or average building quality can be achieved without an assembly floor. **Thus an assembly floor has no clear influence on the end-user evaluation result. However, it seems rather correlate with the good than the not so good evaluation results.**

#### 7.1.1.4 Age of the Building

On average, the IBs were somewhat newer than the reference buildings (Lehto 1996c, Lehto 1999f, Lehto 1999c), which could lead expectedly to the conclusion of a positive correlation between the age of the intelligent building and the building quality. However, the quality of an individual building in this sample does not correlate with this default information about the age of the building (Lehto 1999f). Both new and old buildings are evaluated to have good and not as good spaces and equipment in both groups: in the IBs and in the reference buildings.

The statistical test of this paradigm for the whole data is not finished, because the sample data was gathered from buildings which have been built within a relatively short time span – the building ages being from 2 to 8 years. Comparison according to buildings' age needs a longer time span of finished construction projects including also buildings, which are closer to the average (or nominal) building age.

#### 7.1.1.5 Size of the Building

The building *size* of the IBs is bigger and the occupancies higher than those of the reference buildings (Section 5.3.3.2). The dependency of the building quality (on the basis of the end-user evaluation results) on the occupancies is shown in Table 19. Unexpectedly, this fact together with the summary results of the end-user evaluation (Table 11.) lead to the conclusion that there exists a positive correlation between good building quality and both big unit size and high occupancy. Brill (1985, p. 70) has come to a parallel result: the increases or decreases in occupancy do not affect job satisfaction.

*Table 19. Mean grades of the end-user evaluation of spaces' and equipment's quality according to the office building types and the occupancy rate .*

| | Occupancy ($m^2$/occupant)[2] | Spaces[1] | Equipment[2] |
|---|---|---|---|
| IB 3 | 87.6 | 8 | 7.6 |
| IB 4 | 72.6 | 7.6 | 7.6 |
| IB 1 | 55.1 | 7.7 | 7.6 |
| IB 2 | 46.8 | 7.2 | 7.5 |
| IB 5 | 27.9 | 7.9 | 8.1 |
| Non-IB 2 | 105 | 8.1 | 7.7 |
| Non-IB 1 | 69.3 | 7.4 | 7.4 |
| Non-IB 5 | 54.5 | 7.2 | 7.5 |
| Non-IB 6 | 50.9 | 6.8 | 7.4 |
| Non-IB 4 | 29.8 | 6.4 | 8 |

[1] ≡ an index from 4 to 10 (the best); [2] ≡ Occupancies have been calculated by dividing the floor area with the number of office workers (at present (in 1994) not as designed) without looking at each workroom separately, and presuming that every worker has a desk of her or his own, which is a common practise in a Finnish office (the service, maintenance and FM personnel excluded); Non-IB means reference buildings, which are not built according to the IB concept.

When the evaluators were asked to evaluate the *overall impression* of the building and to pick the three most pleasant building attributes, especially the overall impression of the building is evaluated – with a statistically significant difference – more often as a pleasant attribute in the IBs than in the reference buildings (Table 20., Lehto, Flink & Karjalainen in Lehto et al. 1997, p. 107). But also the building mass and form are evaluated as more pleasant in the IBs than in the reference buildings. The building size is then expectedly more pleasant in the reference buildings (which are smaller in size and thus more near to the human scale than big buildings) than in the IBs (Table 20.).

*Table 20. The meaning of the general view of the building for working efficiency of the office worker. Three most pleasant attributes of the building.*

| *The sample of the second phase of the IBs Survey (n=343)* *Percentages of the respondents (%)* | IB *(n=191)* | Non-IB *(n=152)* | Difference |
|---|---|---|---|
| Overall impression *(Pearson Chi-square p= .00034, M-L Chi-square p= .00033)* | **63*** | 43* | 20 |
| Colours *(Pearson Chi-square p= .00042, M-L Chi-square p= .00043)* | 23* | **40*** | 17 |
| Building mass and form *(Pearson Chi-square p= .01417, M-L Chi-square p= .01339)* | **33*** | 21* | 12 |
| Materials *(n=343, Pearson Chi-square p= .04405, M-L Chi-square p= .04441)* | 27* | **37*** | 10 |
| Building size | 32 | **38** | 6 |
| Facade structure | 41 | **43** | 2 |
| Else | 21 | 28 | 7 |

* ≡ a statistically significant difference p< .05 (F-test); The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept.

The two positive factors of a large building mass, i.e. the overall impression of the building, and the form, make a good end-user evaluation of an office building. **The style of the building seems more important to the end-user than the size of the building or such details as colours, materials or facade structure.**

### 7.1.1.6 Room Size

The room size is different in the IBs than in the other office buildings (Table 21., Section 5.3.3.2). The end-user evaluation based on the second phase of the survey showed differences between the two office building types, and it seemed that the size of the workroom could influence the differing end-user evaluations (Lehto 1999f, Flink and Lehto in Lehto et al. 1997, p. 146).

*Table 21. The room size of the two office building types.*

| *The sample of the second phase of the IBs Survey (n = 335) Percentages of the respondents (%)* | IB *(n = 184)* | Non-IB *(n = 151)* |
|---|---|---|
| Room size < 5 $m^2$ | 9 | 9 |
| Room size 5–9 $m^2$ | 30 | 25 |
| Room size 9–13 $m^2$ | 35 | 36 |
| Room size over 13 $m^2$ | 26 | 30 |

Pearson Chi-square p =.74379, M-L Chi-square p= .74325; Non-IB means reference buildings, which are not built according to the IB concept.

The room size also correlates with the status of the worker and the difference is statistically significant (Table 22, Table 12, Lehto 1999c). The executives have bigger rooms than the professionals and clerical staff. Because the executives' evaluation rate is higher than that of other worker groups, and because their rooms are bigger, it was expected that the end-user evaluation of the space might be lower from those working in smaller rooms than from those working in bigger rooms.

According to the result of the second phase of the IBs Survey, the room size correlates with gender. The difference is remarkable although it is not statistically significant (Table 23.). The correlation with the status of the worker and the gender can partly explain why the women's working rooms are smaller than those of men. Executives, who have the biggest rooms are more often men than women. According to the results of the whole sample the female and male executives both have big rooms (Table 12.), but their number is totally different (Table 22.). Furthermore, the female workers who have smaller working rooms than their male colleagues are the female professionals who work in the IBs (Table 12.). Their rooms are the smallest of all. Still, their evaluations of the spaces and equipment are better than those of female clerical personal, but worse than those of female executives. **It seems that the gender is not as dominant a factor as the status of the worker, when evaluating the quality of the building.**

Both the status of the worker and the room size have a separate effect on how good or bad the respondent evaluates the quality of the spaces and equipment. As mentioned, executives evaluate the spatial quality of the building as better than other groups of workers, and they share the good evaluation grade with the clerical personnel on equipment. The status of the worker correlates with the size of the room. In general executives have bigger rooms than professionals and clerical personnel (Table 12. and Table 22.). Professionals are as critical on the spatial quality of the space as clerical staff, and both groups are more critical on the quality of space than executives. **Thus, it seems that the room size is as important a factor on the end-user evaluation of the spatial building quality as the status of the worker.**

*Table 22. The room size of the different worker groups.*

| *The sample of the second phase of the IBs Survey. Percentages of the respondents (%)* | Executives *(n = 45)* | Professionals *(n = 165)* | Clerks *(n = 81)* |
|---|---|---|---|
| Room size < 5 $m^2$ | 0 | 9 | 15 |
| Room size 5–9 $m^2$ | 13 | **31** | **28** |
| Room size 9–13 $m^2$ | **36** | **37** | **32** |
| Room size over 13 $m^2$ | **51** | 23 | 25 |

Statistical significant difference $p< .05$; Pearson Chi-square $p = .00636$, M-L Chi-square $p= .00233$; The bold text is for the best or biggest values.

The test for the influence of the evaluator's room size on the end-user evaluation result was made on the basis of the whole sample (Table 24.). The result of the F-test shows no significant statistical correlation, however, although a remarkable difference does exist.

The Tukey test showed **significant statistical difference, concerning the correlation of the biggest room size and the best space quality. It showed also significant statistical difference, concerning the correlation of the smallest room size and the best equipment quality. The effect of the status of the worker on the end-user evaluation rate of the respondent is stronger than that of the room size.**

*Table 23. The room size according to genders.*

| *The sample of the second phase of the IBs Survey (n = 325) Percentages of the respondents (%)* | Women *(n = 143)* | Men *(n = 182)* |
|---|---|---|
| Room size < 5 $m^2$ | 10 | 8 |
| Room size 5–9 $m^2$ | 35 | 23 |
| Room size 9–13 $m^2$ | 33 | 38 |
| Room size over 13 $m^2$ | 22 | 31 |

Pearson Chi-square p = .05972, M-L Chi-square p= .05981.

Furthermore, it seems that the good end-user evaluation of the equipment is due to the building type, gender and the small room size (Table 12., Table 13. and Table 24.). The small room size and the good end-user evaluation rate of equipment is rather the consequence of building type and gender, because women evaluate equipment as good and have smaller rooms than men have, in general and because the workspaces are smaller in the IBs than in the reference buildings. The best value for the equipment is originated from the very small rooms, which can also be the working areas of open space offices. The cross-tabulation of this matter is missing.

The analysis of the future wish for room size has been done on the basis of the second phase of the IBs Survey (Table 25. and Table 26.). The smallest rooms are not very popular. Although the working room size is smaller in the IBs than it is in the other types of office buildings, it seems that there are no differences between the wishes for the room sizes in those two office building types (Table

25.). The executives are satisfied with their big rooms, and the professionals and also clerical staff are in need of bigger rooms, either those from 9 to 13 $m^2$ or even the biggest ones.

*Table 24. The test (F-test) of mean grades of the end-user evaluation of spaces' and equipment's quality according to room size.*

| *Samples of the first and second phases of the IBs Survey (n=534)* | All spaces[1,2] *(n=458)* | Personal workspace[1,3] *(n=451)* | Equipment[1,4] *(n=426)* |
|---|---|---|---|
| Room size < 5 $m^2$ | 7.6 *(n=61)* | 6.5[*] *(n=60)* | 8.0 *(n=56)* |
| Room size 5–9 $m^2$ | 7.5 *(n=118)* | 7.0[*4] *(n=119)* | 7.6 *(n=109)* |
| Room size 9–13 $m^2$ | 7.6 *(n=165)* | 7.1[*5] *(n=164)* | 7.7 *(n=152)* |
| Room size over 13 $m^2$ | 7.8 *(n=114)* | 7.4[*6] *(n=108)* | 7.7 *(n=109)* |

[1] ≡ an index from 4 to 10(the best); [2] ≡ p= .078325,[3] ≡ p= .134042, [4] ≡ p= .000001 (a statistically significant difference when p< .05); Turkey test: [4] ≡ p= .002443, [5] ≡ p= .007913, [6] ≡ p= .000016

*Table 25. The size of the working room in the future according to the office building types.*

| | IB | | Non-IB | |
|---|---|---|---|---|
| *Percentages of the respondents (%)* | Now *(n=184)* | Future wish *(n=132)* | Now *(n=151)* | Future wish *(n=100)* |
| Room size < 5 $m^2$ | 9 *(n=16)* | 1 *(n=1)* | 9 *(n=13)* | 2 *(n=2)* |
| Room size 5–9 $m^2$ | 30 *(n=55)* | 20 *(n=26)* | 25 *(n=38)* | 14 *(n=14)* |
| Room size 9–13 $m^2$ | 35 *(n=65)* | 36 *(n=47)* | 36 *(n=54)* | 33 *(n=33)* |
| Room size over 13 $m^2$ | 26 *(n=48)* | 44 *(n=58)* | 30 *(n=46)* | 51 *(n=51)* |

Non-IB means reference buildings, which are not built according to the IB concept.

There is an interesting possible weak signal of the future among executives. That is the wish to have a room of 5–9 $m^2$ in size. There are relatively many with that wish, because the rooms of the executives are not currently that small, in general. It has been also found that although the personal working room in general is very popular, there are executives who would like to move to the open area office space (Flink, Lehto in Lehto et al. 1997, p. 145).

*Table 26. The size of the working room in the future according to the statuses of the workers.*

| | Executives | | Professionals | | Clerks | |
|---|---|---|---|---|---|---|
| *Percentages of the respondents (%)* | Now *(n=45)* | Future wish *(n=32)* | Now *(n=165)* | Future wish *(n=119)* | Now *(n=81)* | Future wish *(n=53)* |
| Room size < 5 $m^2$ | 0 | 0 | 9 *(n=15)* | 2 *(n=2)* | 15 *(n=12)* | 0 |
| Room size 5–9 $m^2$ | 13 *(n=6)* | 16 *(n=5)* | 31 *(n=51)* | 14 *(n=17)* | 28 *(n=23)* | 26 *(n=14)* |
| Room size 9–13 $m^2$ | 36 *(n=16)* | 25 *(n=8)* | 37 *(n=61)* | 38 *(n=45)* | 32 *(n=26)* | 32 *(n=17)* |
| Room size over 13 $m^2$ | 51 *(n=23)* | 59 *(n=19)* | 23 *(n=38)* | 46 *(n=55)* | 25 *(n=20)* | 42 *(n=22)* |

#### 7.1.1.7 Dependency of Spatial Quality on Occupancy

As expected, the occupancy correlates with the space end-user evaluation in the reference buildings: high occupancy means lower spatial quality in the end-users' point of view. The spatial end-user evaluation in the IBs decreases in accordance with the rise of the occupancy, but there is one exception to the rule: IB no. 5. This IB is a building with an exceptionally high amount of male executives, who work in the field of communication technology (Lehto 1997b). In general men and executives give the spaces high grades, and this explains the positive result despite of the high occupancy.

The worker's personal workplace is smaller and the shared space area per occupant bigger in the IBs than in the other types of office buildings (Section

5.3.3.2, Lehto 1999c). Accordingly, the worker's personal workroom is evaluated with a lower grade in the IBs than in the other office buildings, and the end-user evaluation of the shared spaces results in higher grades in the IBs than in the other office buildings (Lehto 1997a, Lehto 1999c). This is a fact despite of one of the primer results of this thesis that, the overall spatial quality of the IBs is better than that of the reference buildings (Table 10.). **It can be concluded that the effect of the size of the workroom does not correlate with the total quality of the office space.**

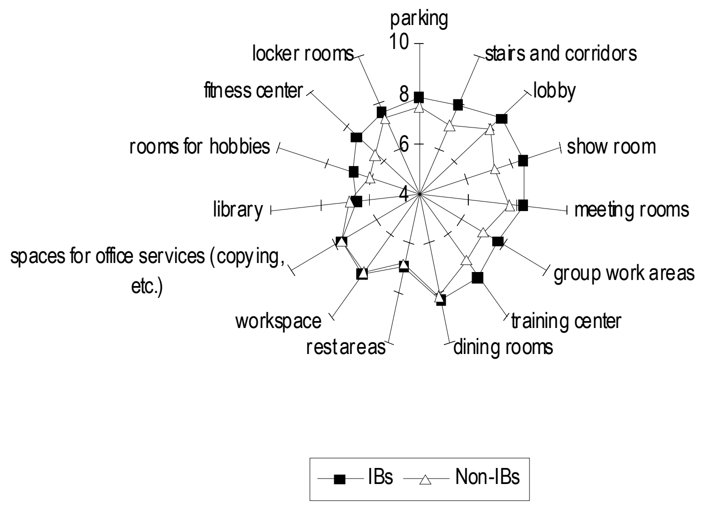
**It can be argued that the occupancy should be expressed with two separate values, the occupancy of the workers' personal working area and that of the shared spaces, before the meaning of the space sizes can be understood in a proper way in building design.**

##### 7.1.1.8 Working Hours in Various Spaces of the Office

Spaces of an office can be divided into two groups: shared spaces and the personal workplaces of each worker. Shared spaces are valued better in the IBs (7.8 on average, using an index from 4 to 10 [the best]) than in the reference buildings (7.2 on average) (Figure 27.). Such shared spaces are, for example, glass roofed lobbies, meeting rooms, auditorium and parking, which had been one of the major concerns in the IB design.

In the first phase of the IBs Survey the respondents were not asked how long a time they work in different types of office spaces. In the second phase of the IBs Survey, the respondents were asked about the duration of the working time in each office space on the previous working day (Table 27., Table 28. and Table 12.).

The time spent in the coffee room is shorter in the IBs than it is in other office buildings (Table 27.). Similar difference is found in the time spent in the meeting rooms. In the reference office buildings more time is spent in the rooms of colleagues than in the IBs. On the other hand, in the IBs more time is spent in spaces for customers and guests than in the reference buildings. **As a whole, the time spent in the shared spaces is in the IBs shorter than it is in the reference buildings** (Table 28.).




| | n |
|---|---|
| parking | 328 |
| stairs and corridors | 355 |
| lobby | 354 |
| show room | 310 |
| meeting rooms | 345 |
| group work areas | 289 |
| training centre | 317 |
| dining rooms | 347 |
| rest areas | 288 |
| workspace | 352 |
| office service space | 323 |
| library | 280 |
| rooms for hobbies | 255 |
| fitness centre | 273 |
| locker rooms | 328 |

Non-IB means reference buildings, which are not built according to the IB concept.

*Figure 27. The end-user evaluation of the various office spaces in the IBs and in the reference buildings according to the second phase of the study by an index from 4 to 10 (the best).*

In general, the working hours are longer in the IBs than in the reference buildings (Section 7.1.1.2, Lehto 1997a, Lehto 1999f), and the time spent in the worker's personal workroom is longer in the IBs than it is in the other buildings (Table 28.). On the other hand, in the IBs relatively short working hours are spent in other parts of the office, i.e. for instance in meetings and in coffee rooms. The workers in the IBs spend more time outside the office than the workers in the reference buildings do. People work longer hours in their personal workplace in the IBs than in the reference buildings (Table 12.), which on its behalf increases the demand for high quality standards in the personal workplace. Thus, the EWE of the worker's personal workplace must have a central importance in the IBs. However, the end-user evaluation in the IBs resulted in a not particularly high evaluation of the worker's personal workplace (Lehto 1999c). This phenomenon can result from the high expectations set on the intelligent working environment.

*Table 27.Working hours in the office and out of office.*

| *Sample of second phase of the IBs Survey (n=291). Percentages of the workers' working hours have been calculated from the minutes of the presence.*[3] | IB *(n=149)* | Non-IB *(n=142)* | IB | Non-IB | All |
|---|---|---|---|---|---|
| | Test | | Mean values | | |
| Personal workplace | | | 64 | 61 | 62 |
| Others' workspace | 32 | 36 | 6 | 7 | 7 |
| Common space for services | 23 | 23 | 5 | 4 | 5 |
| Coffee room[1] | **7**[*] | **19**[*] | 1 | 4 | 3 |
| Dining room | 21 | 24 | 4 | 4 | 4 |
| Meeting room[2] | **21** | **34** | 4 | 7 | 5 |
| Customer spaces | 3 | 1 | 1 | 0 | 0 |
| Spaces for entertaining | 2 | 1 | 0 | 0 | 0 |
| Other | 5 | 5 | 1 | 1 | 1 |
| Out of office | | | 14 | 11 | 13 |

[*] ≡ A statistically significant $p < .05$; [1] ≡ $p = .000002$; [2] ≡ $p = .074100$; Non-IB means reference buildings, which are not built according to the IB concept; [3] ≡ To compare the results the minutes were changed into percentages; The bold text is for the best or biggest values.

On the other hand, it has been found that the meeting and show-rooms, and the lobbies are highly evaluated because of their effect on working efficiency in the IBs, although the working time spent there is not long (Lehto, Flink, Karjalainen in Lehto et al. 1997, pp. 105–107, Lehto 1997a, p. 283). The same is with the lobby. It is evaluated high for the work performance, but the working hours actually spent there are short.

*Table 28. Occupation of office spaces during the working day.*

| *The sample of the second phase of the IBs Survey (n=386)*<br>*Percentages of the workers' working hours have been calculated from the minutes of the presence.*[1] | IB *(n=149)* | Non-IB *(n=142)* | Executives | Professionals | Clerks | Mean |
|---|---|---|---|---|---|---|
| In personal workplace | 64 | 61 | 56 | 61 | 70 | 62 |
| In other spaces of the building | 22 | 28 | 24 | 26 | 24 | 25 |
| Outside the office building | 14 | 11 | 20 | 13 | 6 | 13 |

Non-IB means reference buildings, which are not built according to the IB concept; [1] ≡ To compare the results the minutes were changed into percentages.

It seems obvious that the good spatial evaluation is originated from the spaces, which are sued for short periods, such as shared spaces of the IBs; and the rooms used for long working periods are not evaluated to be the suited best for their purpose, such as the personal workrooms in the IBs.

In some intelligent office buildings the rent of the shared spaces is paid according to the need (demand) or use of the space. This might have an effect on the working time spent in there. Explanations for these two incompatible results can be found, which can be conducted, for example, from the seven forms of human intelligence of Gardner: logical-mathematical, musical, linguistic, interpersonal, intrapersonal, visual-spatial and bodily-kinaesthetic. Among them are a visual-spatial and a bodily-kinaesthetic form of intelligence. They might be better employed in the intelligent environment, where one can walk and enjoy the beauty of the building (Dryden and Vos 1996, p. 86.). More about this reasoning in section 7.4.3.

#### 7.1.1.9 Presence in the Workspace and Occupancy

In the IBs the area of the personal workplace is smaller than in the reference buildings (Table 3., Table 4. and Table 5.). This might be a reason for the fact, that the workers of the IBs do think of their workspace as good as the workers in the reference buildings (7.9 in the IBs and 7.8 in the reference building, using an index from 4 to 10 [the best]) (Figure 27.), although in general the spaces are evaluated better in the IBs than in the reference buildings.

It seems that the time spent in the workspace and its size together correlates with the end-user evaluation result. The small personal workplace with short visits to shared spaces are preferred and give high quality total of space end-user evaluations (cf. Lehto 1997a, p. 283). In other words, the EWE of the spatial working environment quality is high if the EWE of the quality of shared spaces is high, although the small personal workplace alone is not the preferred solution. The highly evaluated bigger workspaces in the other offices cannot substitute for the lower evaluation of the shared spaces, especially when workers tend to spend their time there, which is the case in the reference buildings. Both the shared and the personal workplace have to be well designed.

The sophisticated spatial solutions and the new ways of using space can influence the productivity of the workers or their spatial experience (comfort or discomfort).

#### 7.1.1.10 Indoor Air Quality

Neither is the air quality particularly good from the user's point of view in the intelligent offices nor is it significantly bad, at least, if one looks at the average values (Table 29.). The thermal comfort of the IBs is not as good as that of the reference buildings. The thermal comfort and the indoor air temperature correlate (Figure 28. and Figure 29.). The end-user response on indoor air evaluation reflects quite well the differences of the indoor air temperature measurements (Section 7.2.1.2).

One explanation for the more uncomfortable thermal conditions and high temperatures of the IBs can be the more advanced use of office automation equipment in them than in the reference buildings. The amount of the office equipment in use, however, was not measured within the IBs Survey. It was asked indirectly in questions about the use of computers and communication technology and also respondents were asked if they use the office automation or wish to do so, where can be found if there are more of those who use the technology already. This type of detail analyse is missing.

The effect of the office automation was not taken into account in the indoor air design of offices in the late 1980's in the same way as it is done today (2002). No evidence of this is available, but in some cases the tenants pointed out during the discussions which took place when visiting the buildings, such problems in the HVAC of the IBs, which could be the consequence of unprofessional design.

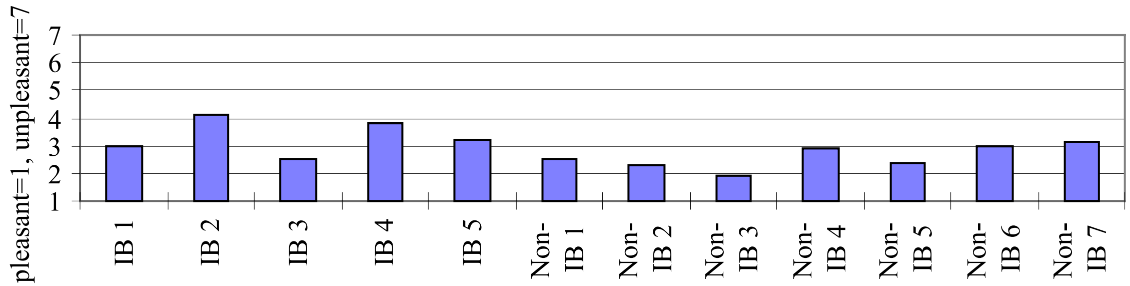
*Table 29. The average values of the indoor climate attributes in the two different office building types. Difference from the target level is presented in parentheses (Karjalainen, in Lehto & Karjalainen 1997).*

| Building type | thermal comfort | temperature | air quality freshness | air quality odour | air quality moisture |
|---|---|---|---|---|---|
| | (1) pleasant<br>(7) unpleasant | | (1) fresh<br>(7) fusty | (1) neutral<br>(7) bad | (1) dry<br>(4) pleasant<br>(7) humid |
| IB | 3.3 (2.3)<br>*(n=180+)* | 4.0 (0.0)<br>*(n=179+)* | 3.2 (2.2)<br>*(n=179)* | 2.8 (1.8)<br>*(n=185)* | 3.0 (1.0)<br>*(n=182)* |
| Non-IB | 2.6 (1.6)<br>*(n=142+)* | 3.9 (0.1)<br>*(n=142+)* | 3.3 (2.3)<br>*(n=147)* | 2.5 (1.5)<br>*(n=142)* | 3.1 (0.9)<br>*(n=146)* |

Non-IB means reference buildings, which are not built according to the IB concept.

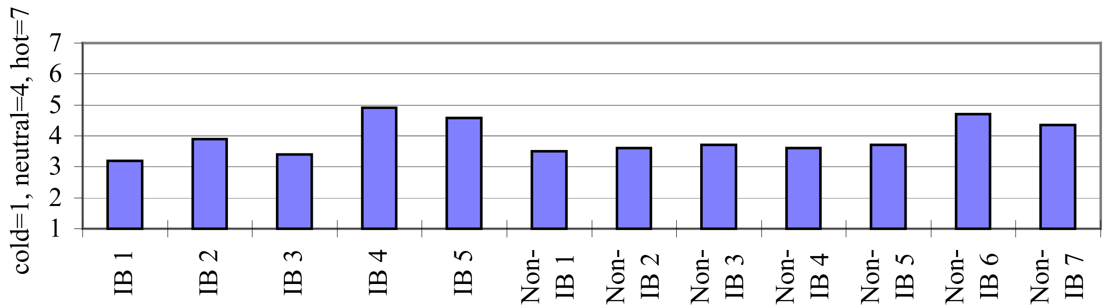
The air temperature satisfies the users best in most of the buildings with personal thermal control units (the reference building number 3. and IBs numbers 1. and 3., Figure 29. and Figure 30.). The IB number 4. makes an exception. The wide use of the open area office layouts and problems with heating due to designers' mistakes, made the high tech solution of the building inefficient in terms of comfortable indoor air. Furthermore, in some of the meeting rooms the control panel was installed out of the reach of the users. The reference building number 6. makes another exception to the rule. There the users are irritated about lacks caused by the construction work being done following the designs imperfectly.

The office workers found their possibilities to influence to temperatures and air-conditioning poor, even in the intelligent offices. The possibility of personal indoor air control has no effect on thermal comfort, while the average value for the index in offices provided with personal control units (2.7) is almost the same as it is in other buildings (2.8). This result tells us either that the control units have no effect on the ventilation or air-conditioning or the ventilation or air-conditioning is not working properly. A third reason is also possible: that the




The users of the IB number 4, the IB number 5, and the reference building number 7 answered in March 1994. The users of other buildings answered in December 1994 and in January 1995.

*Figure 28. Thermal comfort. (Karjalainen, in Lehto & Karjalainen 1997).*




The IB number 4, the IB number 5, and the reference building number 7 were tested by an index from 1 (cold) to 5 (warm) in March 1994. The users of other buildings answered in December 1994 and January1995 to a question of an index of 7 alternatives. The results have been drawn in the corresponding scale.

*Figure 29. Indoor air temperatures (Karjalainen, in Lehto & Karjalainen 1997).*

user-friendliness of the control unit does not meet the needs of human comprehension.

### 7.1.2 The Factors of Intelligent Building Concepts

The proof of the existence of the IB concept was based on the analyses of the differentiating parameters of the two office building types as follows (Section 5.5, Sections 6.2): information intensity, interaction, space flexibility and utilisation, movable space elements and equipment, adaptability, comfort, convenience, service-orientation, ability of promoting health (therapeutic). Of these, space flexibility and utilisation, movable space elements and equipment, and adaptability will be discussed in sections 8.2.4 and 7.1.3.9, and the results of the information intensity and the interaction will be presented in this section. Such factors of the IB concepts as comfort, convenience, service-orientation and ability of promoting health (therapeutic) are presented in section 7.1.2.7.

Such factors of the IB concepts as end-user need orientation and working efficiency are included in the research approach of this study. They were not studied by any particular questions.

Although the primary result of this thesis on the differences of the two office building types, that is, the existence of the use of the IB concept in office buildings was not based on the level of integration, which is one of the factors of the IB concepts, the analysis of this factor has been included in this section. The result of such an IB concept factor as the image of high technology will be described next (cf. Sections 7.1.2.1 and 8.2.7.7) and facts about it can be found from Table 3. and Table 4., as well as from Table 17. and Table 18.

#### 7.1.2.1 Image of the Building

According to the results of the second phase of the IBs Survey the *image* of the IB is described without exception with the phrase "advanced progressive development" (Lehto, Flink & Karjalainen in Lehto et al. 1997, p. 123). The other types of offices are described with the expression "advanced progressive development" by the office workers only in one case out of six. Such phrases as "traditional" and "reliability" were common when describing the reference buildings. This question was not included in the first phase of the Survey.

That the building design and details, such as mass of the building, materials, colours, decorations, etc. can reflect *values* was explained to the evaluators. They were asked, if the building where they are working reflects better their values or those of the company which they work in. The end-user evaluations of all the buildings in the IBs Survey seem to correlate more with the fact that they reflect values of the company (in 74 per cent of the cases of the IBs and in 68 per cent of the cases of the reference buildings) than those of the evaluators (Lehto, Flink & Karjalainen in Lehto et al. 1997, pp. 122–124). Although, in half of the cases (in 53 per cent of the cases in the IBs and in 51 per cent of the cases in the reference buildings) the building also reflected the personal values of the respondent. No significant difference between the two office building types could be found.

According to Brill (1985, p. 64):

> *"There is a sameness to office design, and it is recognised by office workers. Yet they'd prefer more distinctiveness. Overall, workers felt their office areas not particularly distinctive either before or after the facility change. However, those who felt their office were distinctive were more satisfied with their visual quality. For half of the employees, having a distinctive workgroup area was not important."*

In the first phase of the IBs Survey, the tenants were asked whether the building quality had influenced their choice of workplace or not. Further, they were asked if it had influenced in the case of such an option existing. Most of the respondents ($n$=148) reported that the building quality had no influence to their choice of workplace (76.5 per cent of them). Some though it had (15,6 per cent of them) and some thought that it would have had an influence if there had been that option (10.9 per cent of them).

In the second phase of the IBs Survey, the tenants were asked if the building quality had much, some, very little or no influence on their choice of workplace. The quality of the workspace has mainly very little influence on the choice of workplace (Table 30., Lehto, Flink, Karjalainen in Lehto et al. 1997, p. 124).

On the basis of the first and second phase of the IBs Survey, 70 per cent of the respondents answered that the building quality had no influence at all on their choice of workplace. Those who thought it had had influence on their choices were more often found in the IBs than in other offices. This result might be valuable in a situation where the employers are competing for the insufficient markets of ICT professionals (cf. Kostiainen 2002).

*Table 30. The influence of the building quality to the choice of workplace.*

| Building type<br>*Percentage of respondents (%)* | Much | Some | Very little | Σ | Not at all |
|---|---|---|---|---|---|
| IB *(n=192)* | 7* | 14* | 11* | 32 | 68 |
| Non-IB *(n=162)* | 2* | 7* | 17* | 26 | 73 |
| All *(n=354)* | 5 | 11 | 14 | 30 | 70 |

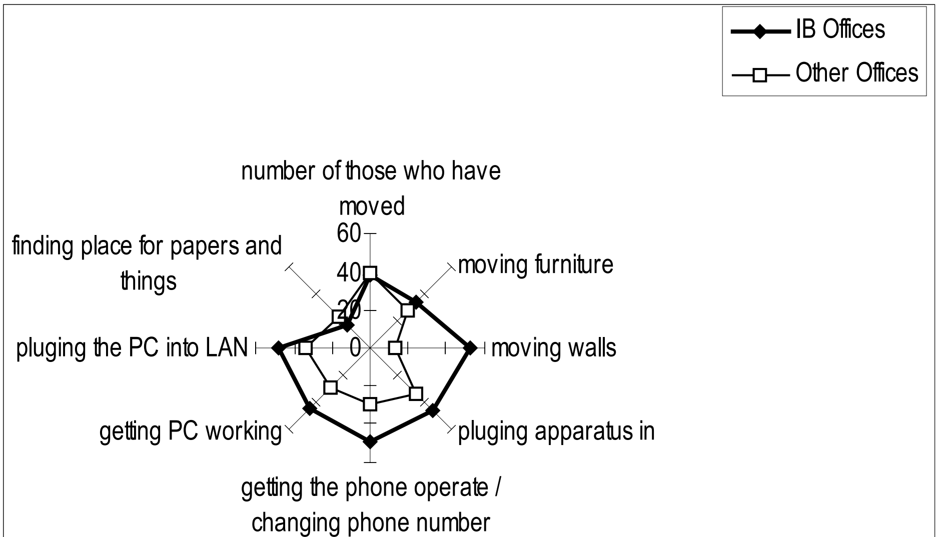
* ≡ a statistically significant difference p<.05 (F-test), Pearson Chi-square p= .01926, M-L Chi-square p= .01617; Non-IB means reference buildings, which are not built according to the IB concept.

#### 7.1.2.2 Moving

During the second phase of the IBs Survey, the office workers were asked, if they had ever moved and if so, how many times in the office building, as well as how long they had worked in the building.

The cross-tabulation between the number of moving occasions and the end-user evaluation of the success of the moving has not been done. However, 38.2 per cent of the respondents (*n*=146, altogether *n*=236) had moved. Half of the respondents (53.7 per cent (*n*=79)), who had moved, had moved once (that is, she or he has moved into the building), 26.5 per cent of them (*n*=39) had moved twice and 15.0 per cent (*n*=22) three times.

The test between the two office building types was made (Figure 30.). Four properties out of seven turn out to be statistically significantly better in the IBs than what they were in the reference buildings, when the possibilities to move into the building or later in the building were concerned. The properties, which were studied, were moving furniture, moving walls, plugging in electrical devices, plugging in the telephone apparatus (or moving it), getting the computer operating, plugging the computer into the LAN (local area network), arranging papers and other things in order.



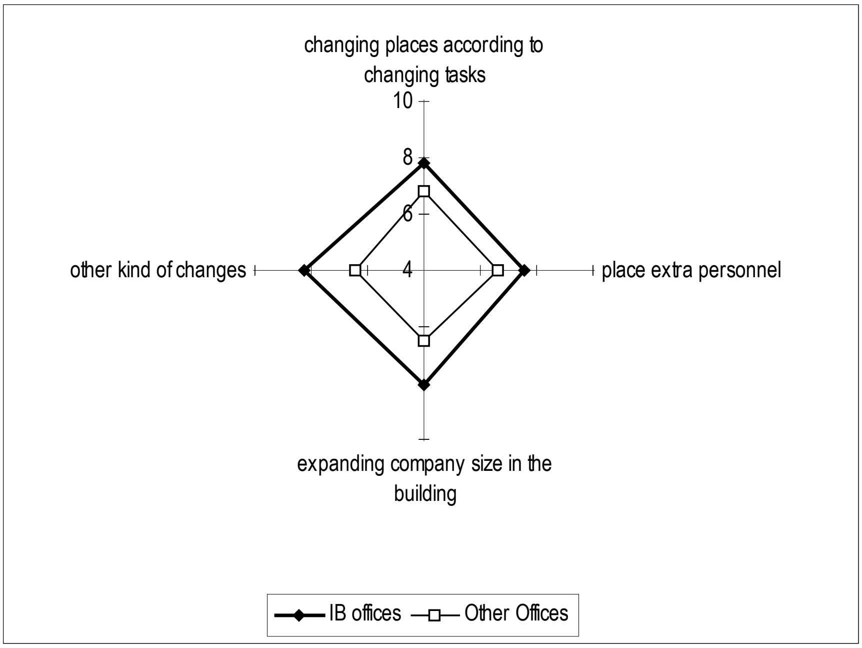

| | n | Pearson Chi-square | M-L Chi-square |
|---|---|---|---|
| moving furniture* | 237 | 0,06676 | 0,06285 |
| moving walls* | 206 | 0 | 0 |
| pluging apparatus in | 236 | | |
| getting the phone operate* | 233 | 0,00128 | 0,00108 |
| getting PC working* | 235 | 0,0069 | 0,00618 |
| pluging the PC into LAN* | 230 | 0,04708 | 0,04647 |
| finding place for papers and things | 237 | | |
| ** Statistically significant difference p<,05* | | | |

Non-IB means reference buildings, which are not built according to the IB concept.

*Figure 30. The shares of spatial flexibility features of the workspace according to the office building types after the worker has moved in the building. Percentages of the respondents who found it easy to move in the buildings.*

### 7.1.2.3 Spatial Flexibility

The spatial flexibility was studied also in the case of a change in the size of the company, which could be temporary or permanent. The flexibility turned out to a strength of the IBs also on the basis of this study (Figure 31.).




Non-IB means reference buildings, which are not built according to the IB concept.

*Figure 31. The end-user evaluation of spatial flexibility according to the office building types by an index from 4 to 10 (the best) after the company has been located in the building some time.*

Good spatial flexibility is due to such building properties as [1)] the good chance for spatial expanding within the same building, [2)] the possibility of changing the workplace in accordance with the changes in the company activities and tasks of the employees, and [3)] the possibility to have extra workplaces for temporary use, as well as [4)] the good possibilities for other changes (Lehto 2000c), such which the respondents named as their own needs for spatial change.

#### 7.1.2.4 Adaptability

Many factors of the adaptability of the workspace were studied in both phases of the IBs Survey (Table 31. and Table 32.). Neither the IBs nor the reference office buildings are particularly good or bad in adaptability of workspaces. If the IBs are good for moving and in spatial flexibility, that is not the case with their adaptability of workspaces. Both moving and spatial flexibility concerns the

*Table 31. The test (F-test) of the differences between the two office building types by the end-user evaluation of workplace properties.*

| *An index from 4 to 10 (the best).* | *The samples of 1 & 2 phases.* | | *The sample of 2. phase.* | | | |
|---|---|---|---|---|---|---|
| | IB | Non-IB | IB | Non-IB | $n^2$ | $p^1$ |
| ADAPTABILITY OF WORKSPACE | | | | | | |
| Changing computer's position* | **7.1** | 6.7 | | | *446* | *0.035338* |
| Changing cabinet storage capacity | 6.8 | 6.9 | | | *450* | |
| Refurnishing | 7 | 6.8 | | | *457* | |
| Adjustment of furniture* | | | 6.7 | <u>7.1</u> | *329* | *0.018855* |
| Changing the size of personal workplace* | | | **5.9** | 5.6 | *330* | *0.034154* |
| Changing the door position | | | 5.1 | 4.9 | *313* | |
| POSSIBILITY TO USE PERSONAL SPATIAL INTELLIGENCE | | | | | | |
| Changing working position (standing) | | | 6.3 | <u>6.7</u> | *318* | *0.059475* |
| Relaxing and moving | **7.6** | 7.4 | | | *454* | *0.200261* |
| Concentrating on thinking in peace* | 7.2 | <u>8.2</u> | | | *471* | *0* |
| MAKING CONTACT | | | | | | |
| Having an outdoor view | 7.9 | <u>8.2</u> | | | *464* | *0.147781* |
| Necessary connections (eye, speech) | | | 7.7 | 7.4 | *322* | |
| Forming temperature working groups | 7.1 | 7.2 | | | *435* | |

* ≡ a statistically significant difference of the test made in the second phase of the IBs Survey; [1] ≡ p-values of the test made in the second phase of the IBs Survey; [2] ≡ n of the whole sample; The bold text is for the best or biggest values. The underlined text is for the smallest values. Non-IB means reference buildings, which are not built according to the IB concept.

*Table 32. The mean grades of female and male evaluations of the workplace properties, and the test (F-test) of the differences between them.*

| *An index from 4 to 10 (the best)* | *The samples of 1 & 2 phases.* | | *The sample of 2. phase.* | | | |
|---|---|---|---|---|---|---|
| | Female | Male | Female | Male | $n^2$ | $p^1$ |
| ADAPTABILITY OF WORKSPACE | | | | | | |
| Changing computer's position (*) | 6.5 | 7.3 | | | *434* | *- (.000001)* |
| Changing cabinet storage capacity (*) | 6.6 | 7.0 | | | *440* | *- (.014432)* |
| Refurnishing (*) | 6.5 | 7.2 | | | *446* | *- (.000005)* |
| Adjustment of furniture | | | 6.7 | 7.0 | *319* | |
| Changing the size of personal workplace* | | | 5.4 | 6.0 | *320* | *.000616* |
| Changing the door position* | | | 4.8 | 5.1 | *303* | *.026614* |
| POSSIBILITY TO USE PERSONAL SPATIAL INTELLIGENCE | | | | | | |
| Changing working position (standing)* | | | 6.3 | 6.7 | *308* | *.037387* |
| Relaxing and moving (*) | 7.3 | 7.7 | | | *444* | *- (.001622)* |
| Concentrating on thinking in peace | 7.4 | 7.8 | | | *459* | – |
| MAKING CONTACT | | | | | | |
| Having an outdoor view | 7.9 | 8.1 | | | *452* | – |
| Necessary connections (eye, speech) | | | 7.6 | 7.5 | *312* | |
| Forming temperature working groups (*) | 6.8 | 7.4 | | | *425* | *- (.003294)* |

* ≡ a statistically significant difference of the test made in the second phase of the IBs Survey; – ≡ no value available (no test based on the whole data); [1] ≡ p-values of the test made in the second phase of the IBs Survey; [2] ≡ n of the whole sample.

whole building or shared spaces, which are evaluated to be good in general for the working efficiency in the IBs, but when adaptability was studied the workspaces were concerned, which are not evaluated to be higher in quality in the IBs than in the reference buildings.

The adaptability is sensitive to the gender (Table 32.). Men find spatial adaptability better than women do. In all cases female workers find the workspace adaptability worse than their male colleagues do, except in one case when both genders have more or less the same opinion. In most of the cases the difference is statistically significant. The possibility of creating needed eye or speech contact is the only factor of fifteen, which does not indicate the women's lower evaluation than men's on the chances in influencing their personal workplace.

The effect of the working status on the adaptability is similar to that on the spatial work environment properties. The executives find their possibilities in adaptability better than the other worker groups, and the professionals find them better than the clerical personnel, who find them worse (Lehto 2000c).

An analysis of the co-effect of the gender and the working status on the office building types might reveal something more about the differences between the two office building types.

*Table 33. The end-user evaluation of control and regulation of the room temperature and lighting.*

| *The samples of the first and second phase (n=534) An index from 4 to 10 (the best).* | IB *(n=286)* | Non-IB *(n=168)* | Mean *(435)* | Men *(n=242)* | Women *(n=201)* | Mean *(425)* | Supervisors *(n=77)* | Professionals *(n=214)* | Clerks *(n=101)* | Mean *(n=455)* |
|---|---|---|---|---|---|---|---|---|---|---|
| Room Temperature | 6.2 | 6.3 | 6.2 | <u>6.5</u> | **5.9** | 6.2 | 6.1 | 6.2 | 6.3 | 6.2 |
| Lighting | 6.7 | 6.7 | 6.7 | 6.8 | 6.6 | 6.7 | 6.6 | 6.7 | 6.9 | 6.7 |

The bold text is for the best or biggest values. The underlined text is for the smallest values. Non-IB means reference buildings, which are not built according to the IB concept.

#### 7.1.2.5 Control and Regulation

The possibilities for controlling and regulating the room temperature and lighting are quite similar in the IBs and in the reference buildings (Table 33.). The control and regulation does not correlate with the office building type, although good personal controlling possibilities have been in focus in the IB design. Men find it somewhat easier to influence their working environment's temperature than women. The result is parallel to the findings of indoor climate quality research, which has found women to be a factor in sick building syndrome. Neither office building type, status of the worker nor gender influences the end-users' evaluation on the quality of lighting control.

#### 7.1.2.6 Communication among Occupant Companies

In the second phase of the IBs Survey, the importance of the possibilities for communication between various companies working in the same building was also studied. The orientation according to companies' values in communication was least important (3 per cent of the respondents). The ability to stand out from others (19 per cent) in communication was the next least important factor, a partnerships between companies (27 per cent) due to good communication possibilities was the third least important factor.

The two most important factors were the possibility to locate according to the activities of the company among other companies (38 per cent) and the creation and maintaining of the personal relationships (37 per cent). Among these also a statistically significant difference between the two office building types were found. The IBs workers consider the personal relationships in the communication between companies (46 per cent) more important than in the reference buildings. For the workers in the other high quality office buildings the possibility to have communications between companies which have common activities, in other words belong to the same cluster (52 per cent), is more important than in the IBs.

#### 7.1.2.7 Health Symptoms

The sick building syndrome related health symptoms' correlation with the end-user evaluation was tested, and several findings emerged (Table 12. and Table 16.). In general, as mentioned earlier the health symptom rate has no direct correlation with the differences between the two building types.

However, there are two worker groups, which have large numbers of health symptoms. These are the female professionals and female clerical staff. Interestingly, the female professionals in the IBs are also taking large numbers of sick leaves, while their colleagues in the reference buildings are working more often despite of the simultaneous high health symptom rate. Conversely, the female clerical workers in the reference buildings stay home from work and have a high health symptom rate, but in the IBs they work despite of the simultaneous high health symptom rate.

**It can be concluded that the female professionals and clerks have exceptionally high health symptom rates. The health symptoms correlate to good equipment evaluation, which means that the health symptom rate reflects rather the heavy use of the equipment than dissatisfaction with it.**

The reaction in the two buildings types is different among the professionals and the clerks. The diamond structure of the knowledge work organisation can explain this difference. The relatively heavy work load of the professionals in the IBs is a reason for a strong reaction in health symptoms among female professionals, who work in a knowledge work organisation. In the reference buildings, where the work organisation is not as typically of diamond structure as in the IBs, the work load is heavier among the clerks, and especially female clerks, who have health symptoms and take sick leaves. In the IBs the situation of the clerks is far better and they do not have health symptoms and do not take sick leaves, which is the case even among the male clerks more often in the reference buildings than in the IBs.

It has been found in social studies that female workers do not consider their work environment to be good in male organisations (Lehto 1997a), which might be a reason for the fact that health symptoms and sick leaves occur among female professionals more in the IBs than in the reference buildings, where there are less male supervisors than in the IBs.

The health symptom rates among executives and male professionals in the IBs are somewhat higher than in the reference buildings. The health symptom rates among female professionals are (more or less) the same in the IBs and in the reference buildings. The health symptom rates among the clerks in the IBs are somewhat lower than in the reference buildings. It is also the professionals who evaluate the equipment as not as good as the other groups of workers. Professionals and clerks use ICT tools more than executives, and, as mentioned, the health symptoms are likely to be related to a heavy work load rather than to dissatisfaction. The low evaluation rate of the professionals on the equipment can reflect their high requirements and their work with the office equipment.

Women more often than men, and executives more seldom than other groups, found their possibilities to influence their working environment poor. More well educated, male executives work in the intelligent offices than elsewhere, and their health symptom rate is also one of the lowest. The female professionals and clerks find their possibilities in controlling their physical working environment poor. The female clerks in general find their controlling possibilities very poor, which gives a good reason for a large number of health symptoms. The female professionals, however, have the same difficulties in controlling their environment as the female executives, whose health symptom rate is not exceptionally high, but higher than that of their male colleagues (Lehto 2000c). It seems that the health symptom rate may correlate with the possibilities for controlling the working environment.

Even the poor adaptability of the workspace could be a reason for staying at home when not feeling very well, because it is difficult to adjust the working conditions to the health conditions. Women found it more difficult to adjust the workspace than men did.

On the basis of the health symptoms the various worker groups could be ranked as shown in Table 34. This list shows that there are no great differences between the two different building types although in some cases the figures of the health symptom rates differ remarkably between the working groups.

Several reasons can be found for the high health symptom rates of the female office workers. These are either organisational or due to the quality of the physical work environment. **It can be concluded that if several reasons for health risks cumulate in one worker group and thus in one person, the health symptoms indicating the sick building syndrome appear.**

*Table 34. A ranking of the health symptom rate according to the statuses of the workers in the two different building types.*

| NUMBER OF SYMPTOMS: FROM MUCH (FIRST ROW) TO LESS | |
|---|---|
| Non-IB | IB |
| the female clerical staff | the female clerical staff |
| the female professionals | the female professionals |
| the male clerical staff | the male clerical staff |
| the female executives | the male professionals |
| the male professionals | the female executives |
| the male executives | the male executives |

Non-IB means reference buildings, which are not built according to the IB concept.

There are also interesting results on each health symptom and their correlation with the end-user evaluation. There is also a clear difference between worker groups and the health symptoms from which they suffer, on the basis of the responses to the first phase of the questionnaire, which included only three buildings (Lehto, Flink & Karjalainen in Lehto et al. 1997, p. 95). This analysis of the correlation with the health symptoms and the worker group should be completed with the whole sample, before it is possible to argue for any result.

Further analysis of the health symptoms would be interesting and fruitful, as the following examples from the results of the second phase of the IBs Survey point out. To begin with, dry skin is a problem for many (52 per cent) who work in a very small room. The effect decreases when the room grows bigger, and in the biggest rooms only 15 per cent of office workers had problems with dry skin. Dry skin is not a problem if the person has chosen the furniture her- or himself (17 per cent), but the problem grows bigger if the employer has chosen the furniture (35 per cent), and it is worst if the furniture has simply been gathered together over the years without any particular plan (50 per cent).

Secondly, eye problems were more general, if the workroom was small, or if one works in the open area office space, or if one looks onto indoors, or if the furniture has been gathered together over the years without a specific plan. A large room with scenery of the city, and with furniture the worker has chosen her- or himself was best for the eyes. Those who had a view to nature were suffering from a runny nose more often than those who had a view to city scenery.

The first example might reveal the effects of the dusty old furniture on the skin, and the latter one tells about the wrong placement of the monitor, which causes reflections from the window and the dust coming through the windows from the wild nature out of doors, among other things.

#### 7.1.2.8 Systems Integration

The integration in the IBs can be based first of all on integrated structures combining building services and technologies to spatial innovations, or on interoffice networking, and also on the interoffice service and spatial arrangements or active structures suitable for the occupants' needs. The end-users' opinion about the level of systems integration was not studied in any particular manner. The conclusions about the integration have been generated from the data gathered on the building properties by several questions, which can reveal the level of integration, as their summary showed the IB equipment to be better than that of the reference buildings.

As proved in the section on the office automation (Section 8.1.4.3) the *integration of the office automation equipment* works, according to the end-user evaluation better in the IBs than in the reference buildings, although the network installations are more or less a standard in office buildings in general (Section 7.1.1.3). The *quality of the equipment* can be another explanation for the better end-user evaluation result of the equipment in the IBs. Any results of benchmark or other tests concerning the performance of installations of equipment were not available.

The next possible explanation for the good overall end-user evaluation of the equipment of the IBs, despite that no remarkable differences in the installations as compared with the reference buildings exists, is that the spatial intelligence makes it possible to carry out the technical installations more feasibly in the IBs than elsewhere (cf. *integrating structures*). That is true on the basis of the end-user evaluation of the spaces. In the IBs, both spaces and equipment are evaluated with good grades, and the spatial intelligence of the IBs is of a high standard because of several structural solutions (Table 17. and Table 18.) and the good quality of the architectural design, which were discussed in the previous sections 7.1.1.1, 7.1.1.3 and from 7.1.1.5 to 7.1.1.7.

A feasible intelligent solution is generated from the intelligent subsystem technologies, which are made to co-operate in accordance with building design resting on the intelligent building concept. The subsystem failures were due to the incorrect basic engineering – such as lacks in indoor air quality due to design mistakes, or unreliability of access control (Lehto & Karjalainen 1997, Lehto and Karjalainen in Lehto et al. 1997, p. 179, Lehto & Karjalainen 1996). Similar examples can be found when looking at the technical and structural sub-solutions of each building separately (Lehto 1999f, Lehto & Karjalainen 1997, Lehto 1999c, Lehto 2000c). *Adding intelligent subsystems* without taking care of their reliability, the quality of installations and the pre-settings, and without a well designed overall plan, seems more likely to be an effective tool for causing problems and for giving a wrong image of the building for the tenants (cf. Lehto & Karjalainen 1997).

**From these partly paradoxical results, i.e. firstly, from the convergent end-user evaluation summary and secondly, from the building specific end-user evaluation variations of spaces and equipment, can be concluded that the use of the intelligent building concept has succeeded in the terms of the end-user's work efficiency, but obviously potential for better results exists.** As mentioned earlier (Section 7.1.1.3), the implementation of the IB concept is based on good engineering practice and on thinking according to the intelligent building concept, which takes into account the interplay between spaces and equipment, as well as the interface of the building and the end-user.

As the case of the room size indicates, this sample has proved the power of the end-user evaluation in pointing out those building characteristics, which might have influence on the building quality in total (Section 8.2.7). On the other hand, this sample has proved the weakness of the technical solutions alone in guaranteeing the presence of the good building characteristics (Sections 7.1.1.3 and 8.1.4.3), which are expected to be achieved by following the intelligent building design criteria. In other words, this weakness lies in the ability of the technical solutions in distinguishing the intelligent buildings from other types of buildings, because of the occurrence of similar technical installations in many buildings.

**Thus, it can be concluded, that the criteria for the use of the Intelligent Building term will be best fulfilled, if the building design is based on more than one of the elements of the IB concept, and if the quality of intelligent subsystems rests on knowledge of high standard engineering for the correct technology needed in each subsystem, and finally if the elements of intelligent buildings form a functional combination which responds to changing user needs.**

Thus the number of needed parameters of the IB concepts will be more than 1 (Equation 4.):

$$BQ_{Difference} = f\,(x_1 \ldots x_y)$$

where y>1.

This result can be compared to the results of the reactions of the end-users. As mentioned earlier it has been found that, if the number of the typical sick building health symptoms reduces from six to two, the work productivity rises 10 per cent (Wyon 1993, cf. also Wyon in Clements-Croome 2000, pp. 192–206).

As found in the previous results, the end-user can stand some unsatisfactory factors in the working environment, but if they are many, the building quality is experienced as poor.

The successful use of the IB concept is based on several successful subsystems and the prevention of several false or inoperable subsystems.

### 7.1.3 Facilities Management

The IBs Survey in all is related to the facilities management phenomenon, as well as the IB concepts (Section 2.3). Concrete evidence of the FM parameters is gained from the results of the IBs Survey. The importance of the building manager and the need for the building amenities have been revealed. The data of these both factors were gathered only in the second phase of the study, and thus they are included in the final results of the IBs Survey.

#### 7.1.3.1 Selection Criteria

When evaluating the selection criteria for the office space, the location is the most important and the image of the building is evaluated also to be highly important both in the IBs and in the reference offices (Table 35., Lehto 1999f). The last mentioned result is similar to that of Brill, who found the distinctiveness of the building important for the tenants. Because the image of the building is an important selection criterion for office spaces, and because it is one of the IB features, the need for further analyses of the subject is obvious (Sections 7.1.2.1 and 8.2.7.7). Other selection criteria for office space are differently important in the two different types office buildings, and statistically significant differences can be found.

The price per square meter or the rent, or the possibility to use the building as an investment instrument, is a more important selection criterion for the office space of the other high quality office buildings than that of the IBs. The type of the building is ranked higher as a selection criterion in the cases of the IBs than when the selection of office space concerns other types of high quality office buildings (Table 35., Lehto 1999f).

Need analysis is not a popular criterion for the office space selection. The need analysis can be unpopular, because it is not well-known, or because it has been misused and has caused frustration, or it is rejected for other reasons.

**It can be concluded, that the location of the building has a definite position as a selection criterion for office space. Further on, the image and the building type count in the selection of office space in the case of the IBs,**

**where as the price and the building used as an investment are dominant in the selection of space from other types of buildings.**

*Table 35. A ranking of selection criteria for the office space.*

| | *The sample of the second phase, n=386.* | | | *Samples of the first and second phases of the IBs Survey, n=534*[1] | | |
|---|---|---|---|---|---|---|
| | IB *(n=199)* | Non-IB *(n=161)* | All *(n=360)* | IB *(n=301)* | Non-IB *(n=186)* | All *(n=487)* |
| Location | 1. (65) | 1. (70) | 1. (68) | 1. (62) | 1. (69) | 1. (68) |
| Same location with the partners in co-operation and with clients | 3. (27) | 4. (26) | 3. (27) | 3. (31) | 3. (27) | 2. (31) |
| Image (representativeness)* *(n=485, Pearson Chi-square p= .03345, M-L Chi-square p= .03205)* | 2. (52) | 3. (29) | 2. (42) | 2.(34)* | 4.(25)* | 3. (26) |
| Price or rent* *(n=487, Pearson Chi-square p= .00000, M-L Chi-square p= .00000)* | 6. (7) | 2. (32) | 4. (18) | 6. (9)* | 2.(32)* | 4. (23) |
| Building type (IB or Non-IB)* *(n=487, Pearson Chi-square p= .00000, M-L Chi-square p= .00000)* | 4. (24) | 8. (4) | 5. (15) | 4.(23)* | 6. (5)* | 5. (14) |
| Employee well-being | 5. (16) | 6. (9) | 6. (13) | 5. (12) | 5. (9) | 6. (10) |
| Investment* *(n=360, Pearson Chi-square p= .01525, M-L Chi-square p= .01505)* | 7. (4)* | 5.(11)* | 7. (7) | – | – | – |
| Recommendation of need analysis* *(n=360, Pearson Chi-square p= .03715, M-L Chi-square p= .03699)* | 8. (4)* | 7. (9)* | 8. (6) | – | – | – |

In parenthesis the importance expressed by percentages of the respondents; * ≡ a statistically significant difference, p< .05 (F-test); Non-IB means reference buildings, which are not built according to the IB concept; [1] ≡ smallest n for any variable 487.

#### 7.1.3.2 The Location

On the basis of the end-user evaluation, the popularity of various types of *views out of the office room* is as follows: the view out to nature is most popular and the city scenery next popular (Lehto & Flink in Lehto et al. 1997, pp. 152–160). The scenery of a not so densely populated area is not in favour of office workers.

The favourable location is due to many variables, other than those of the office window scenery. For example the commuting possibilities and service accessability can be personal reasons for selecting the suitable location of the workplace. The companies have their own reasons for certain locations, such as the short distance to the airport or other travelling modes. In certain fields it is important to be near the customers or even in the best trade centre. Others might seek for a peaceful location, while the constant client contacts disturb the concentration to the creative work.

**Still, from this result of the popularity of the views out of the office, it could be concluded that – if it otherwise possible – a location either in the middle of nature or in the city centre is best in the tenants' opinion for an office building in the Helsinki metropolitan area.**

Parallel result about the popularity of the view out to nature can be found from Finnish housing studies (Lehto 1998b, p. 111).

In the Helsinki city centre, the IBs were not evaluated as good as in the city of Espoo, where the buildings more probably end up to be built near by nature or next to a not so dense area than they do in Helsinki city. In Espoo *the image and type* of the office building meant more to the workers' working efficiency than they did in offices in Helsinki (Lehto 1999f). In Helsinki the location and the *business connections* count more than in Espoo.

The gender and the status of the evaluator, i.e. those of the office worker, obviously influence the results of the comparison between the city centre location of the office (that of the Helsinki city) and a office location in a not so densely populated area (more common in Espoo) (Lehto 1999f). In Helsinki, office workers in the studied buildings were more often women and the *occupancy* was lower than in offices in Espoo, which are two critical factors on the behalf of the spaces. On the other hand, in offices located in Helsinki the good number of male executives had a positive influence on the end-user evaluation.

This sample is too small for detailed analysis of the location. Still, **it can be concluded that the office buildings are different in different locations**, and the factors favouring different alternatives and beneficial office building planning can be identified.

#### 7.1.3.3 Potential of ICT in Business Travelling

A substitution impact of ICT on work-related travelling can be noticed (Lehto & Himanen 2002b). According to the IBs Survey, one third of office workers (who regularly make work-related trips) had noticed it. Very few, only 1 to 2 per cent, of the office workers had noticed any stimulation in work-related travelling because of the use of ICT (or telematics).

About two thirds of the office workers (who regularly make work-related trips) had not noticed any impact of the use of ICT on work-related travelling (Lehto & Himanen 2002b). Because they are also using ICT in their office work, it can be stated that the majority felt that there exists a complementarity between ICT and travelling.

Men experienced the diminishing effect more often than women. Female office workers either have not experienced any effect or have no opinion. Female office workers make less trips than their male counterparts, which might have some influence on their opinion. Most of the executives have not experienced any effect of the use of ICT on business trips. The professionals are not very sure about the fact, and the longer the trip, the fewer of them have experienced the diminishing effect. Professionals make fewer trips than executives, which might have some influence on their opinion. The female executives as a group travel much and they increase the number of executives who have experienced no effect.

Extremely few have experienced an increase in travelling because of the use of ICT. Also the share of people who did not have an opinion on this issue was a minor one. The office workers, who did not regularly travel for business, were more reluctant to decide if ICT had or had not any impact on travelling.

Office workers' experience on the influence of the use of ICT on work related trips was different in the two different office building types: intelligent (IB) and non-intelligent (Lehto & Himanen 2002b, pp. 61, 64, 70). There cannot be found any particular distinguishing trend, or how workers make trips from these two types of buildings within the metropolitan area or to other parts of the country. However, there is a remarkable difference in how many trips are made from the IBs to abroad and how many are done from the reference buildings (Lehto & Himanen 2002b, pp. 61). The number of business trips from IBs to abroad is three and a half times more than that made from the reference buildings. This difference is due to the trips made by the executives and professionals, both male and female. While men travel in general more than women and executives more than other groups of workers, and while there are working more men than women and more executives than other groups of the workers in the IBs this result is inevitable. Even female executives, who work in the IBs travel more than their male colleagues, and increase this co-effect of parallel business travelling and heavy use of ICT for office work.

In the reference buildings, the numbers of "no-effect" responses are bigger than in the IBs (Lehto & Himanen 2002b, pp. 64). In the IBs can be found more respondent, who have experienced the diminishing effect of the use of ICT on business trips which are made to other parts of the country or abroad, than in the reference buildings. Although in general, those who travel most have experienced the diminishing effect within the metropolitan area most often and less so the further they travel (Lehto & Himanen 2002b, pp. 66). In the IBs, where more trips are made to far-off destinations than in the reference buildings, the diminishing effect can be experienced also when travelling far. A telematically better working environment in the IBs may have diminished the trips heading to more far-off destinations, but on the trips made in the metropolitan area this has not been the case.

In 1994, telefax, email and mobile phones were the office automation devices, which are ranked most powerful in diminishing business trips (Lehto & Himanen 2002b, pp. 70). Telefax and email are more effectively used for that purpose in the IBs than in the reference buildings. They belong to those ICT tools of the office which in general are evaluated higher in the IBs than in the other types of high quality office buildings (cf. Table 50.). When avoiding trips abroad women use conference calls more often than men (Lehto & Himanen 2002b, pp. 71), although in general men have conference calls more often than women.

According to the respondents of the IBs Survey, the existence of the complementarity between ICT and travelling is obvious, because the same workers, i.e. executives, travel much and take good advantage of ICT as well (Table 11.).

Because ICT has had an impact on travelling, it most probably will have the same potential also in the future. In that way, ICT can be used as a tool for the mitigation of the negative impacts of restrictive transport policy.

#### 7.1.3.4 Possibility of Paperless Office

The occupancy does not seem to correlate to the end-user evaluation of office and building automation equipment. It should not necessarily correlate with the occupancy in any case, unless the problematic design objective of the paperless office does not evoke interest in the possible correlation. If it is possible to save paper by electronic means, it is also possible to work in a smaller workspace. The smaller workspace is the fact in the IBs compared to the reference buildings. The professionals and clerical staff have the smallest offices.

The paperless office concept is problematic, because of the fact that during the information age paper consumption has risen despite of the efforts of ICT to substitute the use of paper with electronic publishing. The phenomenon is similar to that of the ICT making an effort to substitute trips during an era of increased business travelling (Lehto & Himanen 2002b).

Interestingly though, the office automation equipment installations in all buildings were more or less of the same standard (Section 7.1.1.3). However, the equipment was evaluated higher in the IBs than in the reference buildings. The end-user evaluation grade of the equipment does not correlate with the size of the working area.

In some cases the clerical personnel evaluate the equipment quality as high as the executives do (Lehto 1999f, Lehto 1998d), although their workspace is smaller than that of the executives. They also do so more often than the professionals, although the workspaces of these two groups are of similar size. In all, the modern office equipment is perfect in the period of ever productive office working for clerical work done in a relatively small sized office room. Summa summarum, the possibility of paperless office concept has in a way been realised in the clerical work. Still, it must be remembered that the clerical personnel wish to have larger offices and they are a group of workers who evaluate their workspace as worst of all groups of workers. This result of the possible paperless office can also reflect the fact about the work load focus moved from clerical personnel to the professionals (cf. Section 8.1.4.6).

**It can be argued that occupancy or office room size do not correlate with the end-user evaluation of the quality of office automation equipment in general.** In other words, it cannot be presumed that the high quality office or building automation can substitute, affirm, compensate or mitigate lacks in the spatial quality of the building. **The realisation of the paperless office might change this argument after the office automation is made as suitable for paperless office work in regard to the work of executives and professionals as it is for the work of the clerical staff today.**

#### 7.1.3.5 Flexi-work

The modern office equipment allows better chances for working out of the office and regardless of office hours. This phenomenon has its advantages and disadvantages. An advantage is to work according to personal timing and other needs of life. A disadvantage could be the difficulty in separating the working hours from free time, which can even lead to a burn out.

Without any normative analysis of the need and quality of the office equipment, it can be concluded from the evaluations of the office automation of the IBs Survey, that the equipment of the IBs allows best interoffice working conditions (Table 50. and Table 51.). This seems to be parallel to the fact that in the IBs more work is done both out of the office and in ones personal workplace than in the reference buildings.

The equipment suitable for spatial flexibility of work is better evaluated in the reference buildings (Table 52.). In the reference buildings workers spend time in their colleagues rooms and the paging device and the answering machine are highly evaluated there. There are also working more women than in the IBs, and female office workers prefer the paging device and the answering machine better than their male colleagues.

The mobile phone is also evaluated better in the reference buildings for the sake of the work efficiency than in the IBs. It seems obvious that mobile phones can be more usefully used in the reference buildings and they can even prevent the work needed out of office. On the other hand, it can be concluded that the work in the IBs needs both connections: the personal ones and those via mobile technology, which is in the IBs taken care of with the portable computers better than in the reference buildings.

#### 7.1.3.6 Need of Building Amenities

The need for additional services in the office building was a design criterion for the Finnish intelligent offices (Section 4.3.3.1, cf. also Section 2.4.10), and questions concerning these services are still mostly unanalysed. Despite of the fact that different alternatives for providing the building with additional services, which might help with the every day domestic tasks, and otherwise help daily life etc., (Section 5.3.5.9) were included in the concept of the IBs, very few of these were carried out in the end (Section 5.3.3.2). The new office projects are again planned to include various types of services for recreation, healing and making the workers' day easier. Therefore it would be favourable to analyse if these end-user needs exist, although they are not changing very rapidly, since they are based on the human need of keeping up work performance.

The IBs Survey showed that among the shared spaces of office buildings the sport and recreation spaces were not considered as important (grades from 7.4 to 6.1) for work efficiency as the lobby, show and meeting rooms (grades from 8.5 to 7.2). The Survey also proved that the end-user evaluation of **the sport and recreation spaces in the IBs was significantly better** (7.4) than in of the other offices (6.4) (Lehto et al. 1997, p. 135).

The primary parameters of the building services were secretarial services, conference spaces and services, a reception, a travel office, information service, building management, ICT management and support, and shared services of several companies located in the same building. The IBs Survey proved a statistical difference between the IBs and the other office buildings on the behalf of some primary parameters of building amenities, as well as differences between worker groups and genders (Lehto & Karjalainen in Lehto et al. 1997, pp. 181–186.). The differences between the two office building types were favouring neither the IBs nor the other buildings. This was a reason why this phenomenon has not been studied in more detail yet.

The secondary parameters of the building amenities were: a food and drink vending machine, a cash dispenser (ATM), a kiosk or a grocery, child-care facility, health care services, an hairdresser or a barber, a nature cure or healing service, a car wash and a service station. The analyses of the secondary parameters are unfinished.

The summary of the end-user evaluation of all these parameters of building amenities or services in each building is shown in Table 17. and Table 18. No great differences were found between buildings, if the IB 2 is not taken account, but even it's end-user evaluation does not show a very much better value than those of the other buildings' services.

The analysis of the parameters of the primary building amenities reveals, that they are more important for the work performance of the female workers than for that of the male workers (Lehto & Karjalainen in Lehto et al. 1997, p. 185.). An interesting research problem is, whether it is possible that despite the design of the IBs, which is based on the androgyne needs of a human being (cf. Section 2.4.9.4), the final application of the facilities management services in the buildings of the IBs Survey was satisfying the male needs better than female ones. Accordingly, it is known that the executives have more power over the work environment. How much this fact has affected the assortment of the building services and their quality is another interesting research problem.

These factors of building amenities or facilities management services need a detailed analysis (cf. Sections 8.1.4.6 and 7.1.3.6), because they have so much importance in workspace design today.

#### 7.1.3.7 Man or Machine

The office workers were asked, if they prefer a man to a machine helping them with office tasks. In general, the building management is the most important personal service, in which the office workers who answered the IBs Survey wanted to have personal service (Table 36.). Personal facilities management service seems more important than the personal training or education and help with answering to the phone. **Neither the office building type nor the working status or gender has a correlation with the wish of having the personal building management.** It is universally popular.

*Table 36. The feasibility of machine aided systems.*

| Tasks, activities<br>*The sample of the second phase of the IBs Survey (n=302-339). Percentages of the respondents (%)* | Manually | By machine | Both |
|---|---|---|---|
| Building management (Building automation or building service personnel/building manager) | 92 *(n=279)* | 5 *(n=16)* | 3 *(n=8)* |
| Training and education (Educator or self education by interactive multimedia) | 84 *(n=259)* | 11 *(n=33)* | 6 *(n=18)* |
| Answering to the phone (Secretary or answering machine) | 70 *(n=237)* | 28 *(n=93)* | 2 *(n=8)* |
| Information services (Help from informatician or digging databases) | 42 *(n=127)* | 51 *(n=155)* | 7 *(n=20)* |
| Information transfer (Face to face meetings or conference calls, emailing, video-conferencing) | 37 *(n=116)* | 54 *(n=168)* | 9 *(n=27)* |
| Image handling (Help from draftsman or using software) | 37 *(n=119)* | 57 *(n=183)* | 6 *(n=19)* |
| Copying (Secretarial service or self service with machine) | 37 *(n=125)* | 61 *(n=207)* | 2 *(n=7)* |
| Text editing (Secretarial help or using software) | 27 *(n=90)* | 71 *(n=239)* | 2 *(n=7)* |

The text editing is the only office task, which would be handled differently in the IBs than in other offices. In the IBs office workers want to edit their texts themselves with the software (77 per cent of the respondents), but in the other offices they prefer manual help with text editing (65 per cent of the respondents) (*Pearson Chi-square p= .04146 and M-L Chi-square p= .04149*).

The willingness to use machines or have help from others is dependent on gender in copying and in the preparation of slides. Female office workers (42 per cent of the respondents) want to have help with copying more often than men do (32 per cent of the respondents) (*Pearson Chi-square p= .05297 and M-L Chi-square p= .05204*). Female office workers (43 per cent of the respondents) want also to have a draftsman to help with the preparation of the slides more often than men (30 per cent of the respondents) do (*Pearson Chi-square p= .05204 and M-L Chi-square p= .04447*).

The reparation of the slides correlates also to the status of the worker. The status of the worker influences also the willingness to use interactive education software. The professionals (65 per cent of the respondents) want to prepare their slides more often themselves with the software than the executives (45 per cent of the respondents) or the clerks do (56 per cent of the respondents) (*Pearson Chi-square p= .01154 and M-L Chi-square p= .01086*). Furthermore, the professionals (77 per cent of the respondents) want to use interactive education software less often than the executives (89 per cent of the respondents) or the clerks do (93 per cent of the respondents) (*Pearson Chi-square p= .04243 and M-L Chi-square p= .02488*).

The men and the professionals are more willing to use ICT for their tasks than the other groups of workers are. However, these differences are true only regarding certain office work tasks, and thus the differences are not very remarkable. This is the fact also with the difference between the use of ICT in the IBs and the other office buildings in this respect.

#### 7.1.3.8 Awareness of How the Technology Works

The results of the question about how well the office workers know how to use the technology available in the building according to the second phase of the IBs Survey are shown in Table 37. The detailed analysis of the whole sample is not available. In Table 37. is shown the results of the first phase of the IBs Survey on behalf of the differences between the two office building types. The results from the two phases of the IBs Survey are otherwise quite similar, but the differences between the IBs and the reference buildings on how well workers know how to use everything they need, are more significant on the basis of the sample from the first phase of the IBs Survey.

*Table 37. How well the office workers know how to use the equipment available in the office according to the building types in the offices.*

| Claims, *Percentages of the respondents (%)*<br>*The sample of the first phase of the IBs Survey.*<br>*The sample of the second phase of the IBs Survey in parenthesis.* | IB<br>*n= 118*<br>*(n=194)* | Non-IB<br>*n= 30*<br>*(n=163)* |
|---|---|---|
| I know how to use everything I need | 15 (37*) | 38 (46*) |
| I don't know how to use all technology | 43 (38*) | 25 (29*) |
| I feel I am in need of additional guidance | 33 (20) | 21 (20) |
| I don’t want to use technology any more than necessary | 13 (18*) | 8 (11*) |

Non-IB means reference buildings, which are not built according to the IB concept.

According to the results, the highly educated office workers do not know all the properties of the technical facilities they are using (Table 38.). Female workers and clerical staff are most in need of guidance, and executives the least. It seems important to take care of education and supplying information about new solutions, in order to get the best return out of the use of ICT in offices.

This unawareness of the uses of technical facilities corresponds with statistical significance with gender. Especially women feel that they need additional guidance in the use of technology. The status of the worker does not correlate with the unawareness of the uses of technology with statistical significance, but the differences are remarkable. No difference in this respect is found between the two office building types.

Although there are no statistically significant differences between the two office building types in how well office workers know or how well they think they know the uses of technology, the differences between them in that respect are obvious (Table 38.). In the IBs workers do not know the uses of technology as well as their colleagues in the reference buildings do.

*Table 38. How well the office workers know how to use the equipment available in the office according to the office building types, the statuses of the workers and genders.*

| Claims<br><br>*The sample of the second phase of the IBs Survey. Percentages of the respondents (%)* | IB *(n=194)* | Non-IB *(n=163)* | Men[1] *(n=186)* | Wemen[1] *(n=155)* | Executives[2] *(n=46)* | Professionals[2] *(n=171)* | Clerks[2] *(n=87)* |
|---|---|---|---|---|---|---|---|
| I know how to use everything I need | 37[3] | 46[3] | 44 | 36 | 41 | 45 | 36 |
| I don't know how to use all technology | 38[4] | 29[4] | 32 | 37 | 41 | 32 | 31 |
| I feel I am in need of additional guidance | 20 | 20 | 15* | 26* | 10 | 19 | 29 |
| I don’t want to use technology any more than necessary | 18[5] | 11[5] | 17 | 13 | 16 | 14 | 16 |

* ≡ significant statistic difference, $p< .0500$; [1] ≡ $p= .00909$ (Pearson Chi-square) and $p= .00917$ (M-L Chi-square); [2] ≡ $p= .05475$ (Pearson Chi-square) and $p= .05188$ (M-L Chi-square); [3] ≡ $p= .08881$ (Pearson Chi-square) and $p= .08886$ (M-L Chi-square); [4] ≡ $p= .08442$ (Pearson Chi-square) and $p= .08354$ (M-L Chi-square),[5] ≡ $p= .06397$ (Pearson Chi-square) and $p= .06137$ (M-L Chi-square); Non-IB means reference buildings, which are not built according to the IB concept.

In the IBs men are the majority and they know or they think they know the uses of technology better than women do, who are the majority in the reference buildings. The gender factor cannot explain the poor end-user evaluation results in the awareness of the uses of technology in the IBs. It seems obvious that in the IBs also men do not know well or feel uncertain about their knowledge of the uses of the technology.

*Table 39. How an office worker has learned to use ICT according to the office building types, the statuses of the workers and genders.*

| Claims *The sample of the second. phase of the IBs Survey. Percentages of the respondents (%)* | IB* *(n=197)* | Non-IB*6 *(n=159)* | Men* *(n=185)* | Wemen* *(n=154)* | Executives *(n=40)* | Professionals *(n=174)* | Clerks *(n=89)* |
|---|---|---|---|---|---|---|---|
| By education | 20[1] | 33[1] | 22[3] | 31[3] | 26 | 25 | 30 |
| By personal guidance | 36[2] | 46[2] | 34[4] | 48[4] | 37 | 40 | 41 |
| By reading manuals | 42 | 38 | 42 | 36 | 46 | 39 | 41 |
| Not enough acquainted | 30 | 25 | 25[5] | 33[5] | 26 | 29 | 25 |
| Not at all acquainted | 7 | 5 | 8 | 5 | 9 | 5 | 9 |

* ≡ significant statistic difference, p< .05; [1] ≡ p= .00373 (Pearson Chi-square) and p= .00379 (M-L Chi-square); [2] ≡ p= .04706 (Pearson Chi-square) and p= .04714 (M-L Chi-square); [3] ≡ p= .06183 (Pearson Chi-square) and p= .06223 (M-L Chi-square); [4] ≡ p= .00655 (Pearson Chi-square) and p= .00653 (M-L Chi-square)¸[5] ≡ p= .09417 (Pearson Chi-square) and p= .09461 (M-L Chi-square); [6] Non-IB means reference buildings, which are not built according to the IB concept.

However, it must be remembered that there are more technical installations in the IBs than there are in the reference buildings. This can influence the result, but still, the difference in the number of technical installations between the two office building types is not very remarkable (Section 5.3.3.2). The factor of the image of the high technology might have influenced this result in the awareness of the uses of technology. A study of this phenomenon of the image of high technology has not been included in the IBs Survey, although a question of the image of the building was included. The image of the IBs resembles that of high technology.

There is a statistically significant difference in how the knowledge of the uses of technology is obtained (Table 39.). This question was not included in the first phase of the IBs Survey. In the reference buildings education and personal guidance is more common than they are in the IBs. **Lack of education and guidance is a significant reason for the poor knowledge of the uses of technology in the IBs.**

#### 7.1.3.9 Participation in Design

The possibilities in influencing one's work environment are not evaluated as very good in the IBs, although the spatial flexibility of the IBs is better than that of the reference buildings.

As mentioned earlier (Section 7.1.1.2.) in the IBs the possibility to participate in the design of the work environment has been good and the workers' ideas have been realised well (Table 14. and Table 40.). There is a statistically significant and remarkable difference between the two building types in the workers' possibilities to participate in design, and this difference favours the workers of the IBs.

In general, the possibilities for influencing the design of one’s personal workplace are not very good. The majority of the respondents could not participate in the design of their work environment (60.4 per cent of respondents (*n*=407)). A bit more than a quarter was asked (28.3 per cent of respondents) and 11.3 per cent participated in the meetings which concerned the design.

The correlation between the possibility for the evaluator to participate in design and the good end-user evaluation result of the spaces is obvious (Table 41). All the best end-user evaluation grades originated from those groups of workers of whom at least every second had had the chance to participate in the design of the spaces. A similar correlation can even be to certain extent found between the possibility to participate in design and the end-user evaluation of the equipment

(Table 12.), but this is not as clear as that between the spatial end-user evaluations and the possibility for participation in design.

*Table 40. The test (F-test) of difference of the evaluators' possibilities of participating in design of working environment according to the office building types.*

| *Samples of first and second phases of the IBs Survey, n=534.* | IB | Non-IB |
|---|---|---|
| Participation in design of space [2] *(n= 480, p= .00371)* | 45* *(n=297)* | 30* *(n=183)* |
| Realisation of the design ideas [2] *(n= 280, p= .09208)* | 78 *(n=185)* | 68 *(n=95)* |
| Meaning of the beauty is important[2] *(n=491, p= .02799)* | 82 *(n=306)* | 82 *(n=185)* |
| Meaning of the beauty is not important[2] *(n=491, p= .02799)* | 7* *(n=306)* | 12* *(n=185)* |
| No meaning of the beauty[2] *(n=491, p= .02799)* | 12* *(n=306)* | 6* *(n=185)* |

[1] ≡ An index from 4 to 10 (the best) ; [2] ≡ percentages of the respondents; Non-IB means reference buildings, which are not built according to the IB concept.

According to the results of the second phase of the IBs Survey men (41 per cent (*n*=189)) had the chance to participate in the design of the work environment more often than women did (a statistically significant difference *Pearson Chi-square p= .03304, M-L Chi-square p= .02844*) (31 per cent (*n*=153)). Executives (48 per cent (*n*=48)) had this chance (*Pearson Chi-square p= .26249, M-L Chi-square p= .19935*) more often than professionals (36 per cent (*n*=173)) or clerical staff (34 per cent (*n*=85)) (the analysis of the whole sample is unfinished). Corresponding figures emerged in the end-user evaluation of the fulfilment of the wishes for the design. **Men in the IBs are in the best position to influence the office design of their workplace.**

Similarly, the realisation of the design is an important factor for the end-user evaluation of the spatial quality. A good grade from the end-user evaluation is based on the fact that the evaluator has been heard in the design of the work environment. This is true on the behalf of the other worker groups, but the female professionals make an exception in this positive correlation (Table 41.)

The best grades of the spaces originated from such worker groups to whom the beauty of the environment is important and who have had the possibility to participate in the design of the work environment (Table 41.). The male executives of the IBs make the only exception to this correlation. There are two groups of women, executives and professionals, in the reference buildings to whom the beauty of the environment is important and who have had no possibility to participate in the design of the work environment. They give also poor grades for the spaces.

Satisfaction with the designer and her or his awareness of the spatial needs of the respondent was significantly better (7.2) in the IBs than in the reference buildings (6.8) according to the results of the second phase of the IBs Survey (the analysis of the whole sample is unfinished). Men (7.2) were significantly more satisfied with the designer than women (6.7). The beauty of the work environment is in general important both to men and women, but more important (a statistically significant difference (*Pearson Chi-square p= .00068, M-L Chi-square p= .00064*) to women (very important or important 93 per cent (*n*=144)) than it is to men (87 per cent (*n*=179)).

Not very many would like to design the environment themselves (19 per cent (*n*=66/349)), but workers would like to choose the furniture and materials themselves, or pick one from several design alternatives for themselves, or to tell the designer about their wishes. The possibility to bring small things of their own to the workplace was quite important (27 per cent (*n*=95/349)), which is parallel to what Hood (1993) has notified about the importance of the ability to personalise (cf. also Section 2.5.3).

Hood (1993) has also emphasised the importance of the executives' involvement in the design (cf. also Section 2.5.3). It alone seems not to be enough. Actually Brill (1985) points out that the office workers certainly know more about their work than facility managers and designers, and probably more than their executives and that analysis of needs of work environment during programming and design of it should utilise workers expertise (cf. also Section 4.3.5.2).

*Table 41. The mean grades of the end-user evaluation of spaces' quality and participation in design and the beauty of the space according to the statuses of the workers and genders.*

| | | Executives | | | | Professionals | | | | Clerks | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Men | | Women | | Men | | Women | | Men | | Women | |
| *Samples of the first and second phases of the IBs Survey, n=534.* | Mean | IB | Non-IB | IB | Non-IB | IB | Non-IB | IB | Non-IB | IB | Non-IB | IB | Non-IB |
| Spaces (4–10)[2] *(n=447)* | 7.6 | **8.0** | **7.7** | **7.9** | 7.1 | **7.8** | 7.5 | **7.6** | 7.2 | 7.4 | 7.0 | **7.7** | 7.1 |
| Participation in design of space[1] *(n=407)* | – | **44** | **43** | **62** | 25 | **45** | 36 | **51** | 17 | 33 | 20 | **63** | 35 |
| Realisation of the design ideas[3] *(n= 407)* | – | **100** | 56 | **90** | **75** | **72** | **76** | 72 | 54 | 71 | 40 | **76** | 63 |
| Meaning of the beauty is important *(n=296)* | | 72 | **79** | **92** | **88** | **86** | 75 | **80** | **93** | 69 | 60 | **91** | 76 |
| *n* | | *34-54* | *9-14* | *10-13* | *4-8* | *53-86* | *29-50* | *32-43* | *13-44* | *7-12* | *5-10* | *25-47* | *19-35* |

[1] ≡ The per cent of the responses; [2] ≡ An index from 4 to 10 (the best); The bold text is for the best or biggest values. The underlined text is for the smallest values. Non-IB means reference buildings, which are not built according to the IB concept.

It can be concluded that the possibility of participating in design correlates with the end-user evaluation of the spaces. Women are not as satisfied with the design and designers as men are, and they cannot participate in design as often as men do, but their expectations on the beauty of the environment are higher than men's.

### 7.1.4 Influence of Socio-economic Factors

It has become clear so far that the demography and socio-economic factors correlate with many of the phenomena in the differences between the IBs and the other types of high quality office buildings, and more evidence of this will be given in the following sections.

Due to the random access type approach of this study the overall picture of the intelligent office building is drawn from the pieces of information gathered from the examination done (Section 5.2). Still, many factors need further detailed analyses. During the further studies of this data it would be fruitful to the result of the IBs Survey to analyse statistically the socio-economic factors in a systematic manner (cf. Section 8.2.7). The summaries of the end-user evaluations of the building properties and their correlation both with the status and gender of the worker could be accompanied with analyses, which use such parameters as: education, the number of factors in each category (e.g. whether the respondent belongs to the minority or the majority), the work and life satisfaction correlation per various factors, analysis of the influence of the marital status on end-user evaluations, etc. Overtime workload and sick leaves have already been analysed. This information should be accompanied with the analysis of the questions on the office workers' ability to influence their work environment, and its design, and the importance of the beauty, mass, occupancy, and location of the building.

Of the socio-economic factors, the salary does not have much power as a parameter, because in many cases the income differences between men and women are so remarkable, that the comparison of the differences between end-user evaluations on the basis of incomes end up with similar results as the comparisons on the basis of gender.

**I am arguing that a systematic analysis of the effect of demography and socio-economic factors of the office workers can reveal the true lacks of the office building design, and form the basis for the new design criteria. This will not be only a question of user interface or usability of the building and spaces, but the social and mental human patterns would be used as new criteria for building dimensions** (Figure 34., Section 7.3.7, cf. also Sections 8.2.7.6 and 8.2.7.12).

Interestingly, the transparent information society phenomenon seems to offer a fruitful context for the research on the human behaviour at work.

#### 7.1.4.1 Status of the Worker

**According to the above end-user evaluation results, it can be argued**

- **that the modern office equipment is not as suitable for the work of professionals than it is for the work of executives and that of clerical personnel, and**

- **that the modern office space is more suitable for the work of executives than it is for the work of professionals and that of clerical personnel.**

**Furthermore, it can be argued that the IB concept has had an effect in creation of a good working environment, but the differences between worker groups have remained.** The meaning of the status of the worker seems to have quite a strong effect on the evaluation of the quality of the physical working environment in the organisations of the occupant companies of the studied office buildings, whether they are intelligent or not (cf. Section 7.1.4.5).

#### 7.1.4.2 Gender

The gender differences turn out to be an important factor (together with the status of the worker), which differentiates the IBs from the reference buildings in:

- the character of the office workers (Lehto 1996c),

- the end-user evaluation of ICT-tools' value for the working efficiency of the office worker (Lehto 1996c, Lehto 1997a, Lehto 1998d, Lehto 1999f, Lehto 1999a),
- the need of education in the use of office ICT-tools and IB features (Lehto 1998d),
- business travelling and substituting business trips with ICT aided office working tools (Lehto 1999e, Lehto & Himanen 2002b),
- the possibilities of indoor air control (Lehto & Karjalainen 1997, Lehto 1997a, Lehto 2000c),
- the possibilities to control the working environment (Lehto 1999c, Lehto 1997a, Lehto 1998d),
- and in the possibility for distant or telework at home (only 21 per cent of women and 56 per cent of men think that they can telework and most of these office workers are executives or professionals, while only 17 per cent of the clerical staff claim that they can telework, while the same figures among other worker groups were 49 or 48 per cent).

According to the IBs Survey women in the office evaluate their possibilities in controlling their work environment and adaptability of it poor. It is worth studying this aspect further, while the control over the working environment is essential for experiencing the workspace supportive. Even within this survey it is possible to list systematically all the end-user evaluations on workspace control and study their summary according to gender. So far, the analysis has been made keeping the building properties in focus without focusing on gender. Still, the gender aspects have repeatedly arisen.

The differences between genders seem to reflect the traditional reasoning even though they are not quite unambiguous (Lehto 1999e). Men prefer mobility and trust in mobile phones and portable PCs, while women rely upon devices used locally, such as email and conference calls. The traditional thinking of the use of telematics has also been apparent in the studies on the use of telematics at home (Lehto 1998b, Lehto 1998d, Lehto 1999c). Are the female executives the weak signal of the future trend of productive office work; they are the heavy business travellers, who trust on the best interoffice equipment for superior work performance, not on the portable technology only.

Weak signals of change have been found among female executives, who seem to seek for solutions in order to manage in the knowledge work environment. They are heavy users of ICT tools. At the same time, they travel much although they think ICT can reduce business trips. They can get most out of the modern technology compared to other office worker groups, and they seem to enjoy their stay at work in the IBs. Still, they agree with the critics on such matters as bad indoor air control, poor thermal comfort, etc., which have turned out to be of poor quality according to studies based on both the physical measurements, and the end-user opinion.

Female professionals felt that especially mobile phones and paging devices are not very useful in their work (Lehto 1997a). It was presumed that this could be due to the more numerous interruptions at work (and maybe in life in general) among women than men. Unfortunately, the interruptions were not included in the questionnaire, although among the questions about the voice environment there is one, which included such factors as the speech of others, phones ringing, and the copying machine, which all can cause interruptions at work. A possible cross-referencing of these two questions may give some idea of the problem.

Women are active in the information intensive work, and in the intelligent offices they work longer hours with the computer than their male colleagues (Lehto 1997a, Lehto 1999c). The amount of long working hours and unpaid overtime work correlate to the socio-economic position and gender (Julkunen & Nätti 2000, p.176). They cumulate to entrepreneurs and executives, as well as to men. **According to this sample overtime work is most common among the executives, as Julkunen & Nätti have argued. However, there are no differences between male and female workers, or the overtime work done by the workers in the IBs or the workers in the other types of offices.** This finding is not in line with the findings of Julkunen & Nätti (Flink and Lehto in Lehto et al. 1997, p. 242).

In other worker groups than among executives the overtime work is as common in each without an exception. **The overtime work is as common among female professionals in the IBs (1.6) as among executives in general** (men 1.8 in the

IBs and 1.7 in the reference buildings, women 1.8 in the IBs and 1.6 in the reference buildings).

The overtime workload can on its behalf explain the female professionals' low evaluation grades of the equipment (Lehto 1997a) in the IBs. As stated earlier, the equipment is not as suitable for the professionals' work as it is for the work of the other worker groups. In other words, professionals' work places more demands on the performance of the office equipment than the other worker groups' work (cf. Section 8.1.4.6).

The women's feeling that they are in need of more advise for the use of ICT can also be reflected on their evaluation of office and building automation. On the other hand, it is good to notice that women's attitudes towards the march of ICT into the office is positive. They do not think more often (68 per cent of female respondents) than men (66 per cent of them) that the new technology is there in vain, although the female workers feel that they cannot always use it in the best possible way.

**It can be argued also in the case of the genders as in the case of the status of the workers – on the basis of the end-user evaluations of the working environment – that the IB concept has had an effect in creation of a good working environment, but the differences in the workspace evaluations between genders have remained. It makes one ask, if it does mean that there is a need for having separate workspace design criteria for different genders or if more knowledge of taking the different needs of the two genders into account in workspace design is needed, and further on, if there is need for getting common solutions, which satisfy needs of the both genders.**

The author would like to say that as the differences between genders have remain such as they have traditionally been according to this and some other surveys she has accomplished, it may be that they always should be as they are (cf. also Lehto & Himanen 2000) despite the latest progress towards similarity of the genders. Although the androgyne people use both male and female skills in their work, and such abilities are worth while targets of whom so ever, each of us might still reflect more other of the genders, and get best out of the circumstances planned according to needs of gender, which sounds to be most of the one's own. The equal respect of differences in life styles and working patterns will follow from the approval of all differences, including also those between genders – their needs, behaviour, etc. The well known fact of the difference between similarity and equality has been discovered. The dominating values cast their own shadow over the gender matters during the times.

The end-user opinion has turned out to be very reliable in the case of female executives as the end-user opinion has done in other cases during this research, despite of the fact that they are not many. However, they do agree, and thus the sample is very coherent. Presumably, this is true due to the respondents' ability in judgement due to their high education (cf. Castells in Julkunen & Nätti 2000, p. 179), because over half of them have an university degree. Regardless, this same phenomenon of the reliability of the end-user response has turned out to be true in other post-occupancy studies carried out by the author, also in such cases where the education of the respondents have been lower than that of the population in general (Lehto 1998b, Lehto 1998c, Lehto 1999d).

#### 7.1.4.3 Age of the Occupants

**The average age of the office workers does not differ in the two different office building types** (Lehto, Flink & Karjalainen in Lehto et al. 1997, pp. 82–86). Still, it is known that age has an influence in the working organisations, but it is not known if it places any requirements on the physical working environment, or if the other factors of ageing reflect on the quality of the physical working environment. Some statistical analyses of the influence of age on the end-user evaluation results of the IBs Survey was made, and these showed no significant difference. However, the analysis is not thorough enough to say, if **the age does or does not influence the office workers' opinion about their working environment**.

In the questionnaire, the age was asked previously with two numbers without any categorising, which makes it possible in the future to analyse the age influence in several various sequences. An interesting approach to the age paradigm is to use the age sequences of the life span psychology in the analysis (cf. Dunderfelt 1992). It takes into consideration the human mental progress and the turning points at the ages of 28, from 35 to 42 (or 47), 50 and 60. All these ages have relevance to the working life period.

#### 7.1.4.4 Work Satisfaction

During the second phase of the IBs Survey work satisfaction was measured with different questions than in the first phase of the IBs Survey and therefore they are not comparable. In the second phase of the study the tradition of occupational psychology in formulation of the question about the work satisfaction was followed. The basic idea is that a person can be at the same time satisfied with certain areas of life and work and dissatisfied in others. In the first phase the question was simply asking if the person is or is not satisfied with her or his life by the scale of from 1 to 5 (the worst). Most of the respondents of the first phase of the IBs Survey were quite satisfied both with their life (30 per cent very satisfied, 64 per cent quite satisfied) and work (28 per cent very satisfied, 52 per cent quite satisfied). They were more satisfied with their life in general than with their work.

Work satisfaction was measured with several factors of satisfaction in tasks, in the company, in works mates, in executives, in the choice of profession, and in salary. Also, the satisfaction with private life was measured with several factors of satisfaction: that of the economical situation, of the level of housing, of family relations, friends, hobbies and of self-fulfilment.

The main interest of the study was in work satisfaction, but the satisfaction in private life was included in order to make it possible to check the wider situation in the cases of severe work dissatisfaction. However, severe dissatisfaction occurred neither with work nor with life satisfaction.

The work satisfaction (tasks, work mates, company, executives, choice of a career, salary) of the respondents is in general good (Table 12.). The first analysis of the answers on these questions of occupational psychology based on the second phase of the IBs Survey (Lehto et al. 1997, p. 242, Lehto 1999f) did not reveal any statistically significant differences in any of the worker groups. This means that the respondents are not reflecting their dissatisfaction with work into the evaluation of the building quality although the result is quite strongly dependent on the statuses of the workers.

It is interesting to notice that the female executives in the IBs are not the only group of workers who are exceptionally satisfied with their work. That is the case also with the male clerks in the IBs, as well. **It can be argued that work satisfaction correlates with the positive end-user evaluation of the equipment in the IBs, and vice versa.**

Both men and women are equally satisfied with the company and work mates (Lehto, Flink & Karjalainen in Lehto et al. 1997, p. 95). A statistically significant difference between men and women exists with such factors of work satisfaction as tasks, executives, and the choice of profession and salary (Lehto, Flink & Karjalainen in Lehto et al. 1997, p. 91).

**The satisfaction with work mates is the only factor of work satisfaction, which is statistically significantly better in the IBs than in other office buildings. As noted earlier, also personal contacts beyond company borderlines were valued highly in the IBs.**

It is expected on the basis of the end-user evaluations that the female professionals or clerical personnel might evaluate their working satisfaction as poor. The summarising analysis of the correlation between all the parameters of satisfaction in work and life, and the status of the worker and gender is unfinished. The analysis of the correlation between the status of the worker and office building type reveals, that the professionals in all of the two office building types are equally satisfied with their work. **It can be argued that work dissatisfaction does not explain the low evaluation grades of the quality of the workspace and equipment from the professionals' side in the IBs.**

The satisfaction with the private life (economy, housing, family relations, friends, hobbies, self-fulfilment) is also good and there is no statistical significant difference between the office building types or genders (Lehto, Flink, Karjalainen in Lehto et al. 1997, pp. 93–95). However, the satisfaction to salary and economical situation is dependent on the status of the worker (Lehto 1999f, p. 31). Executives are more satisfied than professionals, and professionals more satisfied than clerical personnel. As mentioned, this is not dependent of the gender, although the women's salaries are far poorer than those of men (Table 12.). The women's salaries were in all worker groups and in all of the two office building types far lower than the men’s. This is the case also with the female executives in the IBs, who are more satisfied with their work in general than other female worker groups (Lehto et al. 1997, p. 242, Lehto 1999f).

Women are statistically more satisfied with friends than men, which is the only factor which separates women from men in satisfaction with private life. **It can be argued, that although it seems obvious, on the basis of the importance of the friendships in private life (cf. Section 7.1.1.2, about the possibility for needed eye or speech contact), that social connectivity might be more the field of women, than it might be that of men, this is not the case at office work if one trusts the women's end-user evaluation about the importance of workmates, which does not differ from that of the men's. This result correlates with that of Goleman (1997) (Section 2.4.9.4), who says that the differences between genders cannot be found in all social indicators.**

#### 7.1.4.5 Nature of Work

The questions concerning the nature of the work were included only in the second phase of the IBs Survey. From the choices of work types (autonomous, group work (interactive), controlled), the executives regarded their work to be to some extent more autonomous (83 per cent ($n$=47)) than that of the professionals (78 per cent ($n$=167)), and much more autonomous than what the clerical staff considered theirs to be (64 per cent ($n$=83)). Group work was not very common; 6 per cent of executives, 5 per cent of professionals and 10 per cent of clerical personnel reported having group work. However, no statistically significant differences between these groups of workers could be found in the nature of the work (*Pearson Chi-square p= .09263 and M-L Chi-square p= .10885*).

In any case, the analysis of the work type cannot explain the difficulties, which especially professionals seem to face in their work regarding the work environment (Table 11.). It can be presumed and the figures above show, that the professionals' work resembles that of the executives more than the work of clerical staff, but the professionals evaluation disagrees about the quality of working environment more with the evaluation of the executives than with that of the clerical staff.

The work of clerical personnel is not very autonomous. In the overall analysis on the equipment clerks agree with the executives, although their work is very different from that of executives. The executives' work is in most cases most autonomous. It can be presumed to have a positive correlation with the end-user evaluation of space and equipment, because the possibility to influence one's working environment, in other words to act autonomously seems to be one of the important factors for the good end-user evaluation results (Sections 8.2.4 and 8.2.4). The proof based on a detailed analysis, however, remains to be found (Section 8.2.7.8).

**In general it seems in this phase of the analysis of the end-user responses of the physical working environment that in the studied offices in the Helsinki metropolitan area the status of the worker is a more dominant factor than the nature of the work or, as was previously found (Section 7.1.1.2) the gender of the office worker.**

#### 7.1.4.6 Working Hours and Overtime Work

The length of the working day is very similar to all. In Finland it is very common to work full time. Accordingly in this sample, the share of those who worked full time was a significant majority (Over 90 per cent of all groups of workers worked full time). Also distant work was very exceptional.

The type of overtime work makes the differences between different groups of workers. As mentioned earlier, it is a feature, which is related to the nature of the work, and which has influence on the differences between the two office building types (Table 14., Table 15. and Table 16.).

As mentioned in the section on the subjects of the questionnaire (Section 5.3.5), the types of working hours, and the types and amount of overtime work were asked about. The types of working hours were fixed, flexitime, free, and a combination of some kind. The types of overtime work were: compulsory overtime work at office, overtime work after consideration at office, voluntary work after working hours, work at home, periodically exceeded and undercut working time, or a second job for extra wages.

The majority of the office workers had working hours based on flexitime. The rest of them had either fixed working hours or free working hours. The fixed working hours are somewhat more common with executives (21 per cent (*n*=47)) and clerks (18 per cent (*n*=85)), while only 13 per cent of professionals (*n*=168) had fixed working hours. Accordingly, flexitime was typical for professionals (66 per cent) and clerks (67 per cent), and free working hours for executives (15 per cent) and professionals (18 per cent). The differences are statistically significant (p<,05; Pearson Chi-square *p*= .00619 and M-L Chi-square *p*= .02068).

The amount of compulsory overtime work is typical for clerks (24 per cent (*n*=75)), while 12 per cent of the executives (*n*=42) and 7 per cent of the professionals (*n*=158) report to work compulsory overtime. The differences are statistically significant (*p*<,05; Pearson Chi-square *p*= .00325 and M-L Chi-square *p*= .00456).

All worker groups (58 per cent in average) reported to working overtime at their own consideration at the office. Voluntary overtime taking place somewhere else than at office and work at home was typical for executives (60 per cent voluntary overtime and 50 per cent at home (*n*=42)), but 32 per cent of professionals (*n*=158) reported to working voluntarily overtime or at home, while for the clerks the corresponding figures were 20 per cent and 11 per cent (*n*=75). The differences are statistically significant as follows: [1]voluntary overtime taking place somewhere else than at office (*Pearson Chi-square p= .00012 and M-L Chi-square p= .00017)*, and work at home (*Pearson Chi-square p= .00006 and M-L Chi-square p= .00003)*. The periodic exceeding or undercutting overtime was typical for professionals (28 per cent) and clerks (32 per cent), while for executives it was 12 per cent. The differences are statistically significant (*Pearson Chi-square p= .06891 and M-L Chi-square p= .04840*). To have a second job for extra wages was not very common (4 per cent of office workers).

**It can be argued that the overtime hours do not explain either the satisfaction of the executives nor the dissatisfaction of the professionals and clerical personnel with the office building properties, because the differences in overtime work between worker groups occur in such cases of overtime work which is taking place somewhere else than in the office building.**

## 7.2 Additional Indicators

Additional indicators are those, which were studied in the IBs Survey either in order to ensure the results of the end-user evaluation or to find out other benefits of the use of the IB concept in office building design than those studied in by the questionnaire. Often, the benefits of the implication of the IB concept are not only seem in the quality of the space and equipment, which the questionnaire measured best.

#### 7.2.1.1 Energy Efficiency

The sample for energy efficiency is very small (Lehto & Karjalainen 1997). The energy consumption reports were gathered from four intelligent office buildings. In every case, the reports were based on the total amount of two energy forms: electricity and heating. It was not possible in 1994 to get further information on the shares of various forms of energy consumption, not to mention reports on the energy consumption shares of each consumption point of the building. It would have been useful to know how much energy was spent for each of the categories of illumination, heating, cooling, computing, control, etc. This could have been especially useful, since the researchers were also studying the possibilities of distant working and its side effects on energy consumption in two office room cases; one at an office building and the second at home (Himanen et al. 1996a, Himanen et al. 1996b). According to discussions with energy experts in Sweden, the Netherlands and France, this has so far been the case in energy management reporting generally in Europe.

The energy consumption of the IBs was compared with the energy consumption of the average Finnish offices (Table 42., Lehto & Karjalainen 1997). The tendency was for the use of electricity to increase and for the heating energy consumption to decrease in the case of the IBs. The same results have been found in a study on the electrical energy consumption in office buildings (Shemeikka et al. 1996, p. 9) and in a resent study on renovation projects (Leskinen et al. 2001) with a somewhat larger sample (over ten) than that of the IBs Survey. The modernisation of the building gives a similar result in electrical energy consumption as when comparing new office buildings to the average energy consumption statistics of office buildings.

*Table 42. Annual energy consumption of the IBs compared to the average energy use of new offices in Southern Finland.*

| | Electricity kWh/$m^3$ | | | Heating kWh/$m^3$ (normalised) | | | Σ |
|---|---|---|---|---|---|---|---|
| | 1992 | 1993 | 1994 | 1992 | 1993 | 1994 | |
| IB 1 | 31 | 29 | 29 | 43 | 40 | 37 | |
| IB 2 | – | – | 16 | – | – | 27 | |
| IB 3 | – | – | 30 | – | – | 23 | |
| IB 4 | 17 | 20 | 23 | 26 | 20 | 27 | |
| Average in the IBs | 24 | | | 29 | | | 53 |
| Average in Finnish office buildings | 17 | | | 35 | | | 52 |

While the shift is towards the use of electricity, in Finland this has so far meant a shift towards the use of a more expensive form of energy. Further, this means that it seems difficult to gain the benefits, which could be gained by using IFM and which were summarised in section 2.5.4 (cf. Lehto 1999a).

The potential for energy saving with the use of the IB technology seems promising however, even according to this very small sample. One of the four buildings was using far more energy than the others did. Theoretically, during the analysis the best and the worst result can be left out. In this case, leaving out two cases (the most consuming and the least consuming) of four cases, the potential for energy saving in heating energy consumption rises from 17.1 per cent of the four cases to 28.6 per cent of the two buildings consumption of energy on average. The electricity consumption reduces from 41.2 per cent to 35,3 per cent. In the best cases the total energy consumption was reduced due to the building automation.

When comparing the energy efficiency of the office workspace and teleworking, it is clear that having two workspaces (one in the office and a second at home) consumes more energy than the alternative of a single workspace. This is especially so, because housing consumes more energy in general than office buildings (Himanen et al. 1996a, pp. 74–75).

On the other hand, if the office workspace is based on the non-individually assigned desk allocation practices and the home office is part of the home media centre, the grand total of the energy consumption can be less than it is in a more fixed system. This is particularly true, if the housing is built taking advantage of the low energy building technology by which the housing energy consumption can be reduced to a third (30 per cent) of current energy consumption in the existing housing stock. The use of renewable energy sources such as heat pumps or solar energy makes the energy budget even more favourable.

The energy saving due to less travelling and increased work performance are the side effects of the teleworking alternative, which speak for it where energy efficiency is concerned. Otherwise, the teleworking alternative is not a clear solution for energy problems, while its popularity is not guaranteed among all who have the best teleworking potential (cf. Himanen et al. 2000a, pp. 96–104).

However, even in the current situation the teleworking alternative for the office worker in the IBs has better potential for energy efficiency than that of the other types of office buildings (Himanen et al. 1996a, p. 87). This is because, despite of the heavy ICT, the automation works towards lowering energy consumption more effectively in the IBs than in other office buildings. The energy conservation potential is good and according to the design criteria of many of the IBs the location is often selected in such a manner that the business trips will be short and convenient, which also makes the energy balance good.

**It can be concluded that although there is not enough evidence of the better energy efficiency of the IBs in comparison to the reference buildings due to the small sample, the energy saving potential of the use of the IB concept seems undoubtable.** This potential confirms the difference found in the building quality evaluation, which speaks on its behalf for the use of the IB concept in office building design.

#### 7.2.1.2 Indoor Air Climate

The results of the indoor air measurements have been reported in the IBs Survey project report (Kovanen in Lehto et al. 1997, pp. 192–209). According to the indoor air measurements, in every building, the indoor air temperatures were too high, air stream velocity was very low, ventilation rates better than the norm and carbon dioxide concentration low, air humidity normal, and the air quality acceptable, but inconsistent, giving divergent values also in the IBs, and not only in the other offices.

The indoor air quality and the thermal comfort evaluation (Lehto & Karjalainen 1997) is very similar to the result of the indoor air measurement.

**It can be argued that the indoor air measurements are supporting the result of the post-occupancy study. However, the results of these both studies are not speaking for the good implementation of the indoor air design criteria in the intelligent office buildings of the sample of the IBs Survey.**

#### 7.2.1.3 Energy Efficiency and Indoor Air Quality

For the modern building industry the balancing of the energy consumption and the indoor air quality is becoming more and more important. **If anything can be said on the basis of this small sample, it can be concluded that it is possible to guarantee a good indoor air climate with a high energy consumption as well as with a low energy consumption (Lehto & Karjalainen 1997). The good indoor air and the energy efficiency in the sense of saving energy are not necessarily in conflict when applying the intelligent building concept.**

On the basis of the IBs Survey nothing can be said about this relationship, since the correlation between energy consumption and indoor air quality was not studied systematically by looking at various spaces, and the energy use of different consumption points. The overall figures about the situation in the buildings in general are not detailed or numerous enough for that type of comparison.

#### 7.2.1.4 Need of Business Travelling and Meetings

Regardless of status of the worker and gender 1–2 work related trips per week is a standard for an office worker according to this questionnaire – except for the female clerks, who travel less than the other groups (Lehto & Himanen 2002). The figure is the same as that of the Finnish employees on average, which make 0.28 work related trips per day (see Himanen et al. 1996a).

When comparing male and female executives, professionals and clerical staff in the IBs and in the reference buildings, it was found that those who travel most are male executives working in the IBs. They make more than 2 trips per week inside the metropolitan area, almost 4 trips a month heading for other parts of Finland and 7.4 trips per year abroad. Also, the female executives working in the IBs travel a lot for their work. They even have more trips abroad (8.4 per year) than their male colleagues have, but very few trips (0.4 per month) heading to other parts of the country (cf. also Lehto 1998d).

In all, professionals and clerical staff travel far less than executives in the metropolitan area and abroad. Personal differences may be greater. The number of those, who do not travel at all for business is very small (4 answers), as well as that of those, who have experienced the increasing potential of telematics (3–4 answers, 1–2 per cent).

Those who travel most are working in the intelligent offices. These professionals may have tried to find a workplace suitable for their tasks, which require many (foreign) contacts and a venue of telemetric services. Female executives in particular combine these two trends: a tendency for heavy travelling and an appreciation of the telematic devices.

The use of ICT is growing rapidly – much faster than travelling. In spite of the apparent complementarity, invisible substitution probably exists. Actually, we do not know how big the growth of travelling would be without telematically aided information exchange.

Human contacts seem inevitable due to many reasons, despite of the growth of the computerised information sources. 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 to keep up close relations and prevent loneliness, etc. by meeting. Although the limitations of the technology cannot be denied in substitution of face to face contacts, human engineering, usability studies, etc. try to develop new more user-friendly technical solutions, and at the same time prevent travelling. This has not been accomplished, since travelling and communication grow very fast together (Lehto & Himanen 1998), although their growths do not depend on each other's progress anymore (Himanen et al. 2000a). Still, it can be stated that the speed and effectiveness of the current exploitation of the global business opportunities, could not be possible without the efforts in information management and communication technology, and it might have had invisible influence in preventing the growth of travelling.

## 7.3 The Building Intelligence Framework

The BIF is on one hand, a result of the analysis process of the IBs Survey, and on the other hand, a result of the author's interest in the scientific research on the essence of the IB concepts (Sections from 4.1 to 4.3). The BIF is a combination of independent creative (systems) thinking and a literature review. During the problem setting of the IBs Survey in 1992, and especially during the analysis of the results of the IBs Survey since 1996, the idea of the metaphor between human intelligence and building intelligence became studied more deeply. In this section the IB concept is explained further and finally the definition of the building intelligence is presented.

This section also covers the conclusions of such results of the IBs Survey, which on the first glance seem incomprehensible. By understanding the incomprehensible seeming results of the IBs Survey the key factors of the BIF were found. In addition to the definition of the building intelligence the implementation of the BIF to the results of the IBs Survey will be covered.

A turning point in the research on the BIF was the fact that in the IBs of the IBs Survey, the glass roofed entrance lobby was evaluated as very important among the office workers for their work performance, although the time which they spent there during the working day was very short compared to the time they spent in their personal workspace, to which was not given good evaluation grades. There can be several mental reasons for this fact, which have not yet been studied, but are considered to have influence on good grades of end-user evaluation of the "empty" space in the office. In addition to them, a very practical reasoning for the result was found. MD. Hannu Penttinen and I had a conversation about the difficulties of female professionals with the ICT tools of the offices and the possible reasons for this. During that conversation Dr. Penttinen suggested to me that I read the book *Learning Revolution* by Dryden and Vos for a reason, which I cannot remember. Anyhow, there I could find the explanation of the meaning of exercise for the creative mental thinking of humans, which could explain the need of lobbies, which were not used all the time, but still important for the working efficiency.

After reading many books of human behaviour, in this book *Learning Revolution* I also found for the first time Gardner's classification for human intelligence, which seemed interesting in the terms of building intelligence, because it included so many human intelligent qualifications, which could right away have relation to the building intelligence, such as visual-spatial and bodily-kinaesthetic. They reminded of the existence of the spatial instinct in humans and its relation to the architectural design. Inter-personal and logical-mathematical intelligence seem to have a connection to ICT and building automation as well as. The beginning of the path to the scientific evidence of the metaphor between the human and building intelligence and the proof to the hypothesis of the human ability to lend her or his intelligence to the building, was found.

### 7.3.1 Technical Development in Relation to Human Characteristics

#### 7.3.1.1 Eras of Societies

For hunting food humans needed to be fast. Humankind solved the problem of food shortage with farming, but created concurrently the means of getting from one place to another faster by developing modern transport means (Figure 32.).

The basic idea of industrialism was to make hands work more effectively when manual work was aided by machinery in factory. Now, during the information era, it is the brain’s turn to become more effective. If more cannot be done, at least computing gives humans an additional artificial memory.

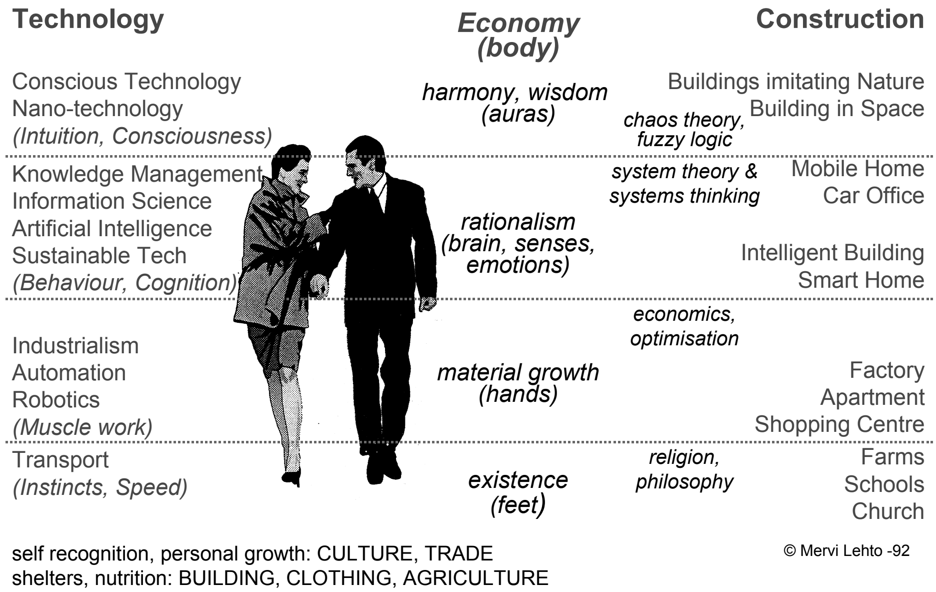



*Figure 32. The metaphor between human and technical development.*

A computer is also a patient repeater for constantly needed calculations, and even certain thinking patterns emerge in the solutions of artificial intelligence. Interactive information systems can teach through loudspeakers, by video and simulation tools repeating the message as many times as needed. It can test the skills of the student. A machine can watch and listen for us. If it cannot exactly see, smell and hear, it can get wind of the environment with its sensors. It extends our senses as well as our brains.

It is said that conscious technology is to come – could we say that it is coming already before there exists a good share of conscious, enlighten people? The progress goes from information via intelligence to wisdom in technology, nature, society, and individuals (Figure 32.). Material, social and mental (spiritual) insights work in this direction (cf. Section 2.4.8.2). The equality of social and mental values to techno-economic ones makes harmonious progress possible (cf. Wilenius 1999, Wilenius et al. 1976). Also individual needs, such as those of the Maslow's Hierarhy of Needs, determine considerations in the R&D work of IBs (cf. Section 4.3.5.2).

The IB concept of the author, dated to 1989, has turned out to be compatible with the idea of a wisdom age (cf. Rantanen 1996). It is following the information age or the service age, which may take place after industrial age (Zuboff 1990, Malaska 1993). The intelligent person is growing in wisdom by recognising himself and using emotional intelligence, life experiences, etc. (cf. Section 2.4.8.2).

**The intelligent building is dated to the information age, which is the time between the period of industrialism and the future wisdom age.**

Intelligent building is a tool for the activities of information intensive work of the information era. It aims to the material growth of the information age, but it also struggle with such problems as sustainability and ethicalness. Its near past is in the factory building of the industrialism, which was a shelter for the industrial production. Its future will be in the service or in the wisdom age. What will it be like? For the definition of the intelligence of the building is not necessary to know what the future building will be like or what the past building was like, because important is to understand that it is different from those. All information of the buildings of the past as those of future helps, of course, in determining the nature of the building intelligence of the building of the information age. The phenomenon called intelligent is widely used in machinery and production in general, not only in building in the information era.

It seems that intelligent is a simultaneous keyword with the information age, which is much about the implementation of the information and communication technology, e.g. technology for the satisfaction of the human social needs.

Next, after the detailed description of the IB concept definition of the author, the building of the wisdom age and that of the period of industrialism will be discussed. This is how the nature of the building intelligence – the property of a building of the age between the period of industrialism and coming wisdom age – can be discovered.

#### 7.3.1.2 Personal Growth

The IB concept is not only developing over time (Section 4.3.1), but every human's own history gives her or him the possibilities to understand what is smart, intelligent and wise, etc. Each has an interpretation coloured by his or her background, training and experiences. Groups of people form, via different types of organisations, the intelligence and wisdom of the whole mankind, or in other words, there are six billion (thousand million) different brains for six billion wise universes.

The definition of the IB concept by the author (Section 2.1.5) was based on two ideas: [1)] embedding the intelligent building concept to the information society paradigm and [2)] understanding the intelligence to be common both to mankind – the end-user of the building – and to a building.

This first estimation of the author's definition of the IB concept was based on the idea that the building built according to the IB concept satisfies the needs of an occupant, who is growing in wisdom.

A wise person can be characterised as a mature, enlightened person, who combines facts with experience without feelings based on irrelevant fears. She or he lives without sophistry, over-sensitivity, or unnecessary expectations for formal rigid esteem. She or he knows herself or himself, is aware of her or his rights, and is thus understanding, gentle and loving towards others, i.e. able to take the necessary responsibility for herself or himself and others. Dr. William G. Huitt holds that wisdom involves for example (Huitt 1998):

> *"Seeing things clearly or as they are, acting in prudent and effective ways, acting with well-being of the whole mind, deeply understanding the human and cosmic situation, knowing when to act and when not to act, being able to handle whatever arises with peace of mind and an effective, compassionate, holistic response, being able to anticipate potential problems and avoid them."*

An intelligent person is not necessarily wise, because the intelligence and wisdom are different dimensions (Himanen 1990). People in the information age add intelligence side by side to the physical strength, which was a powerful tool during the industrial age and essential for living of farmers and hunters (Figure 32.). Knowledge workers use even the bare knowledge for earning their living and satisfying their needs. These needs can follow the classification of the Maslow's Hierarhy of Needs. According to it humans are heading to the high mental abilities, which the author has understood to be those of a wise person, who is on her or his path towards the clear conscious state of mind and harmony between mind and body.

#### 7.3.1.3 Roles of Needs, Intelligence and Wisdom in Knowledge Management

The Maslow's Hierarhy of Needs starts from the physical needs of a human, continues with the social ones and comes finally to the mental wishes. The wisdom grows from the experience, but it is also typical for a mentally strong person, whose intuition is the capability to use and access the tacit components of meaning and knowledge. Intelligence however drives our quest for knowledge, the two faculties of consciousness are intelligence and intuition, but without intelligence intuition would just remain as an instinct. Wisdom can be considered as also a tool for choosing between various strategies, when targeting the knowledge or action in need (Figure 33.).

If the IB design criteria is looked at from the point of view of the definitions of the IB concepts, it can be seen that the IBs have been generated out of the new design criteria (Figure 46.). This is not based only on architecture, interior and layout design principles, civil engineering, building physics, indoor air paradigms, buildings services, etc., but on the combination of the technology and economy, and that of the technology and sociology (end-user orientation). Ecology has also been mentioned in the connection of the IB concepts, although the green building term has been used for the product of the sustainable building industry (cf. USGBC (www.usgbc.org), Green Building News (www.oikos.com)). Then the economy is understood as a concept of inputs and outputs, not that of costs only, how it has often understood in building (Figure 20.).

Human wisdom starts with the everyday acts performed by each of us (see also Figure 18.). The more conscious an individual is, the clearer her or his choices can be, and the more concerned of surrounding environment, for example of fellow men and nature she or he is able to be (Figure 43.). A conscious person understands the balance between their own (personal) and others' (collective) needs as well, and is thus able to work for their own and other's living and well being. Such a wise person knows also how to limit living within reasonable terms.

The process of clarifying the IB concept brings an awareness of both the needs of the building user, and the possibilities of combining hi-tech building solutions together. The needs of the occupant seems to be beyond all in today's construction and FM. Earlier they were in the shadow of technology.

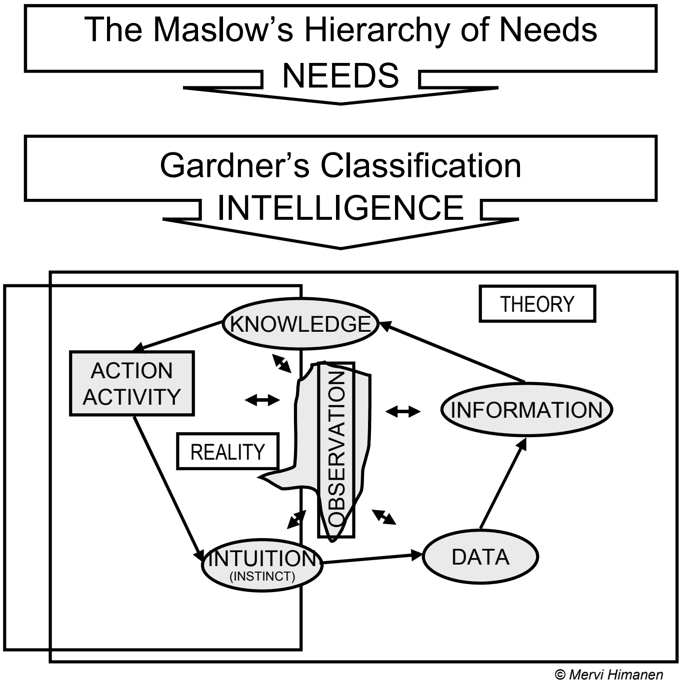



*Figure 33. The human strategy from need to satisfaction.*

Certain human needs, behaviour patterns, life styles, etc. are common to all of us or at least a large group of people. An aim of the process of defining intelligent building is to achieve an intelligent overall system of all kinds of building solutions that will serve the building user, in either the residential or office context, and in other types of buildings as well, such as hospitals, libraries, schools, etc. On the other hand, the perspective of an intelligent building will change when considering the use of a building and personal or organisational needs instead of the universal human needs. Therefore, each overall interpretation for the IBs is context based. Therefore, both universal IB solutions can be found and their implementations will be needed.

#### 7.3.1.4 Connectivity

Human species use their intelligence, while using articles designed for everyday use or professional work. Development of the user interface and usability has started from the solutions of ICT. The user interface is a well-known concept in other technologies also in building industry. How to connect the end-user to the building is a complex phenomenon. Good knowledge of this connection can be found from the research on interactive data bases. Already in 1987 the author distinguished that the user interface is including several facilities between the machine and man (Lehto et al. 1987, pp. 84–85).

The term "käyttäjäliityntä" in Finnish was used for **the connection between man and machine** within the interactive data base research team: Heimbürger, Nurminen and I. The Finnish Centre for Technical Terminology (Tekniikan Sanastokeskus ry. (TSK ry.)) agreed of it. It **could be called user connectivity** in English (Figure 34.).

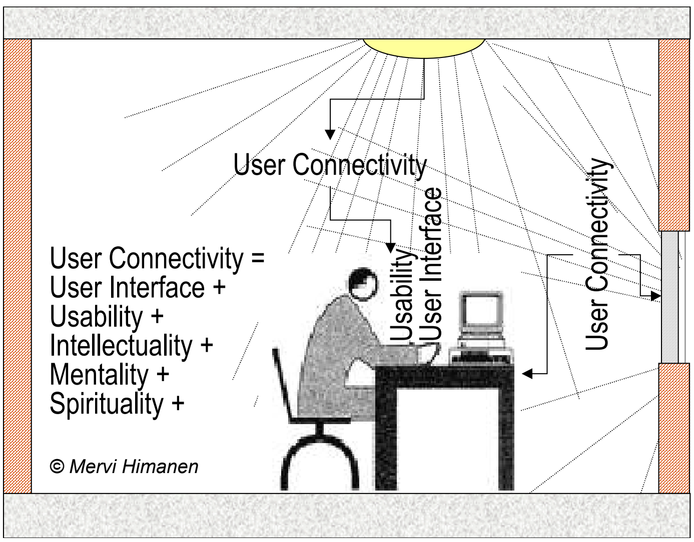



*Figure 34. The office worker faces the working environment. Examples of the user connectivity to the computer, lighting and the window.*

Today, it is easy to determine that this connection means at least the same as usability and user interface together. But it can be more. The psychological and social or other human aspects form natural design criteria for the user connectivity (cf. also Figure 46.).

**The user connectivity includes the user interface – a connection to human physiology which is made of an arm, a switch, a mouse, etc. This user connectivity can be broaden to include intellectuality, mentality and spirituality between man and machine in addition to human behaviour or psychology, which are included in usability.** Will there be more? In the IBs Survey this connection between man and building has been studied on the behalf of several factors (Figure 35.).

A basic idea behind industrialism was the fact that machinery took over the manual labour, which so far had been done by human hands. As mentioned above the building of the industrial age was a shelter for the industrial production. In science during the industrial age, the connection between the hand and productivity appeared for instance in the economics in Adam Smith's writing of invisible hand[2].

The metaphor between the hand and the brain or the connection of the hand and the brain has emerged with the adoption of intelligence in production. This connection is monitored in the research on cognition, and in usability studies of the information sciences. The latter is also taking into account the user of the object. **The connection between the brain and the hand makes it possible for a human being to use her or his intelligence** or as Bergson put it:

> *" ... [E]nable an intelligent being to act in its environment according to its capabilities and needs;"*

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[2] Smith's theory of invisible hand explains that if each person pursues his good, the good of society as a whole will result.

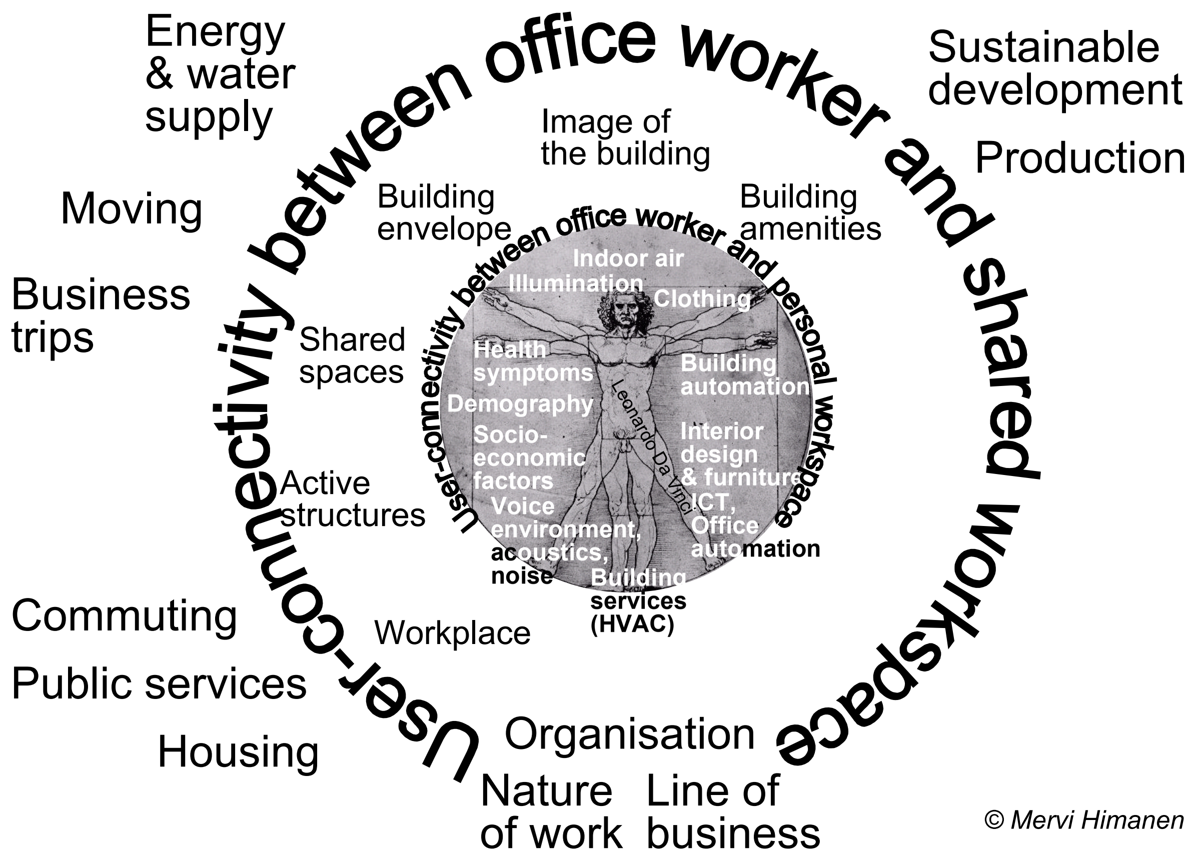


Figure 35. The user connectivity between office worker and building.

The idea of studying the connection of the building and the user in the sense of usability has already reached the construction field and as examples can be mentioned such projects of the European Commission Fifth Framework Programme as EBOB and IDEA. Studies about the usability of the control units of the automated production lines, which actually are rooms in the factory building, has been under careful research for some time. Within this research senses and emotions are also included in addition to cognition.

**I am arguing that, the idea of the metaphor between the hand and the brain used in (industrial) economy, has been articulated in building industry in the realisation of the fact that buildings should be kept as assets in the production.** It has been articulated within the building industry relatively late, on the stepstone of the information age. Still, **it has existed since functionalism became a leading architectural style, which is particularly true in the architecture of industrial buildings, but also in the office building architecture**.

The articulated intelligence of the information age could be applied in the building industry in a manner, which also looks to the next step in the continuation of eras of civilisation, towards the service age, due to the development of the usability and demand driven construction. There lies the idea of combining the hand and the brain. In what extent this message of usefulness of the usability studies and the results of the cognition science will be heard in the building sector, influences not only the speed of progress in the construction industry of the information society, but the whole information intensive progress, which is going on in various sectors. If one of the sectors is slow and retarded or conservative, it will slow down the whole progress. The progress goes on via mistakes and successes in any case, slower or faster. **I am arguing, however difficult it is to separate the functions of brain and hand, that the application of the results of the cognition science as well as connectivity are the key factors in the development of the intelligent buildings.**

### 7.3.2 Proof of the BIF – Chain of Evidence

The strong dependency of the differences between the two office building types – intelligent ones and reference buildings – on such factors as the status of the worker and gender speak first of all for the influence of the human factors in end-user evaluation of building and technology. It tells also of the existence and importance of the human dependent features in the technology and building (Figure 34.). This may be forgotten or even earlier denied in many cases. After the introduction of the IB concepts – such as the one of the I.B.I.'s in 1988, those by the EIBG during the 1990's and many other that after – the role of the end-user has become more important in the building industry.

By definition engineering[3] is copying the nature. Engineering is not only copying the nature that exists outside of humankind, but a human being is building houses – and machines – of her or his kind, i.e. she or he is copying her or himself (Figure 32., cf. also Sections 4.3.3.1 and 4.3.3.4). The definition of the human intelligence can explain (Gardner 1983 in Dryden & Vos 1996, pp. 120–123, Gardner 1991 in Dryden & Vos 1996 pp. 345–352, Gardner 1993 in Tuomi 1999, pp. 107–110, Gardner (1993) in Dunderfelt 1998, p. 28) the recent development of intelligent buildings (Figure 36., cf. also Figure 49.).

#### 7.3.2.1 Intelligent Building Features

As mentioned, the clarification of the IB concept is a development process, which brings an awareness of the needs of the modern building purchaser or real estate developer, and of the possibilities of combining hi-tech building solutions. The aim of this process is to achieve an intelligent overall system of building solutions that will serve the building user. This intelligent facility must have a long service life and must lend itself to modifications during its life cycle. The development process has consisted of assembling different concepts, extracting from them the core constituents of an intelligent building concept, and passing on information concerning international developments.

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[3] Technology is defined as (Nykysuomen sanakirja): "1. jnk valmistamisessa, suorituksessa tms. käytetyt menettelytavat, menetelmät; teko- ja suoritustaito; jnk tarkoitusperän saavuttamiseksi tarvittavien ... keinojen tuntemus ja käyttötaito ja 2. luonnon ja sen lakien tuntemiseen perustuva (käsityömäinen tai tehdasmainen) toiminta, se aineellisen kulttuurin puoli, joka perustuu tähän toimintaan". (free translation: "1. procedures, methods used for production, achievement of something; ... 2. action (manual or industrial), which is based on the knowledge of the nature and the laws of natural sciences.)

The IBs Survey results show the clear differences between the IBs and other office buildings, but the reasoning based on the existing IB concepts is not totally clear. The difference in technical installations does not totally explain the better grades given to the equipment in the IBs compared to the reference buildings. It can be concluded, as has already been done previously, that it seems that the IBs superiority is based on more than one of the elements of the IB concept, and the intelligent subsystems of good standard, which form a functional combination. All this rests on knowledge of high standard engineering for the correct technology needed, i.e. on systems thinking.

The IB concept parameters are factors of the use of human intelligence, a consequence of the existence of human intelligence, and also a measurement for the existence of a building, to which humans have lend their intelligence (Figure 36.)

Intelligent building concepts have been used for technical purposes. They can be considered as a part of the technology (cf. Section 4.1), which produces products, or in the case of construction industry buildings. The definition of the building intelligence is a result of science, which produces knowledge. As mentioned earlier, the IB concepts have been used both for the means of creating space and as a concept for spatial requirements. For both of those above mentioned purposes the definition the building intelligence is needed, but it is especially important for the latter one.

Humans are lending their intelligence to the building, while they build a building according to their wishes by imitating nature, i.e. him or herself (Sections 4.3.3.4 and 4.3.3.1). The logical-mathematically talented engineers are installing computers and sub-control units to buildings as "brains" and local area networks as "nerves". Via these lines and knots messages interact, and the building is aware of its state. Artificial vision or hearing refers to the human senses as well as to technical sensors. The building has senses for knowing about the indoor air quality, the condition of the structures, the need for maintenance, the outdoor air quality, etc. (Figure 4.).

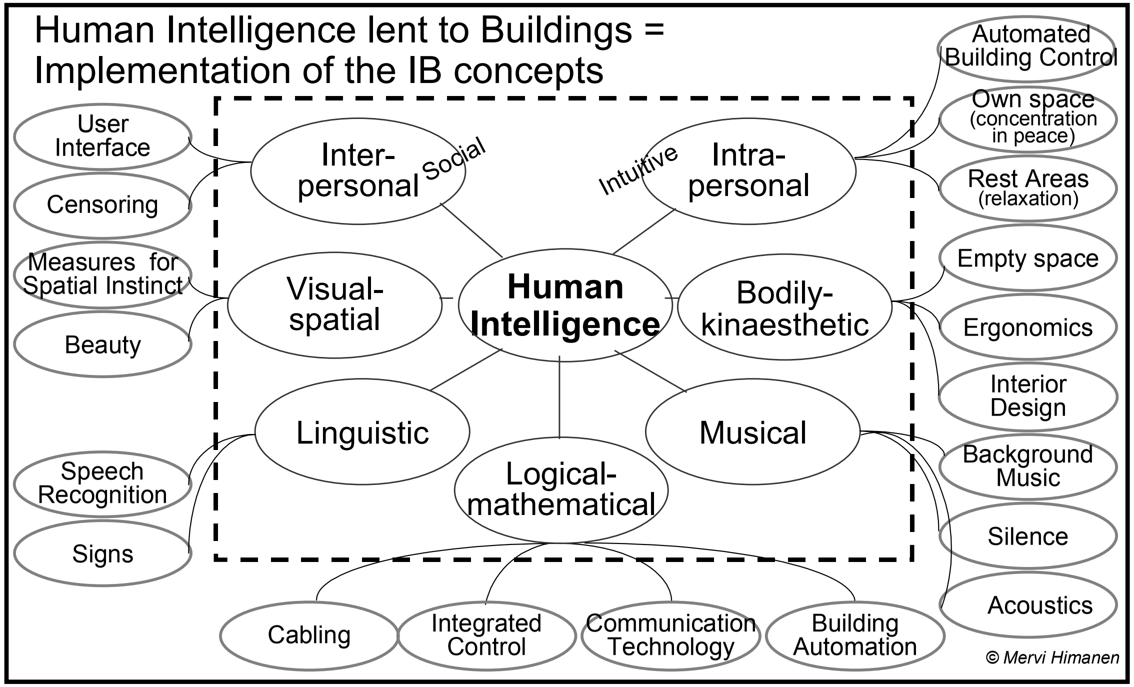


*Figure 36. Examples of the implementation of the intelligent building features and their connection to human intelligence.*

Further more, the IB system is interactively aware of the number of occupants, their needs and conditions. It can accept or not the calls of visitors knowing the allowances for accessing codes for tenants, regular visitors, outsiders and those not invited at all. The structures and furniture can monitor the occupant and help in communication, as it is the case with the healthy toilet seat, which sends information of health condition directly to the doctor.

Having signs, speech recognition, etc. refer to the linguistic intelligence. The building properties, such as sounds from an indoor waterfall, background music and silence or acoustics indicate human musical intelligence. Although building is having senses through its sensors and it can speak by repeating a tape or it is able to synthesise speech, it is hard to think that it could speak, sing or listen to the music, etc. for the sake of, for example, its own entertainment or intellectual enjoyment. The building properties related to human senses are more the building ability to interact and they correspond to human intrapersonality.

Active structures like automated doors and windows, moveable kitchen cabin, sun shadings controlled by the weather condition, etc., resemble the bodily-kinaesthetic human quality. On the other hand, human bodily-kinaesthetic intelligence might be promoted by spatial flexibility or by empty space and mobile technology, which allow the physical motion needed for creating new ideas (Dryden & Vos 1996, p. 354). Exercise and good indoor air together give needed energy and oxygen for brains and digestion (Dryden & Vos 1996, p. 135). Mobile phones together with the glass roofed lobbies are a mean for promoting new healthy office design which allows human bodily-kinaesthetic to act. The ergonomics of the office work has new dimensions (cf. Section 2.4.). Having everything within the hand's reach is not the only design criteria for office rooms any more. Floor plans and indoor air design are to have new design criteria as well. The beauty of the space can promote human intelligence through the visual-spatial experience.

#### 7.3.2.2 Stakeholder Actions

The end-user orientation has been an important key word of the IB concepts (including my own). Usability faces the different user groups or stakeholders of the IBs mentioned already in Section 2.1.6. End-user orientation and use of usability are a common trend in the business life of various sectors.

As mentioned earlier, Bergson has argued that:

> *"A fundamental role of intelligence is to generate distinctions that enable an intelligent being to act in its environment according to its capabilities and needs;"*

**I am arguing that this factor of user orientation in the IB concepts has been a weak signal of the desire to find the metaphor between human intelligence and building properties.**

**I am arguing that the human intelligence has generated the IB concepts (Section** 2.1.6**), which enable an intelligent human being to act in his/her environment according to his/her capabilities and needs.** The IB concepts are distinctions of various kinds of IBs – various kinds of stakeholder needs (Figure 36.). That has been the purpose of several IB concepts, and in it they are very accurate.

The market pull oriented construction industry, which is not especially typical only for the IBs, but all buildings, highlights the importance of the paying customer, which is the organisation and its representatives, who are in charge of the purchase of the workspace. The intelligent building concepts are rather dealing with the use of human intelligence as tool for benefiting the needs and interests of the building stakeholders than consciously lending the human intelligence to the product: building, equipment or service.

**The IB concepts based on the end-user or other stakeholders needs and interests do not separate the IBs from other types of buildings, because the IB concepts include parameters, which are also common to other types of building concepts.**

When defining the IB concepts the roles of each stakeholders have not been discussed or defined. On the basis of the IB concepts it is unknown, whose intelligence is lent to the intelligent building features (Figure 36.). This issue will be clarified using the stakeholder classification defined in this thesis as a starting point (Figure 16.).

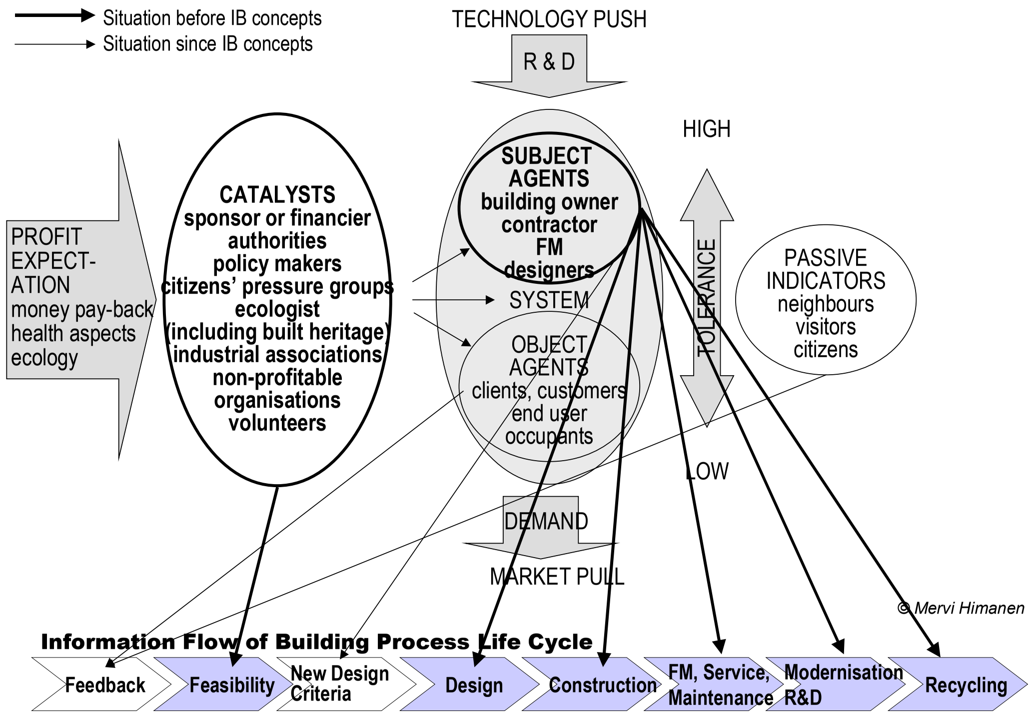


*Figure 37. The object agents and passive indicators can take the role of subject agents in the design process via the feedback information. Simultaneously the role of the subject agents becomes two sided. It will be that of the designer and that of the creator of new design criteria.*

From the comparison of the stakeholder roles it is clear that the subject agents lend their intelligence to the buildings rather than object agents (Figure 37.).**The end-users, it is, the object agents will not get that role of the primer lender of their intelligence to the building ever, if the end-user is not taking part to the building process. In other words, if they are not taking the role of the subject agent.**

The role of the users in making the building work intelligently is mainly unknown, while for example, the effect of other factors than those of the indoor air quality on working efficiency have not been studied widely (Figure 38.).

The methods for gathering the end-user feedback are not very well developed and systematic methods for the creation of the new design criteria for the new construction projects on the basis of the end-user feedback is hardly at all existing (Figure 11., Section 4.3.2.1). The post-occupancy study has been the only one for end-user feedback. Several possibilities to develop new methods and improve or adapt the existing ones are available (Figure 10. and Figure 17.).

So far the methods of taking the end-user feedback into account are not well developed and the end-users' subject role is doubtful in building.

**I am arguing that the end-user orientation does not identify current intelligent buildings and other intelligent systems, because so far the end-users have not lent their intelligence to the buildings.**

At the latest since the introduction of the IB concepts the end-user participation to the design has become more common, and work on the subject is vital at the moment. How important the end-user feedback ever can become, the fact is that the building industry or builders take care of building. It is mainly the role of the subject agents to take care of the lending of their intelligence to the building (Figure 16.).

The IBs Survey – an occupancy study of its kind – has shown that the end-user participation into the design makes the use of the building – the created intelligent tool – more useful proved by the EWE. Via participation into design the end-user can lend her or his intelligence to the building or space.

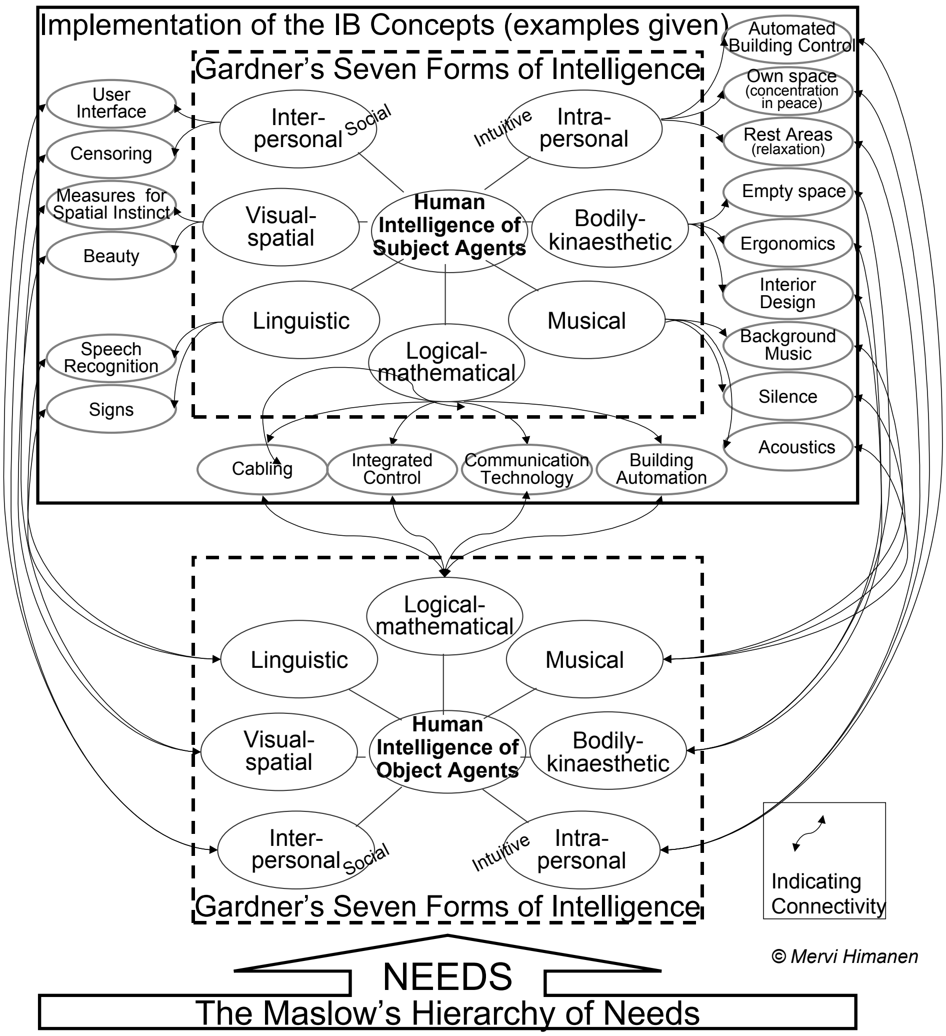


*Figure 38. The roles of the end-user and other stakeholders of the buildings, and their connectivity to the IB concept implementations.*

The IBs Survey has shown that the IBs are able to take the end-user needs of the working efficiency better into account than the reference buildings, which proves that implementation of the IB concept has succeeded.

**Till the introduction of the IB concepts the building intelligence has been due to the ability of the building developers and designers to lend their intelligence to the building. Since the introduction of the IB concepts the**

**building intelligence has been due to their ability to understand, interpret and decode the end-user information into the design criteria.**

**Further more the result of the IBs Survey proves that the developers' and designers' ability to understand, interpret and decode the end-user information into the design criteria has succeeded in the IBs (**Figure 37**.).** Understanding is due to their skills in implementation of the interaction between the building and the end-user.

**It can argued that the end-users can take the position of the subject agent in the building by means of the end-user participation into the design or via the feedback information to the creation of new design criteria. Then also the object agents are lending their intelligence to the building.**

The catalysts and passive indicators are seeking this same position of the new type of subject agent in building as well as the end-users do. No wonder that the green building concept, for example, has been mixed into the IB concepts or the FM concept.

#### 7.3.2.3 The Workplace

While humans are wise as well as intelligent, there are several parameters involved in the interplay of the building intelligence and the human occupant. It is a well known fact that we should be able – at least – to separate phenomena or concepts of the physical working environment (workspace), those of the personal characters (work cell) and the organisational or social factors (workplace) from each other in order to be better able to understand the roles and interaction between human, building or the collective intelligence of them (Figure 39.).

The interaction between the building and the end-user can take part in understanding each other, if not even the building could be in the role of sympathiser. This doesn't work, if the building is not able to self recognition and on the other hand to interpret the information from the interaction into the building operations such as building services, amenities, etc.

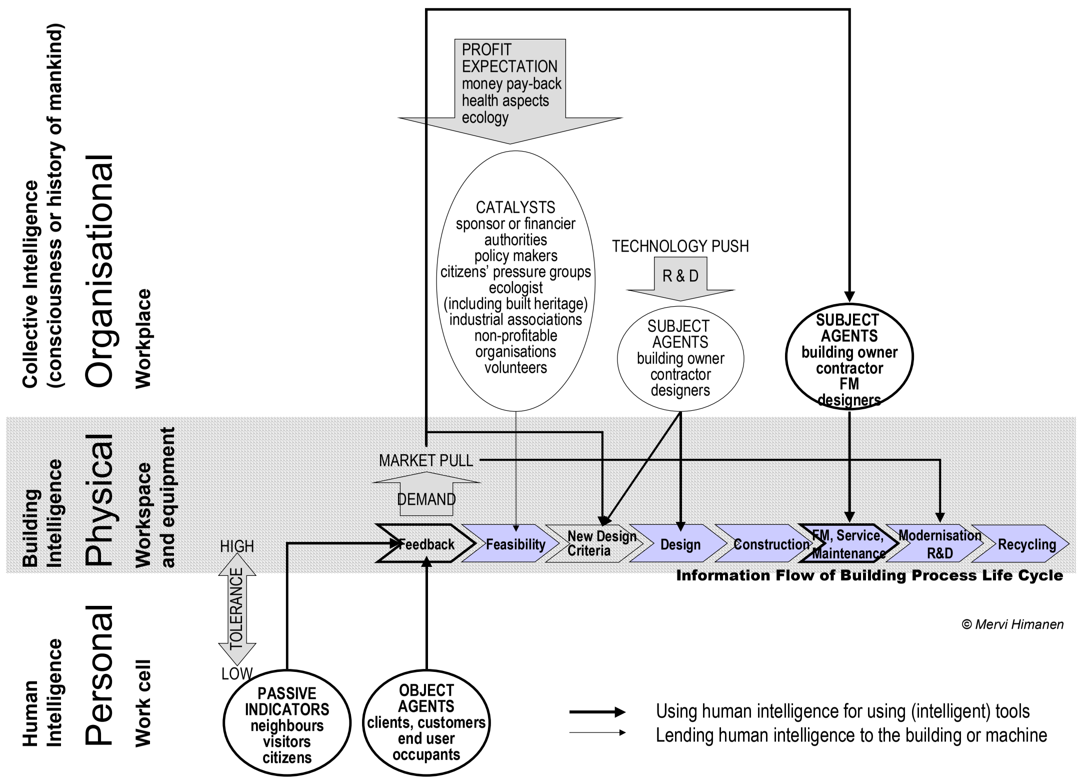


*Figure 39. It is needed the sorting of the personal, physical and social space in order to understand the function of the human intelligence, when it is used for human tendency to make artefacts and when to the satisfaction of human needs.*

Then it is once again the intelligence, which is operating, but now in the role of using tools not making them. As well as the human intelligence uses tools, the building intelligence can use the tools. Buildings benefit the stakeholders and building itself, which can mean for example the pre-emptive maintenance.

Still following Bergson's idea it can be argued that:

**A fundamental role of building intelligence is to generate distinctions that enables the intelligent buildings to act according to their capabilities and needs.**

However, the building intelligence enables the intelligent buildings to act according to their capabilities and "needs", which can be originated for example from the fault diagnosis. The building capabilities are according to the IB concepts shown in Table 7.

These capabilities are those, which have been included into the IB concepts and summarised in section 2.1.6. However, they are not the parameters of the building intelligence. Bergson sees the capabilities and needs as characters of an intelligent human being. Human capabilities and needs are not the same as human intelligence. Accordingly, the parameters of the IB concepts are not the same as building intelligence.

When the building intelligence works in the role of the user of tools, it is rather satisfying the needs of the stakeholders and not increasing the building intelligence, it is, making the artefacts or products by lending human intelligence to the building. However, the service created by the building intelligence can take or have this position of an intelligence, which is creating new products and borrowing human intelligence. This is the case when the intelligence of FM together with the intelligence of the building make the new service product – which widely can be understood as an artefact – come true. Then FM has the key role in creation of the building intelligence. However, this is not exactly what the building intelligence is about. Rather it is the intelligence of the FM.

The same is the case with the occupants. The end-users' intelligence together with the building intelligence influence to how the intelligent tool can be used.

The above explanation of the use of IB concept and the roles of the stakeholders in it is defining the use of IB features and their relation to the stakeholders. The IB features are understood as the connectivity between the end-user and the other building stakeholders. While the other building stakeholders have lent their intelligence to the building, the IB features are the connectivity between the end-user and the building intelligence.

This is actually what such the post occupancy studies as the IBs Survey are measuring.

#### 7.3.2.4 Metaphor between Human and Building Intelligence

The hypothesis of the building intelligence is tested against the following theories of human intelligence (Section 7.3):

- An intelligent building has its own design criteria, the IB concepts; this is the knowledge combined in the design work process (Section 2.1.6). The ability of the human intelligence to lend its intelligence to the building is proved by Bergson's argumentation:

> *"Intelligence ... looks upon all matter as if it were carvable at will. It makes us consider every actual form of things ... artificial and provisional ... indifferent from form ... it also creates a space ... lending itself to any mode of decomposition whatsoever ... Objects, as extended things in an undifferentiated space, symbolize this tendency of human intelligence to fabrication",*
>
> "*[H]uman beings do not only use existing tools, but also create tools using their intelligence."*

According to this argument **the intelligent building can be understood as an embodiment of tool creation by the human intelligence.**

- To the previous can be added from the argument by Vygotsky:

> "*[H]uman being are able to create cognitive tools that can become integrated parts of our thinking"*,

**that means that the IBs can be understood to be cognitive tools and they can become integrated parts of our thinking. The cognitive tools can relate to the combination of human intelligence and matter.**

Building intelligence can be seen as human intelligence emerging in building (Figure 40).

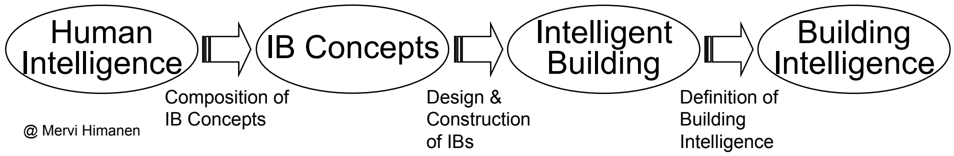


*Figure 40. Transformation of human intelligence into building intelligence.*

The steps of the transformation of the human intelligence into building intelligence can be seen to correspond with the levels of the articulation of knowledge as given by Tuomi: tacit – focal – articulated – verbal – socially legitimized (1999, p. 100). The building intelligence has to be articulated, because it seems unarticulated in science. The building intelligence is the consequence of the tendency of human intelligence towards fabrication (Bergson in Tuomi 1999, p. 131) and it is articulated in the form of construction of the IBs.

Intelligence can be considered as an internal stock of knowledge. Each building property carries its own internal stock of knowledge. This knowledge can be tacit or explicit.

**I am arguing that the intelligent building design has its own internal stock of knowledge, which has not yet emerged in the form of the explicit or verbal knowledge, but has emerged in the form of the building, that is, in the form of the tacit, focal and articulated.**

**Furthermore, I am arguing that despite of the fact that the internal knowledge is unknown in terms of conscious knowledge management, it becomes more conscious through the IB concept definitions. The articulation of the knowledge of the IB concept in verbal form makes it explicit.**

**Finally, it can be argued that the process of clarifying the IB concept has not achieved the point where socially shared conceptual knowledge could be possible, although efforts to that direction have taken place in various parts of the world in the form of various IB concept definitions. The knowledge of the IB concept has been articulated in the form of the buildings, and the knowledge of it has thus become interpersonal and socially shared. However, it is not yet explicit enough for an agreement on the universal definition to emerge.**

This claim carries with it the fact that the construction practice has included the conscious and unconscious expertise, the tacit and explicit knowledge (Tuomi 1999, p. 99), the intelligence and intuition of the person involved (Bergson in Tuomi 1999, p. 135). Understanding this internal knowledge of the IBs can make the comprehension of the meaning of building intelligence possible.

The clarifying process of the IB concepts can be parallel to the interest in the strategic thinking of the utilisation and development of internal stocks of knowledge. The sharing of the IB concepts within property and facilities management and building industry in general means to make the tacit knowledge work in the designers' conscious minds, i.e. to make it work in the form of explicit knowledge, in the form of spoken, written, drawn, filmed, etc. communication (cf. also Himanen & Lehto 2001). Conscious ideas are more understandable in thinking and thus can be submitted to scientific examination (Bergson and Husserl in Tuomi 1999, p. 99, cf. also Lehto 1999a).

#### 7.3.2.5 Building Intelligence by Concept of ba

The hypothesis of the building intelligence will be next tested against the following theories of human intelligence (Section 7.3):

- Following Gregory the intelligent building as a man-made product:

  "*[S]erves as models of world, and guided scientific and philosophical thought.*"

He continues:

*"We live off intelligence stored in artefacts designed by our ancestors."*

In other words, **we live off the human intelligence stored in the building as models of the world, and guided scientific and philosophical thought**. The IBs Survey studies this life of office workers. The results are usually clear and comprehensible. However, there are also the mystery of the empty, rarely used space with high grades from the EWE, the difference in the EWE of the equipment between the two building types with rather similar building automation and ICT installations, the rather high number of health symptoms of the female professionals in the IBs and their high sick leaves compared with the same group of female professionals in the reference buildings with as many symptoms but far less number of sick leaves. The existence of the explicit and tacit knowledge is obvious in models of the world, and guided scientific and philosophical thought which is stored into the buildings.

The transformation of the human intelligence into building intelligence can be seen to correspond with the knowledge creation which means the creation of various bas (Nonaka & Takeuchi, 1995, p. 69 in Tuomi 1999, pp. 325–326). The concept of ba reveals the conversation modes (Section 4.3.3.2). A idea of the concept of ba is that new knowledge is created in the articulation of tacit mental models, when converting the tacit knowledge into explicit form. For this is needed not only the externalisation, which is the conversion mode of the concept of ba that turns the tacit knowledge into explicit, but also the internalisation, the conversion mode of the concept of ba, which is a process of embodying explicit knowledge into tacit knowledge. The knowledge is converted into individual's tacit knowledge bases of technical know-how (Nonaka & Takeuchi, 1995, p. 69 in Tuomi 1999, pp. 325–326).

From the conceptual knowledge point of view, i.e. from the IB concept point of view, the transformation of the tacit knowledge into explicit knowledge is interesting at time being, when the building intelligence is not verbal or socially legitimised. This means need of externalisation of the building intelligence. In this thesis, the difference between intelligent buildings and buildings, which are not built according to the IB concept, is the same as externalisation. It is the proof of the existence of the IB concept, but it is also a proof of the existence of the building intelligence.

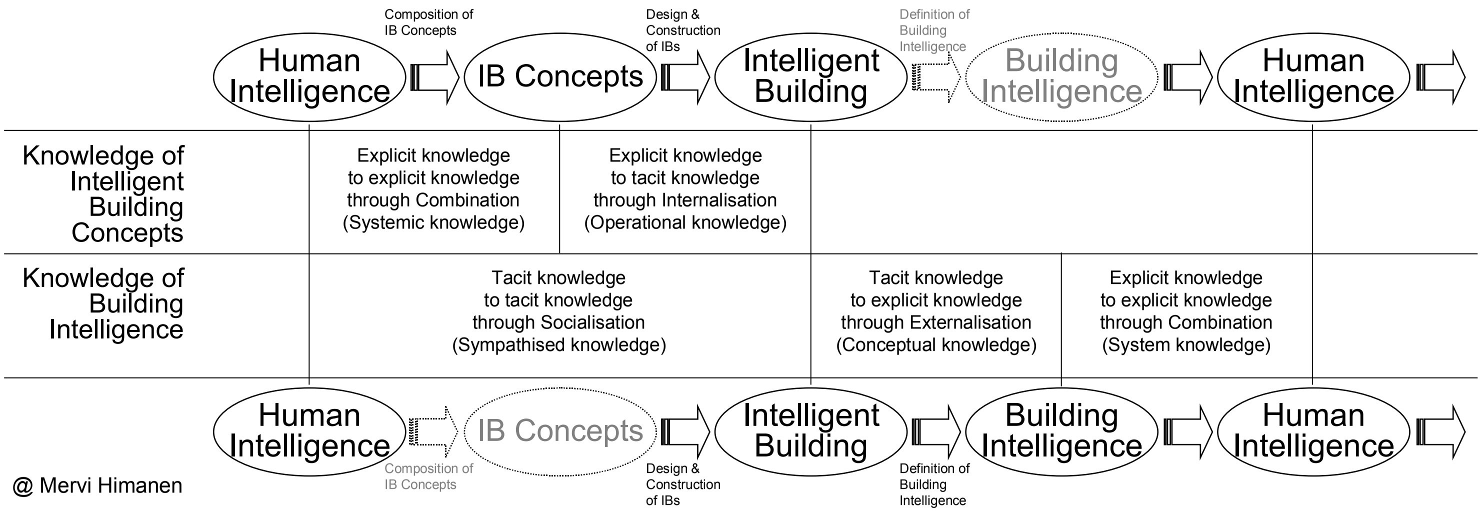


*Figure 41. Transformation of human intelligence into building intelligence by using the knowledge conversation modes of the concept of ba.*

**The IBs have been built according to the IB concepts, which do not include explicit information of building intelligence. However, on the basis of the differences between the end-user evaluation results of the two office building types it seems obvious that the tacit knowledge of the building intelligence exists, because existence of very similar installation or the way how the IB concepts have been implemented in the IBs cannot explain all the differences of the end-user evaluation results** (Figure 42.).

**It can be argued that the four forms of knowledge transformation in the concept of ba have relevance not only in the terms of current IB concepts but also in the terms of the building intelligence.** This is true, because it has been proved above that [1]the intelligent building can be understood as an embodiment of tool creation by the human intelligence and [2]the IBs can be understood to be cognitive tools and finally [3]that we live off the human intelligence stored in the buildings as models of the world, and guided scientific and philosophical thought, and that intelligent has both tacit and explicit forms, which are changing according to the form of knowledge implementation.

In spite of the fact that the history of the use of the IB concept is not long in the terms of modern IB concepts (Section 2.1), and that the emphasis of the concept has been so much on the integrated rather than intelligent buildings, it is interesting to notice that the difference emerged also in the terms of the spatial factors, not only of those factors relevant for the equipment. **It can be argued that the difference between the two building types of the EWE of spatial parameters represents the mode of knowledge conversation, where the tacit knowledge changes into explicit, and thus it has relevance to a verbal articulation of the spatial building intelligence.**

**According to the concept of ba, the combination of the human intelligence into a building can be considered as the combination, which converts a form of knowledge into another form of knowledge** (Figure 42.). **Then the explicit knowledge turns into explicit. The implementation of the IB concepts turn into the IBs.**

**The difference between the two compared office building types, proved by the IBs Survey, is in this case articulation of the different embodiments of knowledge before the combination and after the combination. The reference**

**buildings are without the combined intelligence while the IBs have the combination of building and intelligence** (Figure 41.).

The equipment of the IBs and that of the reference buildings is quite similar. However, when using the IB concept as a design criteria, the result will be a building, which is evaluated by the post-occupancy study to be better on the behalf of the work performance than the buildings, where the installations of equipment are quite the same, but the IB concept has not been implemented.

The practical example of the combination of a building and intelligence, especially if the combination is understood as forming a new collection of facts from the previous knowledge, is the concept of looking at the intelligent office systems as a set of technical subsystems, which interface with user behaviour. It is possible to trace and list all the technical systems, which the office worker will be connected to during the working day. The way with which the worker will be integrated in the IB system is the connection of the building intelligence and the end-user. As defined this connectivity has different forms: physical, behavioural, intelligent, social, mental, spiritual, etc. (Figure 35.). The final IB concept is composed out of the combination of these integrated or integrating systems, with which the office worker interfaces the workspace during the workday.

Because the ICT tools connected to the interoffice network turned out to be more effective than standalone equipment by the IBs Survey, by building a building of her or his kind, a human being is not integrating her or his knowledge to the building such a way, which could be the same as placing an extra organ in to the human body, but the intelligent systems of the building are integrated and embedded.

This combination (organisation of systematic knowledge) even in the form of piling fact onto the newly organised pile of information, has relevance to the IB concept through the next step of the conversation, where the explicit knowledge, which is the knowledge of the IB concepts, converts into tacit knowledge, when the intelligent building will be built through internalisation, which means trough the construction process (operational knowledge). After this tacit knowledge of the IBs has, through externalisation, transformed into explicit again, if a implementation of the definition of the building intelligence has taken place in

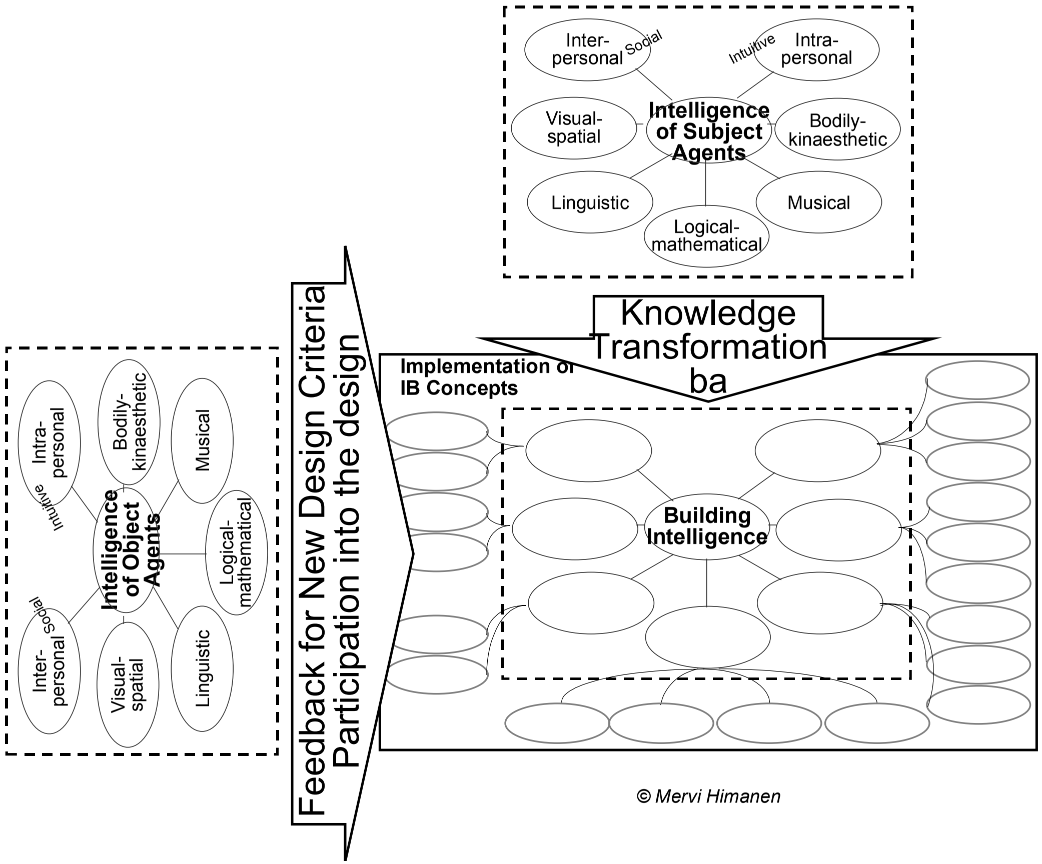


*Figure 42. Human intelligent emerging in building via knowledge transformation.*

the articulation of newly built house. Then knowledge can through socialisation transformed to new verbal form of explicit knowledge, and so on (Figure 48.).

It is a task for the information and communication sciences to develop the sophisticated building automation, office automation and communication tools, and take care of their integration into a multimedia, a sky-phone or whatever the new media created for knowledge transfer will be called. **I am arguing that an IB is not the same as the adoption of the ICT into a building.** Building intelligence can be very similar to the ICT intelligence, and they both can follow same tacit or focal knowledge, but the articulation of the intelligence of the two will be totally different, as the ICT consists of bites, micro-ships, etc. and the building of bricks, steel, glass, etc.

Building intelligence becomes from the emerging of the human intelligence within the building just as the intelligent information and communication comes from the emerging of the human intelligence in the ICT. **It is the task of the construction field to adopt and integrate or merge the ICT into the building in such a manner that the end-user can use her or his intelligence (cognition, senses, feelings, etc.) in accordance with the building intelligence. Furthermore, this embedding will follow from the creation of the building intelligence independently, without focusing only on the adoption of the knowledge of the ICT.**

**The role of the intelligence in the context of the buildings has relevance, when the combination can refer rather to embedding than integration of conceptual knowledge.**

Flexibility is a important key word of the IB concepts. However, it can be understood as spatial flexibility or periodic flexibility, which can be called adaptability. These two different forms of flexibility are not verbally articulated although they can be found, for example from the results of the IBs Survey. The spatial flexibility in the intelligent buildings reflects the knowledge of the need for spatial changes in the context of the organisational change of the building occupants, the need for technical space in the building, when technical systems are integrated, etc. Accordingly, the flexibility of the IB concepts should include spatial change and adaptability, which is caused by the implementations of new technology, changes in the working processes, changes in the product of the occupant company, etc. Even the socially legitimised forms of knowledge, such as flexibility carry tacit knowledge, which will be articulated in the building, and through research or (systems) thinking it becomes verbalised.

In practical terms, the previous argumentation means that the IB concept most probably cannot short-sightedly be seen as only having existed from the 1980's, when the ideas of the usefulness of the ICT entered the office building, but rather longer, as the idea can easily be traced back to the Egyptian times (Section 4.3.1). **This is because the new buildings built according to the IB concept have many previous articulations, from where the knowledge could have been transformed in any form to be converted further from one form to another.**

### 7.3.3 Difference between the Intelligent Building Concepts and Building Intelligence

My theoretical and empirical approach has lead to the understanding of the difference between the building intelligence and the intelligent buildings built according to the intelligent buildings concepts. In next sections some ideas on how these two phenomena are related will be discussed.

The separation or identification of the intelligent building could follow from the building intelligence, which human intelligence has lent to it. The definitions of the human intelligence can be kept as models for the building intelligence, which seems logical, if the building intelligence is the same as human intelligence lent to the building. The core of the essence of the building intelligence is something different than what the IB concepts are saying about the IBs.

#### 7.3.3.1 Measurements of Intelligence

Efficiency, effectiveness or efficacy can be found in the IB concepts in various forms. They can be found in energy, in material, in space area, in building management, in end-user productivity measured by the EWE, in business travelling, etc. both during the construction process and the utilisation period of the buildings, as well as afterwards in recycling (cf. Figure 11.). These are good measurements for the existence of intelligence.

Such parameters of the IB concepts as life cycle costing, marketability, working efficiency, service-orientation, image of high technology, construction process and structure and productivity are similar to effectiveness, which is rather a measurement for the existence of building intelligence than a parameter of the building intelligence itself.

#### 7.3.3.2 End-user Needs

Security is a frequent keyword in the context of the IB concept. Safety is a human need, according to Maslow for example. It can be satisfied by several means in the building, and also for example, by the ICT of the intelligent buildings (cf. Bernaden & Neubauer 1988, p. 5). This has been among the first solutions of the IBs, and thus might have received much importance within the concepts of IBs. As mentioned above needs do not actually describe intelligence although needs can be used for the definition of intelligence. Security can be classified as a need and thus does not describe the essence of the building intelligence but rather the aim of it. Similarly comfort and convenience, as well as the ability to promoting health (therapeutic) are not related to the parameters of the building intelligence.

#### 7.3.3.3 Connectivity

The ability to fulfil the end-user needs however, can be a character of building intelligence, when it is in the role of the connector between the end-user and the building.

Although it is almost impossible to make a building look like a human or make it resemble a person, if it is needed at all, still it can be presumed that intelligent buildings have other abilities of man-machine connectivity than only that of the user interface. The further the consciousness technology will develop the more there will be other forms of connectivity in the buildings than what is described with the phenomenon of user interface.

#### 7.3.3.4 Flexibility, Adaptability, Regulation and Control

Flexibility is also a common keyword of the IB concepts just as it is a keyword, for example, for the concept of FM. Flexibility includes on two dimensions: time and space. Therefore, it would be good to use separate terms for each of them. Need for spatial changes causes need for flexibility in buildings, i.e. the ability to change within current spatial scale, which is not necessarily as regular and periodic as that based on timing and seasons, i.e. on astronomy, which is called technological adaptability. Energy, lighting and HVAC regulations typically operate in periodic cycles.

Spatial flexibility benefit out of spatial freedom due to the sophisticated structural solutions of bearing structures, out of building service installation concepts with adequate technical space, ans spaciousness in general.

Flexibility and adaptability, as well as activity (active structures Section 7.3.2.1) can be based on manual operations and on "press button" automated solutions, which both regulate the working environment directly on the needs of the occupant. Further more, they can be behind a fully automated regulation controlled by sensors, which watch for climatic and other environmental changes regulating working environment accordingly on the grounds of designers' knowledge of the technical and end-user requirements.

Regulation is not working, if the controlled solution is not adjustable enough for correct control operations. This is the case, if the design is not correctly carried out, and the technical and structural system cannot work correctly, in term of the technology, to serve the purpose it was meant for.

As it can be noticed from the above description, flexibility is a combination of various aspects and objects, or is in a close relationship with them. **Because I have not yet analysed the flexibility and technological adaptability, and their parameters or subsystems in detail, I do not wish to argue anything about their role within the intelligent building concept or building intelligence.** For time being I include in this context flexibility and technological adaptability in the building intelligence, and find them related to kinaesthetics.

#### 7.3.3.5 Integration

The industrialism has caused fragmentariness; systems have fallen apart to (effective) subsystems. Unity is needed so the subsystems can merge. Integration takes place in construction differently from integrated structures and building services, via controls, from the integration of the space and structures to the occupants' operational productivity, and through networking, to intelligent city.

Intelligent building concepts talk about integration. Green “walk ways” in the IB offices stand for the integration of various types of intelligence: interpersonal, while serving as meeting places for creative ad hoc meetings, bodily-kinaesthetics when allowing free movement during the working day, visual-spatial by satisfying the end-user needs with the beauty of the space and scenery, intrapersonal through making it possible to have a moment of your own, and with sounds for the fulfilment of musical needs.

The ability for conscious thinking, and creating a new idea by combining several facts separates humans from machines. Machines are programmed only to repeat given facts after each other. However, the conscious computer is under development (Aleksander 1999, Haikonen 1999). It may employ combinations of neural networking, fuzzy logic and object oriented expert systems. Although the aforementioned terms are said to be over-used in construction and in the facilities management's point of view, scientists are looking for ever more sophisticated solutions from nano- or biotechnology. They are actually based on new combinations of the scientific traditions of chemistry, physics and biology. Their study object has just grown smaller over the times, which has lead to the nano-biotechnology.

Integration can be understood as a human skill to create a new idea, object, model, tool, or house from the combination of the existing knowledge. The metaphor between human intelligence of several kinds and a correct holistic combination of technologies brings together an embedded system architecture of complementary sophisticated solutions and not only a set of highest technologies.

Keeping in mind, what is previously said about the need of instead of integration – of piling up various systems into the building – to embed data, information or knowledge to the intelligent building system could be argued that integration is not a parameter of intelligence. Rather, it seems obvious that a good term for replacing the word integration (or integrating) in the context of intelligent building or that of building intelligence definition is needed.

Accordingly, I am arguing that for separating the intelligent building as a concept of its own, the copying of nature – which is the same as technology – would be understood in such a way that the lending of the human knowledge to the building means more than integration, which so far has been a keyword in the IB concepts (including my own). **The human intelligence is merged into the building rather in the form of embedded systems than integration.**

However, integration can be understood as a logical act, which combines the various intelligent elements. The concept of ba suggests that combination is the process of systemising concepts into a knowledge system, and it integrates different bodies of explicit knowledge (Nonaka & Takeuchi, 1995, p. 67 in Tuomi 1999, p. 325). Combination converts explicit knowledge into explicit knowledge.

**I am arguing that the human skill causing the knowledge integration is the human logic, and the intelligent building know-how of integration is an expression of the human logic. It is suggested to use the word combinativity for the embedding new knowledge into the building.**

#### 7.3.3.6 Intuition and Spatial Instinct

Finally, what can be said about the buildings of the wisdom age? The mental skills of humans have started to be under growing interest in the sciences. The knowledge of human qualifications is becoming more conscious in the understanding of the human mental existence. It seems obvious that the next step towards a more conscious building design, R&D, and construction will emerge with the skill of lending – not only human intelligence – but the knowledge of all human mental qualifications to a building. To put it simply, humans recognise their mental body and lend the knowledge of that structure to the building. Interoffice communication network resembles human nerve systems or, in some cases, the wireless technology could even be considered to resemble human mental bodies. The utopian idea of using telepathy becomes true?

Nevertheless, in the future there will be an intelligence, which has its roots in human instinct and senses, but is different from them, as well as it is different from the intuition as previously was proved by the literature:

- *... [I]n Bergson's sense, .... instinct and intelligence ... imply two radically different kinds of knowledge... "this knowledge is rather acted and unconscious in the case of instinct, thought and conscious in the case of intelligence" ... instinct is reflected outwardly in exact movements, instead of being reflected inwardly in consciousness ...*

- *According to Bergson ... instinct is not within the domain of intelligence, it is not situated beyond the limits of mind. ... We can access instinct through feeling, in unreflecting sympathy. We can live knowledge, instead of representing it.*

- *... Polanyi's terminology ... intuition is the capability to use and access the tacit components of meaning and knowledge. But according to Bergson, the push for this transcendence comes from intelligence. Without intelligence, intuition would have remained in the form of instinct ... .*

- *The two faculties of the consciousness are the intelligence and the intuition."*

- *The consciousness explained by Dennett does not exist as a separate unit in human being."*

**Thus it can be argued that the human intelligence does not necessarily lend its instinct and intuition to the building.** Yet, the senses have been considered as a part of IBs (2.1.3).

To the human intrapersonal intelligence belongs the human ability of spatial instinct, with which the atmosphere of an empty space can be felt when entering the room, and which becomes richer when staying within the space. Measures, colours, materials, scenery, interior designs, room temperature, etc. can all be sensed. Afterwards, the person forms her or his opinion of the space qualities instinctively, based on feelings, the history of the personal experience, etc.

The architecture has to do with this phenomenon of the spatial instinct. It is impossible to argue anything about this, because the term spatial instinct is a word for ordinary conversation, not a scientifically determined term. It seems obvious that especially when spatial instinct is taken account in the context of implementation of architectural expert knowledge to building design it is hardly any more an question of instinct but rather intuition, which is originated from the use of intelligence with instinct.

Nevertheless, what the type of spatial instinct is, it is most probably articulated in building design, but the verbal articulation of it is lacking. It was also interesting to find out from the results of the IBs Survey that although the architectural paradigm includes the idea of human scale in building, still the massive and tall buildings could be more attractive to the end-users than the smaller ones in certain conditions. The architectural paradigm seems not very well socially shared and explicit.

##### 7.3.3.7 Holistic Sustainability

Green plants and glass surfaces, for example, are common in the intelligent buildings of the 80's and 90's. Green building qualifications seem have no other connection with intelligence besides simultaneous timing. It is worth knowing, if these trends are detached or if they are linked to human intelligence, for example through the human desire to connect to nature, the ultimate creator, inner wisdom, etc. Intelligence is a part of human mentality. Stewens (Stewens 1995, Stewens & Warwick-Smith 1995) has made the description of the human mind placing intelligence, emotionality and spirituality in their own categories (Figure 12.). This viewpoint refers to the life-cycle of mankind (cf. Myss 1997, Chu 1995, Chang 1988), emphasising the human mental growth in consciousness.

The harmony in the holistic sustainable development is based on individual responsibility, which is parallel to individual decision-making (Himanen et al. 2000a, p. 59). This has been emphasised in sociology and in psychology (cf. Redfield 1998, Stevens 1994). In a balanced situation society does not rely on a few individuals, but on all its members. All of them – from the weakest to the strongest – are supported in the struggle for sustainability taking place in the whole society. The demand driven construction industry acts for the sustainability by its nature, because it means taking the humans, the consumers, into account, which is also the aim of the sustainability. The ecological manufacturing of products have had more demand from the consumer market in the building sector than what it has been promoted by the professional builders (Lehto 2001b).

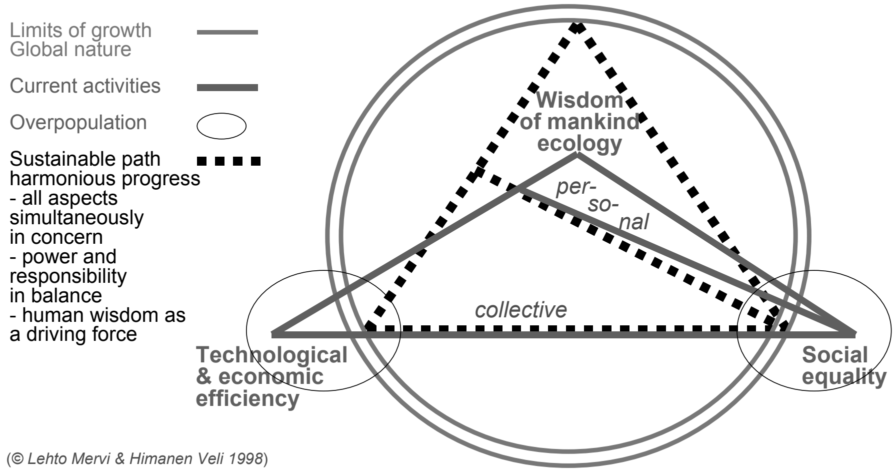


*Figure 43. Holistic sustainable development.*

Reasonable does not always mean saving but effectiveness. For example, giving value to empty space – I mean metaphorically and also literally in an office building – for promoting wise thinking in a peaceful corner, or in a common corridor for information exchange, and so on. Many examples of this kind can be found in every day office work (cf. Lehto 1999a).

Technology imitates nature. Skills in it are essential for engineers and architects. Humankind is a part of nature. Architecture and engineering serves humankind. The more the technology is in harmony with nature the better it serves humankind in the long run. The technological progress will no only exploit the nature for humans' advantages, but architecture and engineering are giving it back the nature that belongs to it. The target of sustainable building intelligence can be attained by taking steps in this direction.

The intelligent building concept and its implementation are applied in technology, architecture and engineering. Building intelligence can strengthen sustainable development and develop ecological and human friendly construction. Actually, building intelligence emerges through embedded concepts of human mind and body as organic elements in inorganic elements of the buildings.

Integration in nature means that the previous phase produces the raw material for the next phase, and the cycle is the key word. Intelligent buildings may use integration as a means for efficiency, which is a factor of the FM or IFM.

Sustainable development in the IBs is mainly based on effectiveness and usability, and on human comfort and health (cf. Figure 43.). It can also be added to the same category with efficiency, effectiveness or efficacy. It is rather a factor of the green building concept – if such a concept exists – than that of IB concept. Sustainable development is also related rather to human wisdom than to human intelligence (Section 7.3.3.7).

### 7.3.4 Factors of the Building Intelligence

Simple examples of the compatibility of human intelligence and building properties can be found (Figure 36.) by taking Gardner's definition of the human intelligence as a starting point (Gardner 1983 in Dryden & Vos 1996, pp. 120–123, Gardner 1993 in Tuomi 1999, pp. 107–110, Gardner (1993) in Dunderfelt 1998, p. 28).

**I am arguing that Gardner's psychological paradigm of human intelligence corresponds to the current building intelligence, which is based on the human tendency of fabrication – lending human intelligence to the building. It encourages deriving the essence of the IB concepts – the building intelligence – from the forms of human intelligence defined by Gardner with such components as:**

- **building connectivity (speaking and speech recognition including music and linguistics; user-connectivity and either personal, organisational or automatic control),**
- **building self-recognition (building knows the state it is in, growing in consciousness),**
- **spatiality (a more conscious understanding of the spatial expression of the architecture, structures, interior design),**

- **building kinaesthetics (a sense of change, active structures, moveable structures, furniture and equipment, adjustable technology or building services), and**

- **building logic (the embedded follow up of the occupants' daily activities, combinativity).**

**These components which form the building intelligence are called the Building Intelligence (BI)** (Figure 44.).

The spatiality could be also explicit spatiality, because at the moment there is need of transforming this in many ways tacit knowledge into explicit.

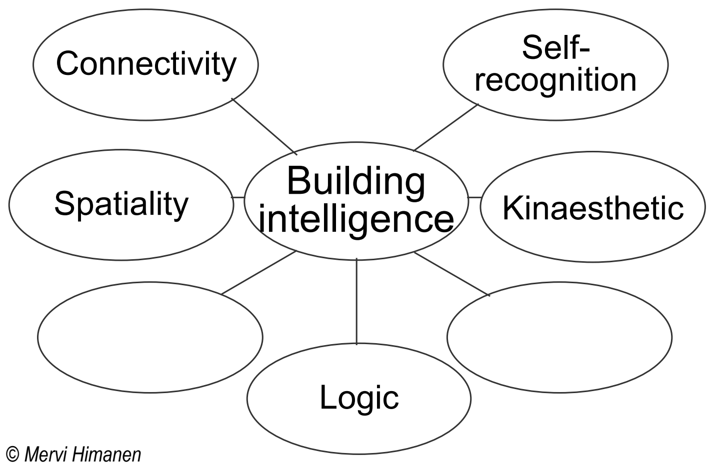


*Figure 44. The forms of the BI.*

In other words the definition of the building intelligence can be presented mathematically as follows (Equation 6.):

*Equation 18.* $BI = f\,(bi_1 \ldots bi_5)$

where bi is the form of the BI and they are: $bi_1$ is building connectivity, $bi_2$ is building self-recognition, $bi_3$ is spatiality, $bi_4$ is building kinaesthetics, and $bi_5$ is building logic.

Because constant transformation takes place new forms of the BI will be discovered as shown in the Figure 44. with the empty ellipses (cf. also Section 7.3.6).

The levels of the articulation of human knowledge into the knowledge of the intelligent building as given by Tuomi (1999, p. 100) can be as described in Table 43.

*Table 43. The levels of articulation of the factors of the transformation of human intelligence into building intelligence*

| *Level of articulation* | *Steps of transformation* | *Characteristics* |
|---|---|---|
| *Tacit* | A part of the human and a part of building intelligence | *Unorganized and dynamic meaning relations* |
| *Focal* | The IB concepts | *Conscious organized patterns of meaning relations* |
| *Articulated* | IBs | *Meaning relations sedimented in produced artifacts or expressions* |
| *Verbal* | The BI and the BIF | *Meaning relations sedimented within a system of concepts* |
| *Socially legitimized* | Universal definition of IB | *Socially shared conceptual knowledge* |

As the IB concept parameters are factors of the use of human intelligence (Figure 36.), the forms of the BI are a consequence of the existence of human intelligence lent to the buildings (Figure 45.).

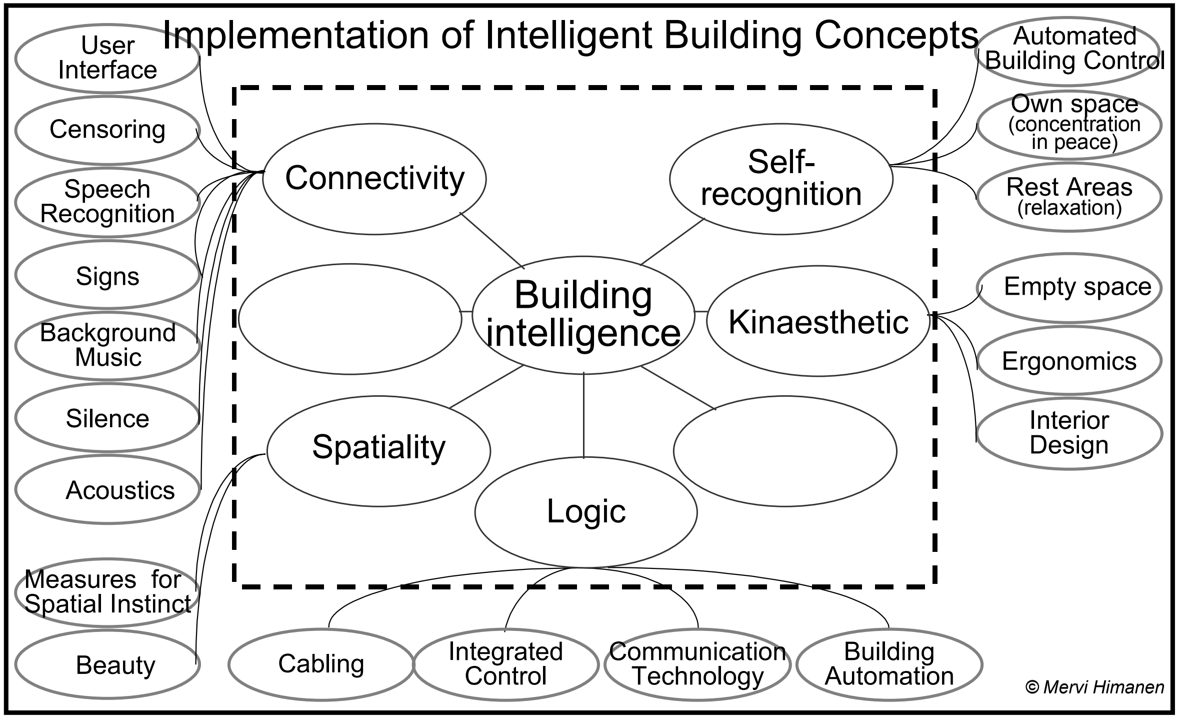


Figure 45. Examples of the implementation of the intelligent building concepts and their connection to the BI.

### 7.3.5 The Building Intelligence Framework – Interplay between End-users and Buildings

In any case, research is targeting high ends to improvements also in practise. A future alternative is that the building reflects human intelligence (Section 4.3.3.1) in its whole variety, not only modelling the logical mathematical intelligence with digital control. However, there already exist special cases, where a digital computer is superior to a human. Such an example is the computer aided tax advisor with a tax calculator, with "whom" it is safer to try various alternatives of tax return than with a human clerk, who might reveal one's "secrets of incomes".

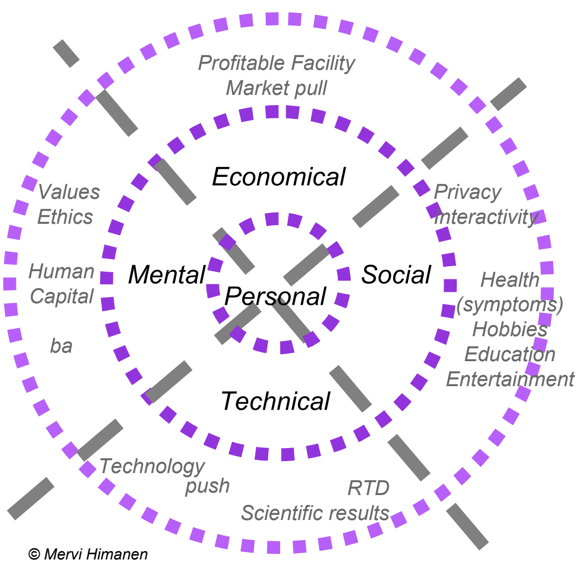


*Figure 46. New techno-socio-economic design criteria for construction derived from mental and social sciences related to technology.*

**Finally, the interplay between the stakedolders and the building is called the Building Intelligence Framework (**Figure 47**).** The building intelligence is the function of the forms of the BI (Equation 8.) and the human intelligence is the function of the forms of human intelligence defined by Gardner (1983) (Equation 7.). The BI includes mainly the human knowledge of designers, building owners, property managers, etc., but also that of the end-users, which has transformed into the IB. Thus, the BIF is the interplay between the built environment in the intelligent buildings and the human intelligence of both the object agents – the end-users – and the subject agents – the professional stakeholders of building.

The BIF is a function of the intelligence of the end-user and the BI. The intelligence of the end-users or the object agents becomes a part of the BI via the feedback data bases used for the creation of new design criteria and through end-user participation in design.

The human knowledge of designers, building owners, property managers, etc., that of the subject agents has transformed into the IBs. The professionals take into account in their work the technical possibilities available for the satisfaction of the needs of the end-users and the business. Their work is relevant in the context of both technology push and the market pull oriented R&D.

The end-users use the building intelligence for satisfying their needs. The building developers' and designers' ability to understand, interpret and decode the end-user information into the design criteria form the user-connectivity between the user and the building. FM services serve this same purpose.

The BIF is the interplay between the built environment and the stakeholders as in Equation 10. BIF = f (HI, BI), where HI is human intelligence, the BI the building intelligence.

In this thesis the Gardner's classification of the human intelligence have been taken as a starting point for the definition of the building intelligence, because it fit best to the ambiguous problems of some results of the IBs Survey of all the definitions of human intelligence, which has been found from literature of human intelligence (cf. e.g. Dunderfelt 1998, pp. 26–29, Tuomi 1999, pp. 107–110). Thus of the intelligence common to the stakeholder and the building can be written as follows:

$$\textit{Equation 19. } BIF = f\,(hi_{Gardner1} \ldots hi_{Gardner7}, bi_1 \ldots bi_5)$$

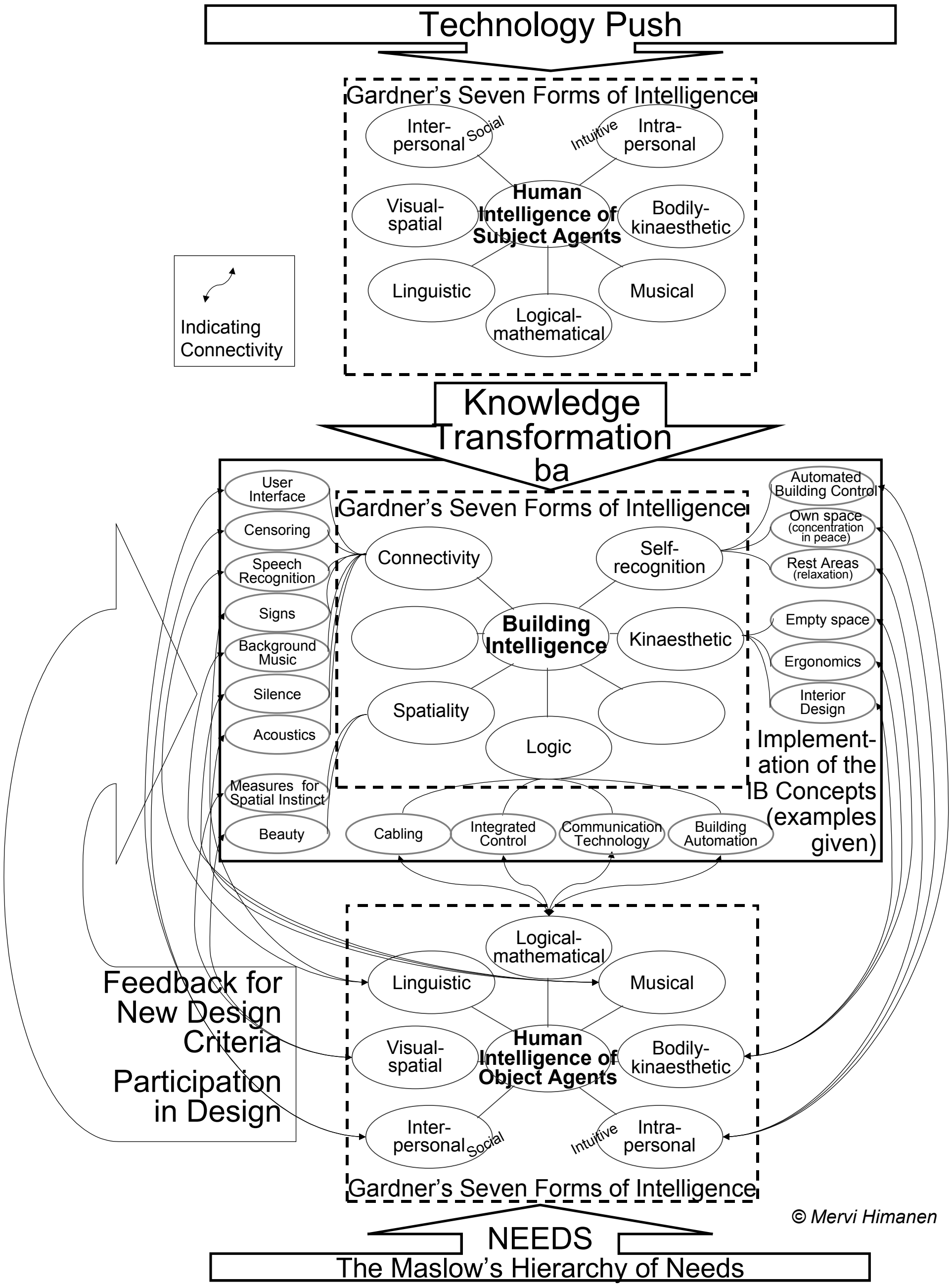


*Figure 47. The BIF is the interplay between the end-user and the intelligent built environment of the intelligent buildings.*

where $hi_{Gardner}$ is a form of the human intelligence as defined by Gardner and bi is a form of the BI.

Gardner (Gardner 1983 in Dryden & Vos 1996, pp. 120–123, Gardner 1993 in Tuomi 1999) suggests – as mentioned later in next section – that in the future it is possible to classify the human intelligence in a more sophisticated way. This is also true with the building intelligence, as well as with the progress of the building concepts in general (Figure 48.). Thus the Equation 10. than the Equation 19. is describing the definition of the BIF, which the end-users' human intelligence and the building intelligence form now. Thus the use of the Equation 10. makes it possible also to use the future definitions of intelligence in this context.

### 7.3.6 The Constant Cyclic Change Spiral

The concept of ba or the understanding of the cycles in nature tells of how the world is under constant change. The current explicit knowledge will turn into tacit and the tacit into explicit. The intelligence of the building will change accordingly. The forms of knowledge or intelligence change, but the metaphor between the human and building intelligence remains, because as Bergson says the objects, it is, buildings symbolise the tendency of the human intelligence for fabrication. The intelligent buildings can be understood as an embodiment of the tool creation or modelling of the world of human intelligence. As long as the buildings exist, we live off the human intelligence stored in the building.

The change from tacit to explicit knowledge can be imagined happening on various levels (Figure 48.). Thus a spiral is formed out of the curve describing the progress of the construction. In the economics as well as other scientific literature, the cyclic spiral has been used as a symbol of favourable or not so favourable progress. Favourable progress means climbing up the spiral, and the not favourable down. The growth in consciousness in the construction sector can mean the transformation of the tacit knowledge into the explicit – and vice versa – in a favourable or not so favourable way as well.

Sometimes human intelligence is confused; it is difficult to judge what is favourable and what is not. The course of the progress might change. The course of the favourable progress might even look like going downwards on the spiral.

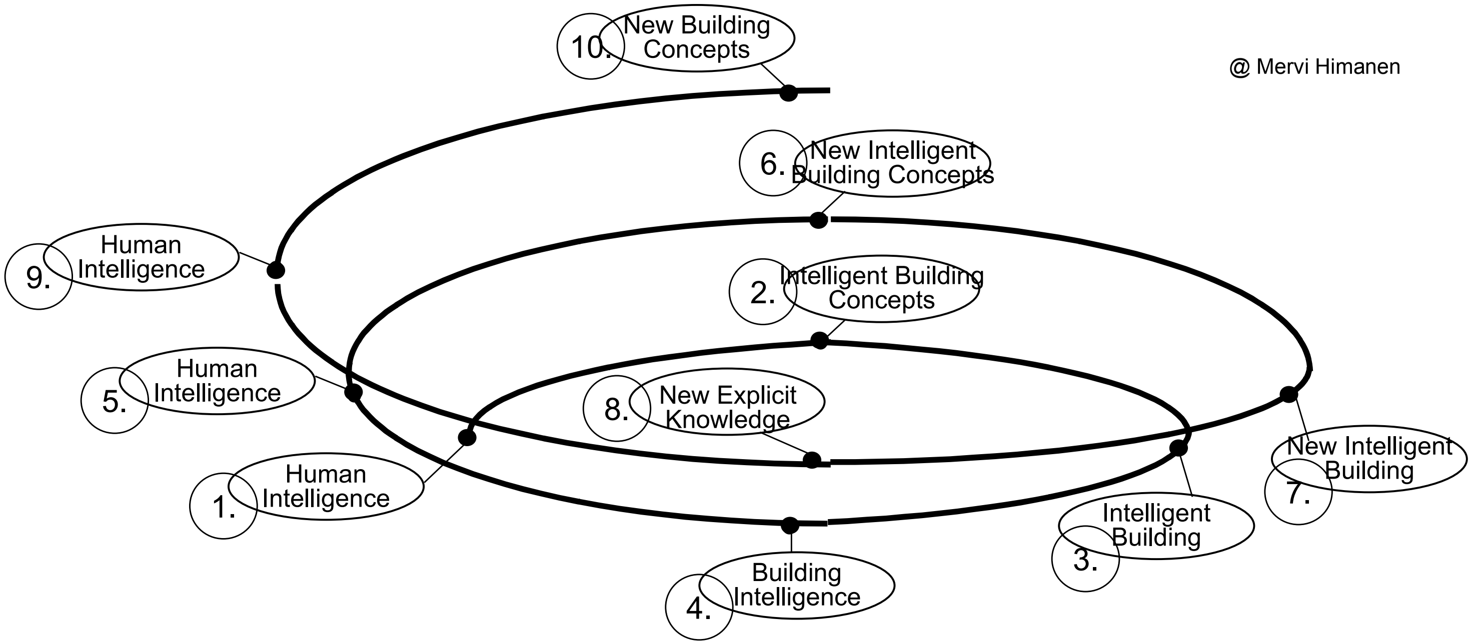


*Figure 48. Spiral of the transformation of human intelligence into building intelligence.*

In such a case, the tacit knowledge is changing the course of the progress or, to put it another way, the previous explicit knowledge is not valid any more for describing the new situation.

Sometimes experimentation is the only way to find answers. Anyway, human has to think of the next step. One can look at a phenomenon in the long run; judging if and how the traditional solution is the best or if it is time to start something new. One can look at a phenomenon from different perspectives, for example, from the point of view of various stakeholders. Because of this difficulty, several problem solving methods have been created.

One solution is to look at the progress of the construction industry – or which ever business – from the point of view of the wise or that of the not so wise person (cf. Section 4.3.3.5). While doing this, it can be presumed that, at the time being, a wise person or organisation, industry, country, humankind, etc. can cope with the change in time perspective and the conflict of various interests and interest groups with sustainable solutions based on win-win or technology-for-all type principles (Section 7.3.3.7, Figure 43, cf. also Section 2.1.4).However, the relevance of the existing literature of standard of intelligence and wisdom of human species is arguable in the scientific context since the introduction of Maslow's theories of it (cf. e.g. Chang 1988, Myss 1997, Stevens 1994).

It is presumed that the tacit knowledge dominates the progress in the case of above mentioned confusion, not the explicit. The author would like note that she does not claim that tacit knowledge is always dominant. Quite the opposite, both tacit and explicit knowledge dominates in turns. In the case of the explicit knowledge being in the leading position, the situation seems good on all terms, also on paper or on the screen.

Gardner has pointed out that (Gardner 1993 in Tuomi 1999, p. 132):

> *"... [L]iving systems are not static. ... Intelligence is a product of history and development, and it is a relational concept. ... Gardner points out that his list is only a 'fist cut' and that there probably is no final list of intelligence".*

As claimed, the building intelligence is the consequence of the human intelligence, it is inevitable that also the building intelligence will change with the change of human intelligence. **It can be claimed that any explicit universal concept of building intelligence is valid for a certain period, but the change of its essence seems inevitable.** The building intelligence follows a constant cyclic change spiral of its own, and the contents or essence of the factors in it change (Figure 48.). Accordingly, the intelligent building business changes as the factors of the BIF or those of the Intelligent Building Index change.

### 7.3.7 Intelligence as a Production Factor

What Tuomi (1999) says about knowledge and its importance in production, is a fruitful view for understanding the essence of the IB concept, and further the main result of the IBs Survey. According to this result, there is a difference between the IBs and the reference buildings, although a particular difference in the quality of the technology, spaces or structures in the buildings cannot be pointed out.

In the first place, Tuomi (1999, p. 78) points out that the application of knowledge into the design work processes has increased productivity. In a previous section (Section 4.3.5.6), it has been argued that information and communication work as parts of the inter-linking systems, and it was noted also that information is a production factor. Information is connected to the products in the production processes of the information age. This can take place in many ways and in different phases of the innovation, not only during the design, but also during the production and creation of the brand of the product, etc. Above and beyond that, information, expertise or knowledge can work as an independent actor in the form of consultant work.

Following Gregory the intelligent building is understood as a man-made product:

> "*[S]erves as models of world, and guided scientific and philosophical thought.*"

He continues:

> *"We live off intelligence stored in artefacts designed by our ancestors."*

In other words, **we live off the human intelligence stored in the building as models of the world, and guided scientific and philosophical thought**.

Furthermore, Tuomi (1999, p. 82) points out that during the last three decades, it has become obvious that products come and go, and markets get reshaped, which is true especially for manufactured products. He continues:

> *"Therefore strategy cannot be based on outputs of the industrial system. It has to be based on the internal capabilities that make those outputs possible. This has lead strategy researchers study knowledge-based competencies. Where as the earlier phases of strategic thinking could be characterized as focusing on the acquisition of knowledge about the environment, the focus has now moved to the utilization and development of internal stocks of knowledge (Spender, 1996)."*

The IBs are the outputs of the construction system. The IBs Survey has studied the outputs of the construction system, the quality of the IBs and the reference buildings. It focuses on the acquisition of knowledge about the environment in the form of design criteria of the Finnish IBs. **I am arguing that the development of IB concepts and the IBs Survey as well as other post-occupancy studies are on the internal capabilities that make the IBs (outputs of construction industry) possible.** The interest has turned from the post-occupancy studies measuring the quality of the building to the knowledge stored in the (I)Bs, which make them work as a profitable and useful asset for the stakeholders.

**The study of the definition of the BI and the BIF study knowledge-based competence of the IBs. The time for strategy researchers to study knowledge-based competence of the IBs has come.**

## 7.4 The Building Intelligence and Intelligent Buildings

### 7.4.1 Examples of Building Intelligence from the Intelligent Buildings Survey

The IBs Survey proposal was written on the basis of the IB concepts and the knowledge of the post-occupancy studies in the office buildings. Thus, it was not at all a systematic study of the building intelligence. However, to get some idea of the research results, which could reflect the building intelligence, some examples of the results of the IBs Survey are presented next. At the same time is pointed out those questions, which rose during the analysis of the IBs Survey.

Within the empirical data there are some unanalysed end-user responses to such questions, which were knowledge-related or based on semiotics, which may in the future explain more of the following theoretical analysis of the intelligence's role within the IB concepts. In any case, studies on this particular issue – the role of the intelligence in the IB concepts – are needed in order to understand how the information and knowledge will be formed in the end product, i.e. in the IB, and also in the design process of the IB.

#### 7.4.1.1 Building Connectivity

It is difficult to find the entrance to the office buildings and the poor signing makes it difficult to orientate oneself and to find one's way inside the building. In semiotics it has been found that if attention is paid to the road leading to the buildings, or if big staircases are favoured, the entrance of the building is not as hard to find. This is not the case in Finland, where the architecture often favours a quite lean style.

In philology it has been found that in Finnish communication the train of though or the attention to issues is following the order as follows: who, what and where. For example in the Indo-European languages the order is: where, what and who. It is thus understandable that the signing is not considered the most important factor in communication in Finland, if it does not identify a person.

#### 7.4.1.2 Building Self-recognition

The building self-recognition can be used, for example, for indoor air regulation or fault diagnosis. Questions of fault diagnosis was not included in the IBs Survey, but the end-user evaluation results of the indoor air regulation are available. They proved that the indoor air regulation of the intelligent office buildings is not very good on average. The differences between office buildings were quite significant.

In those office buildings which were included in the IBs Survey and built in the end of 1980's or in the beginning of the 1990's, the building automation systems did not have enough such instrumentation as regulators, censors, alarms or other monitoring points to guarantee a good quality of indoor air regulation.

However, even more difficulties were due to the false interconnections of the control units and the instrumentation of the HVAC technology. Unfortunately, the quality of the HVAC design was not good either in every case. It can be due to many reasons as mentioned earlier, but not to mention it could have originated from the oversize trust on control's possibilities.

#### 7.4.1.3 Spatiality

Questions which could possibly give answers to the spatiality remain yet unanalysed for the most part (cf. 8.2.7.4, 8.2.7.5 and 8.2.7.6). Particularly, the analysis of the respondents' drawings of their workspace may give information about the architecture of the space, which is an important form of argumentation of space.

As a whole the spaces got higher grades in the IBs than in the reference buildings. Certain spatial and structural qualities can cause this difference. They are the existence of the glass roofed entrance hall, the wide assortment of shared spaces, and assembly floors. Still, it can be possible that the difference includes factors of the building intelligence, in other words the internal stock of knowledge of building intelligence, which has remained tacit during the building of the IBs and during the data gathering and analyses of the IBs Survey.

#### 7.4.1.4 Building Kinaesthetics

The office buildings which were studied in the IBs Survey did not have massive kinaesthetic systems such as halls, which could be turned automatically from sport halls to concert halls, etc.

However, various attributes of the furniture and equipment, adjustable technology or building services were studied. A clear difference was found between the intelligent and the reference buildings in their ability to adjust to the occupants needs of changing furniture and equipment in their personal workplace. That ability was better in the intelligent offices.

Also, the sense of change was measured and analysed within the IBs Survey. It was found a clear difference between the intelligent and the reference buildings in their ability to adjust to the occupants changing spatial needs. This ability was also better in the intelligent offices.

#### 7.4.1.5 Building Logic

The quality of the intelligent building hardware installations – including the building automation and ICT – cannot explain the differences in the EWE of the quality of the equipment between the IBs and the reference buildings, because the installations of the equipment in both buildings types are so similar. Their quality is high in both office building types.

In the case of equipment, in particular it seems obvious that its intelligence, in other words the internal stock of knowledge of the equipment includes factors, which have remained tacit during the building process of the IBs and during the IBs Survey. That intelligence could be as simple as the location of equipment, which helps the daily activities of the office workers.

The system integration has been a keyword of the IB concepts. This integration has reached from integrated structures to the integration of the needs or requirements of the occupants and their activities to the building amenities, services and to the technical, structural and spatial applications.

### 7.4.2 The Correspondence between the IB Concepts and the BI

After this analysis, it can be stated that the following factors of the IB concepts, environmental friendliness ($z_3$), life cycle costing ($z_6$), safety and security ($z_9$), comfort ($z_7$), convenience ($z_8$), marketability ($z_{15}$), ability of promoting health (therapeutic) ($z_{19}$), productivity (profitability) ($z_{22}$), working efficiency ($z_{10}$), image of high technology ($z_{11}$), construction process and structure ($z_{13}$), are not related to the building intelligence, as it is defined by the BIF.

Reliability (stabile sand accurate) ($z_{21}$) and correctness of basic technical solutions ($z_{23}$) are required for the successful control of the building. However, it is difficult to conclude whether they are parameters of any good building or if they are typical only for the intelligent building. They describe clearly neither the standard of intelligence nor human needs. They seem to be consequences of the use of human intelligence. In this context it is suggested that they be included in the building logic, because adaptability, regulation and control are all dependent on them.

The following ten factors of the IB concepts are left: level of integration ($z_2$), space flexibility and utilisation ($z_4$), movable space elements and equipment ($z_5$), culture ($z_{12}$), long term flexibility ($z_{14}$), information intensity ($z_{16}$), interaction ($z_{17}$), adaptability ($z_{20}$), reliability (stabile sand accurate) ($z_{21}$) and correctness of basic technical solutions ($z_{23}$). Their relation to the BI is shown in Table 44. It is based on the randomly found results of the building intelligence from the results of the IBs Survey, which is a systematic study on the quality of the intelligent buildings. The research of the IB concepts has been an essential part of it, and the result, i.e. the description of the building intelligence has emerged during this research.

According to the Equation 5. $IB_{concepts} = f\,(z_1 \ldots z_n)$ and on the basis of this study (Table 44.):

*Equation 20.* $bi_1 = f\,(z_{12}, z_{17})$ *i.e. building connectivity = f (culture, interaction)*

*Equation 21.* $bi_2 = f\,(z_{16})$, *i.e.. building self-recognition = f (information intensity)*

*Equation 22.* $bi_3 \neq f\,(IB_{concepts})$*, i.e. spatiality ≠ f (any factor of the IB concepts)*

*Equation 23.* $bi_4 = f\,(z_4, z_5, z_{14}, z_{20})$*, i.e. building kinaesthetics = f (space flexibility and utilisation, movable space elements and equipment, long term flexibility, adaptability)*

*Equation 24.* $bi_5 = f\,(z_2, z_{21}, z_{23})$*, i.e. building logic = f (level of integration, reliability (stabile sand accurate), correctness of basic technical solutions)*

In summing up, it can be written on the basis of the descriptions of the IB concepts (from Equation 20. to Equation 24.) that:

$BI = f\,(IB_{concepts}) = f\,(z_{12}, z_{17}, z_{16}, z_4, z_5, z_{14}, z_{20}, z_2, z_{21}, z_{23}) \Rightarrow BI = f\,(bi_1, bi_2, bi_4, bi_5)$, which is not true according to Equation 18.

The factors of the IB concepts describe only a part of the BI. That is the explicit part of the BI:

*Equation 25.* $BI_{explicit} = f\,(IB_{concepts}) = f\,(z_{12}, z_{17}, z_{16}, z_4, z_5, z_{14}, z_{20}, z_2, z_{21}, z_{23}) = f\,(bi_1, bi_2, bi_4, bi_5)$

where $BI_{explicit}$ is the explicit BI.

**The explicit BI is the function of such factors of the IB concepts as the level of integration ($z_2$), space flexibility and utilisation ($z_4$), movable space elements and equipment ($z_5$), culture ($z_{12}$), long term flexibility ($z_{14}$), information intensity ($z_{16}$), interaction ($z_{17}$), adaptability ($z_{20}$), reliability (stabile sand accurate) ($z_{21}$) and correctness of basic technical solutions ($z_{23}$).**

On the basis of the Equation 22. it can be argued that there is also the tacit part of the BI:

*Equation 26.* $BI_{tacit} \neq f\,(IB_{concepts})$

On the basis of the Equation 22. and the Equation 25. it can be argued that the BI is:

*Equation 27.* $BI = f\,(BI_{explicit}, BI_{tacit})$

where $BI_{explicit}$ is the explicit BI and $BI_{tacit}$ is the tacit BI.

By using the algorithms of the set theory it can be written:

$$\textit{Equation 28. } BI = BI_{explicit} \times BI_{tacit}$$

and

$$\textit{Equation 29. } BI_{tacit} = - BI_{explicit} \textit{ and } BI_{tacit} \Leftrightarrow \{z_{tacit}, z_{tacit+1}, \ldots , z_{tacit+n}\}.$$

The set of parameters of $BI_{tacit} \Leftrightarrow \{z_{tacit}, z_{tacit+1}, \ldots , z_{tacit+n}\}$ are not known yet. They can be found as well among the parameters of the IB concepts by expressing the essence of them differently than it has been done so far as they can be found from other sets of parameters. In other words, the parameters of the IB concepts can carry various contents; those which are familiar so far and expressed by from $z_1 \ldots z_n$ and others, which can be very parallel to them and expressed by $z_{tacit}, z_{tacit+1}, \ldots , z_{tacit+n}$. The first ones are for the $BI_{explicit}$ and the second ones for the $BI_{tacit}$.

Spatiality is a factor of building intelligence, which has no verbal argumentation among the IB concepts. In other words it is tacit knowledge by IB concept-wise. On the basis of the result of the IBs Survey, the good spatial quality of the IBs is inevitable. The good spatial quality of the IBs is partly due to the flexibility of the buildings, which has clear argumentation among the IB concept factors. But it is also due to the good mass and form, and overall impression of the IBs, which are not mentioned in the IB concept factors and which do not all describe the building properties very precisely. There may be unknown influencing factors of how the tendency of human intelligence to produce is expressed in the building. Thus **the existence of the spatiality in the IBs is true, although it has not been articulated in the IB concepts.** What is unknown is, how well the spatial quality could be found from the architectural drawings of the IBs and from the analysis of the respondents' drawings of their workspaces. These both are argumentation of the spatiality, i.e. they are forms of spatiality.

In summing up, the spatiality is so far the tacit part of the BI. The tacit BI is the function of spatiality ($bi_3$), i.e. a form of the BI itself, but it is not a function of the IB concepts, which is a clear consequence from the definition separating tacit and explicit knowledge from each other.

*Table 44. The correspondence between factors of the intelligent building concepts and the Building Intelligence Framework.*

| FORMS OF THE BI | FACTORS OF THE IB CONCEPTS |
|---|---|
| ($bi_1$) Building connectivity (speaking and speech recognition including music and linguistics; user-connectivity and either personal, organisational or automatic control) | culture ($z_{12}$), interaction ($z_{17}$) |
| ($bi_2$) Building self-recognition (building knows the state it is in, growing in consciousness) | information intensity ($z_{16}$) |
| ($bi_3$) Spatiality (a more conscious understanding of the spatial expression of the architecture, structures, interior design) | |
| ($bi_4$) Building kinaesthetics (a sense of change, active structures, moveable structures, furniture and equipment, adjustable technology or building services) | space flexibility and utilisation ($z_4$), movable space elements and equipment ($z_5$), long term flexibility ($z_{14}$), adaptability ($z_{20}$) |
| ($bi_5$) Building logic (the embedded follow up of the occupants' daily activities, combinativity) | level of integration ($z_2$), reliability (stabile sand accurate) ($z_{21}$), correctness of basic technical solutions ($z_{23}$) |

### 7.4.3 The Difference of Personal Workspace and Shared Spaces as Withdrawal of Collectivism and Emergence of Individualism by Concept of ba

The ideas about combining human and building intelligence (cf. Figure 13., Figure 32., Figure 46., Figure 48. and Figure 42.), which have been created during the analyses of the IBs Survey and the writing of this thesis in 1996–2002, have turned out to have similarities with the Japanese concept of ba. In the intelligent buildings the personal workplace did not get as high grades as the shared spaces (Lehto 1999c). This case of the results of the IBs Survey is now studied by using the theory of concept of ba.

According to the above mentioned result, it has been difficult for the designers to understand the end-user's needs in the context of the personal workplace. It is difficult to find those design criteria, which are common for all end-users in the context of the personal workplace, when they are not articulated. Similarly, for the same reason it has so far been difficult to recognise those factors of the personal office space, which should be flexible for personal adjustments. This difficulty can be due to the difficulty to share the information among the end-user and the designer, but it can be also due to the end-user to understand her or his needs.

However, according to the above mentioned result, the designers have understood the end-user's needs in the context of the shared spaces. What is the difference between the end-user needs and wishes between personal and shared spaces? The end-user is the same – the office worker, but the purpose of the usage of the space is different. The personal workspace is for individual use and the shared space for social activities. Thus, the current office building design criteria is more powerful in satisfying the end-user needs of the social activities than those of individuals.

Understanding sympathised knowledge, which is personal and connected to tacit knowledge according to Nonaka–Takeuchi learning cycle (Nonaka & Takeuchi 1995 p. 62, in Tuomi 1999, p. 325) seems so far to be more difficult to use in building design than conceptual, systemic or operational knowledge, which are connected to explicit knowledge.

The futures studies have discussed the existence of the human information and knowledge heritage in the form of the collective human consciousness. In the social sciences, the phenomenon of the collective field effect exists, and the scientific proof of its existence and function can be found, but very few books on it exist (Dunderfelt 2001).

In the Western economy the Maslow's Need Hierarchy (Huitt 1998), which reaches from the basic human needs of food and shelter to the sophisticated human abilities of understanding the connection of all creatures, has been used as a base for the need analysis of product R&D. The results of the futures studies claim that collectivism is drawing back and the time for individualism is emerging (Dryden & Vos 1996, Himanen et al. 2000a, p. 60, Naisbitt 1984, Naisbitt & Aburdene 1990, Toffler 1980). This march of individualism has been discussed as a phenomenon of the information age. It seems that the collective field effect has been working for the shared spaces, but the time is still to come for individualism to help with the personal workplace design.

The use of design criteria or design concepts and the understanding of end-user needs and wishes and turn them into building is knowledge transformation process, which Nonaka–Takeuchi describes with the learning cycle (Nonaka–Takeuchi in Tuomi 1999, p. 325). The use of design criteria and design concepts is the same as use of conceptual knowledge, which has become from sympathised knowledge. The sympathised knowledge is personal knowledge, which becomes conceptual knowledge after a group of people have shared it. **According to the results of this study, I would like to state that it seems possible that he transformation of the tacit sympathised knowledge into the explicit conceptual knowledge has succeeded better in the case of collective human information and knowledge heritage than what it has done in the case of individual personal end-user need and wishes. In this case the sympathised knowledge is not understood only personal. It can be tacit knowledge created by society, which is in reach of as well groups as individuals.**

The sympathised knowledge of personal needs and wishes is not well socialised and externalised, and no wonder, that the search for oneself or the growth in self-consciousness, a sort of introspection has been one of the trends in the society since the end of 1980's, at the same time, when the externalisation, combination and internalisation of the building intelligence has taken place, because the implementation of the IB concepts.

Design starts from the premise that the needs and wishes – building requirements or design criteria – are known. Need for the end-users of getting the position of subject agent in the building is parallel to this wish to know oneself better, which makes it possible to be aware of one's needs and wishes. The future will be promising, if the growth in self-consciousness of the end-users and the possibilities of taking the role of subject agents in building improve simultaneously.

Accordingly, it seems from the point of the fact that end-user evaluation of the shared spaces is evaluated as good, that the shared spaces have been designed according to explicit knowledge, that is transmittable in formal, systematic language, and thus more comprehensible and easier to implement.

# 8. Discussion

In business life, productivity is essential. This thesis concentrates on the end-user evaluation of two different kinds of office environments and on their possibilities to influence the office workers' working efficiency. Working efficiency is seen as a reflection of the total office space quality, but not as the only factor, which can indicate the standard of physical office environment. The quality evaluation measures correctness or incorrectness of the second hypothesis of this thesis.

Criticism on the chosen method, absence of some analyses, alternative approaches, possible reasoning to the results, comparison of the result to the literature review and some creative suggestions for future intelligent solutions will be the subjects of this chapter.

## 8.1 The Intelligent Buildings Survey

The effectiveness of the space has been measured by the end-user evaluation of building properties' influence on the working efficiency of the office worker (the EWE). This means the efficacy of the building, i.e. its space, equipment and some of the services. The efficacy has also been studied by the IB concept's feasibility in business travelling, energy management, indoor air quality and building economics. They are relevant for the building owners. They are also, in accordance with the customer oriented construction policies, and to a greater extent indirectly helping the productivity of the business of the companies located in the office space.

### 8.1.1 Selection of Method

The choice of using system theory as a starting point for the IBs Survey, together with quality management and a post-occupancy study with statistic analysis, has its influence on the result. It can be argued that these are, at the same time, the means by which the researcher has influenced the result. The latter issue has been under discussion within research even in natural sciences based on the strictest empiristic epistemology and positivism. It is an aim of the research to be as open as possible for the new knowledge emerging from the data gathered, or cumulated from the conclusions which follow each other.

This study is no exception when considering the problem of the researcher's influence on the research results. Since the basis has been on the system theory, the results will give answers about the system and its subsystems. And since the evaluation was based on the end-user opinion, the results reflect the importance of the end-user need orientation. Several means have been used for ensuring the correctness of the results, which are reported in section 5.3.7.

During the analysis of the IBs Survey data, the neural networking was also tried on the basis of the Kohonen map. This was done because the author believed the data could be analysed by learning from the material in such a manner that the scientist was not making any choices or decisions on the grouping of the factors. I was wrong. In beginning to use the Kohonen map, the scientist makes some decisions on the grouping in any case, although the neural networking system analyses the data by learning from the material to a certain extent.

The second problem with using the neural networking for the data analyses was the lack of cases in the sample, in comparison to the number of parameters in the study. This was the main reason for giving up this very promising way of analysing scientific data. The neural network analysis needs 100 times more cases than there are parameters. The neural networking analyses were possible for a limited set of parameters in order to analyse a subsystem. Further, the matter of transportation was studied by neural networking analysis, where for example, the profiles of the drivers, pedestrians, or passengers can be identified (Himanen et al. 1998). This was not the focus of this study, but the short try within the study as well as the further use of the method in transport research revealed the possibilities and limitations of this approach (cf. Jurva 1999).

### 8.1.2 Relevance of the Sample and Generalisation

The number of buildings of the sample is relatively small compared to the whole office building stock of Finland, but not that small compared to the yearly office building construction projects. The sample covers 15 per cent of a normal yearly production volume of office buildings, and even over 50 per cent of the construction volume of the year when the study was carried out (Section

5.3.3.2). Yet, the buildings of the IBs Survey are typical high quality office buildings. During the selection of the buildings the aim of the expert group was to find typical high quality office buildings, and according to the results it seems to be true also on the basis of the end-user evaluations, as well (Table 17. and Table 18.).

There has been some intention, but little possibility to extrapolate from the survey any generalised scientific results of the differences of the two office types. However, as there is not available much evidence from literature of the difference of the IBs and the reference buildings, this attempt towards this goal is valuable.

Some results of the IBs Survey parameters seem very relevant, when they are compared with the results of similar phenomena from the literature. If this similarity is valid in such a feature which is related to the IB concepts, then it is a proof of the validity of the result of this thesis for generalisation. If the above mentioned similarity is valid in such a feature which is related to any office building feature, then it is a proof of the validity of the result in general.

However, the number of respondents, who evaluated the quality of the buildings, is relatively large and the end-user evaluation results seem to be in general quite coherent. One reason for this might be the high educational status of the respondents. Further more, the end-user evaluation results seem to reflect the importance of the building quality to the working efficiency of the respondents accurately, although a study of end-user feedback can result also with an evaluation, which reflects other than physical or technical building features directly or indirectly. From the end-user evaluation results it can be concluded that the respondents have had a strict professional approach to their task rather than reporting their personal opinions of buildings (Section 7.1.4.4).

All the buildings are located in a special area. The office building market in Helsinki metropolitan area is strong, but there are other similar strong markets in Finland. The speciality of this market is the international investors' interest in the market of office buildings mainly only in the metropolitan area in Finland (Kaleva & Olkkonen 2001). The metropolitan area includes three major cities: Helsinki, Espoo and Vantaa, which were presented in the sample. Some differences between the office buildings in Helsinki and in Espoo were found

(Lehto 1999f). There was also an IB case from Vantaa included in for comparison.

The IBs Survey is in the first place a case study of office buildings in the Helsinki metropolitan area. The nature of building industry is regional in any location (cf. Section 2.5). However, the end-user evaluation results are based on the fairly large number of the respondents, who are well representing the average Finnish office workers. This is a fact, which supports the generalisation of the results in the context of the offices located in the Helsinki metropolitan area, and even in certain limits in the cases of other cities of similar office markets (Lehto 1999f). Certain study results, such as the diamond structure of the working organisation are not dependent on the location of the building, and even the transferability of such a result into a wider context than that of the Helsinki metropolitan area's office buildings case is possible.

### 8.1.3 About Validity and Reliability

This thesis is presenting a new definition of the building intelligence, which is not done before. I have come up with the hypothesis of the metaphor between human and building intelligence already in 1989 (Section 3.4) and the evidence of it is based on the results of the IBs Survey (Section 7.1) and the argumentation of this thesis (Section 7.3.2). The IBs Survey was carried out by a group of researchers (Sections 1.3 and 5.3.4) under the supervision of the author, who wrote the research proposal alone and selected the methods and approaches (Sections 5.1, 5.2 and 8.1.1). This thesis is a study independently done after the IBs Survey (Chapter 7, and Chapters 9and 10 consequently). The results of the group work have been reported in section 8.1.4, and in the following tables and figures: Table 9., from Table 20. to Table 23., from Table 25. to Table 30., from Table 36. to Table 39., Table 42., from Figure 27. to Figure 31. They show final results of analyses based on the second phase of the IBs Survey, because questions on these matters were not included in the first phase of the survey.

The validity of the samples have been proven by the statistical analysis using the F-test of variance analysis. The chosen and measured parameters well separate the two studied building types from each other (Section 7.1). The additional indicators, which are the indirect benefits of the implementation of the IB concepts support the results of the questionnaire study and thus the correctness of the selection of the parameters (Sections 7.2 and 9.1.5). The reliability of the samples have been described in section 5.3.3 and discussed in section 8.1.2. It is done on the behalf of the office workers in section 5.3.3.1, which shows that the sample is rich and well representing the average Finnish office workers. It is done on the behalf of buildings in section 5.3.3.2 telling that despite of the limited number of twelve office buildings the volume they are representing is that of 15 % of the whole office building volume built in 1994. The variety of the occupant companies has been described in section 5.3.3.3.

Despite of the fact that I am aware of all stakeholders of the office building (Section 4.3.5.3), the end-users have been in the focus, because their role is not as clear than that of the building professionals and those end-users who represent the companies working for the building services have the change to express their thoughts concerning the building and its use better than the office workers, whose supervisors quite often represent the occupant company and its needs.

#### 8.1.4 Preliminary Studies

As mentioned earlier, the IBs Survey was in the first place analysed and reported for the needs of the industry (Lehto et al. 1997). This analysis was based on the results of the second phase of the IBs Survey, because of practical reasons. Afterwards, for scientific purposes, the outcomes of the data gathering of the two different questionnaires of the two phases of the IBs Survey have been analysed together as often as possible. Even certain combinations of the results have been made for making a common analysis possible. The results of this study are based rather on those analyses than on that of the second phase of the IBs Survey.

The analysis of the second phase of the IBs Survey resulted in certain differences between the IBs and the reference buildings, and on the other hand certain parameters showed no difference at all. This has guided the selection of the focus for the further analysis of the whole sample. **Nevertheless, the systematic analysis of all questions could be best in revealing all aspects of the gathered data as have been found when summarising the results of the questions of the quality of spaces and equipment.** This work is not completed yet. The results gained so far are reported in this thesis. The analysis made so far concentrates on the differences between the IBs and the reference buildings, and the existence of the IB concept, which is a consequence of the difference.

As mentioned earlier (Section 5.3.4), the questionnaire included questions on the IB features and office space quality in general. Therefore, the result of the IBs Survey can serve as a source of the study of the office environment over a wider range.

The analysis of some office workspace qualities and their influence on work efficiency has resulted in different results, when the results of the second phase of the IBs Survey has been under examination than, when the whole sample has been analysed. In this case, the bigger sample has not resulted in any statistical differences on the behalf of some parameters, which on the basis of the second phase data were showing statistically significant difference, and vice versa.

Nevertheless, some results from the analyses of the second phase are valuable background information for this study and will be presented in the next sections. They are also valuable information on those factors, which influence the differences between the two building types, but which have not been analysed systematically on the basis of the whole sample as yet. The need of further analyses is reported in section 8.2.7.

In this section, all the parameters of the statistical analyses are not presented, although all results presented are based on careful statistical analyses made with the aid of the SPSS software. Only the existence of the statistical significant differences are marked systematically (no values of Chi-squares (p's) or no numbers of cases will be shown).

#### 8.1.4.1 Office Room Type

The work spaces were categorised into five groups in the questionnaire: personal work room, a shared room, a work space with partitions in the open area office, a work space without partitions in the open area office, and no personal desk. The respondents were asked what kind of workspace they have now, have had previously and would like to have (Table 45.). The comparison between the two office building types was made (Table 46.). Also, the comparisons of the effect

*Table 45. The types of workspace.*

| Type of Workspace<br>*Percentages of the respondents (%)* | Previous<br>*(n=263)* | Current<br>*(n=330)* | Future Wish<br>*(n=206)* |
|---|---|---|---|
| Own room | 60 | 70 | 76 |
| Shared room | 25 | 18 | 10 |
| Open area office space (partitions) | 10 | 6 | 6 |
| Open area office space (without partitions) | 4 | 4 | 5 |
| No personal workplace | 1 | 1 | 1 |

*Table 46. The test (F-test) of the difference of the workspace types between the two office building types.*

| Type of Workspace | Previous[1] | | Current*[2] | | Future Wish*[3] | |
|---|---|---|---|---|---|---|
| *Percentages of the respondents (%)* | IB *(n=158)* | Non-IB *(n=132)* | IB *(n=192)* | Non-IB *(n=155)* | IB *(n=140)* | Non-IB *(n=107)* |
| Own room | 58 | 62 | 64 | **77** | 71 | **83** |
| Shared room | 30 | 19 | **24** | 12 | 14 | **4** |
| Open area office space (partitions) | 9 | 11 | 5 | 8 | 6 | 7 |
| Open area office space (without partitions) | 3 | 7 | 7 | 1 | 6 | 4 |
| No personal workplace | 1 | 2 | 1 | 1 | 1 | 2 |

[1] ≡ A statistically remarkable difference Pearson Chi-square p= .10315, M-L Chi-square p= .09846;* A statistically significant difference; [2] ≡ Pearson Chi-square p= .00218, M-L Chi-square p= .00112; [3] ≡ Pearson Chi-square p= .03135, M-L Chi-square p= .01425; The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept.

*Table 47. The types of the workspace of the different groups of workers.*

| Type of Workspace | Executives | | Professionals | | Clerks | |
|---|---|---|---|---|---|---|
| *Percentages of the respondents (%)* | Now *(n=48)* | Wish *(n=34)* | Now *(n=168)* | Wish *(n=123)* | Now *(n=86)* | Wish *(n=57)* |
| Own room | **98** | **91** | 68 | 76 | 63 | 74 |
| Shared room | 2 | – | 21 | 10 | 23 | 12 |
| Open area office space (partitions) | – | 3 | 5 | 6 | 7 | 7 |
| Open area office space (without partitions) | – | 6 | 5 | 5 | 6 | 5 |
| No personal workplace | – | – | 1 | 2 | 1 | 2 |

The bold text is for the best or biggest values.

*Table 48. The difference of the types of the workspace between genders.*

| Type of Workspace *Percentages of the respondents (%)* | Men *(n=161)* | | Women *(n=119)* | |
|---|---|---|---|---|
| | Now | Wish | Now | Wish |
| Own room | 72 | 78 | 68 | 74 |
| Shared room | 18 | 10 | 17 | 9 |
| Open area office space (partitions) | 6 | 6 | 6 | 7 |
| Open area office space (without partitions) | 3 | 4 | 7 | 8 |
| No personal workplace | 1 | 2 | 1 | – |

of the working status of the workers and that of gender were studied (Table 47. and Table 48.).

The private workroom is a current workroom type and a favourite in the future in comparison to the other workspace alternatives of a shared room, an open area workspace with partitions and an open area workspace without partitions (Lehto and Flink in Lehto et al. 1997, p. 145). A few professionals and clerks would like to have a shared room in the future. Shared room is not a favourite, neither is the open area office space as an personal workplace on the basis of the future wishes. **There are more unfavourable shared rooms in the IBs than in other office buildings,** which is a reason for the lower grades of the workspaces in the IBs.

There is no difference between genders in the current situation and in the future wishes of the workspace types. The test of the effect of the status of work is unstudied. However, there are obvious differences between workroom types of executives and those of the other worker groups. **The executives have more often their own room than the other worker groups do.** It is interesting to discover that although executives do not work in the open area office space, there are weak signals of the wishes for doing so in the future.

Interestingly though, none of the executives wished to move to a shared room, which was not popular among other worker groups either, but a handful of them prefer an open area workspace to a private workroom. According to Brill (1985, p. 51) they are making a mistake. The analysis of the effects of workroom on communication is yet to be done.

#### 8.1.4.2 Sound Environment

In all offices the sound environment was found by the IBs Survey relatively neutral in general (Karjalainen in Lehto et al. 1997, p. 221). It was clear that the background music (54 per cent of the respondents) and the music of own free choice (32 per cent of the respondents) were overwhelmingly the most pleasant voices of the office. The next pleasant voices in the ranking of the voices were voices of the workmates and the sound of air-conditioning (10 per cent of the respondents). Accordingly, overwhelmingly the most disturbing voice was originated from copying machines (40 per cent of the respondents). Ringing of the telephone sets (29 per cent of the respondents), background music (28 per cent of the respondents), the sound of the display terminals (26 per cent of the respondents) and the voices of the workmates (24 per cent of the respondents) were the next in order in the list of the disturbing voices. Most of the office workers of the IBs Survey agree on the disturbance of the copying machines and the pleasure of the music, especially that of free choice. However, the background music is not a favourite of all. Roughly as many like it as dislike it. Otherwise, there are personal differences in appreciation of the sounds, too.

Worth of noting is the fact, that the sound of water was not mentioned as exceptionally pleasant, only 6 per cent of the respondents ranked it pleasant, while most of them thought it is neutral (74 per cent of the respondents). There are indoor fountains in Finland, as well as for example in Japan. Among the IBs of the IBs Survey there was only one with a fountain in the lobby. It would be interesting to analyse if the appreciation of the sound of water in this building is different from the other offices.

Brill (1985) has found that more noise related to higher ease of communication. The comparison between the IBs and the reference buildings on the quality of the background music could tell about the meaning of the noise to the ease of communication, which in general was got good grades in the IBs (according to the result of the question about the claims of the office space qualities, not the one about voice environment).

An interesting result is that the silence of the workspace is appreciated better in the IBs than in the other office buildings (Table 49.). It seems also that there is not a big difference between women and men in the appreciation of the silence, except on the behalf of the wish of constant silence. This could be interpreted as a sign of the fact, that it is other things than the noise, which makes women complain more often than men of the difficulty of concentration on ones work in the office. Such things can be other interruptions excluding those caused by phones.

#### 8.1.4.3 Office Automation Integration

All the answers on equipment are summarised in Table 50., Table 51. and in Table 52. **The end-user evaluation of various office automation reveals that in the intelligent offices such equipment, which is either used personally, but take advantage of the integrated office equipment technology or which are shared among several users via an interoffice network service are more**

**often valued to be better for work efficiency than those in the reference buildings** (Table 50. and Table 51.). In other words it can be concluded that the interoffice networks seems to aid the use of office automation rather in the IBs than in the reference buildings. **It can be argued also that the interoffice network integrating the office automation equipment is working better in the end-users' opinion in the IBs than it does in the reference buildings.** In the IBs both the target of personal use of the office equipment and taking advantage of the technology common to all have been gained. Women prefer these solutions more often than men do, and the clerical staff more often than the other groups of workers.

*Table 49. The appreciation of silence in the personal workplace.*

| *Percentages of the respondents (%)* | Always | Part of the time | Every now and then because of concentration | Other |
|---|---|---|---|---|
| All of the respondents | 15 | 38 | 45 | 1 |
| Workers of the IBs *(n=186)* | **18** | 34 | 46 | 2 |
| Workers of the Non-IBs *(n=149)* | 12 | **44** | 44 | 0 |
| Men *(n=185)* | **18** | 37 | 44 | 0 |
| Women *(n=143)* | 10 | 41 | 48 | 1 |
| Executives *(n=45)* | 18 | 38 | 42 | 2 |
| Professionals *(n=168)* | 17 | 42 | 41 | 0 |
| Clerks *(n=82)* | 9 | 41 | **50** | 0 |
| Other employees *(n=26)* | 15 | 19 | 58 | 8 |

The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept.

**Equipment, which is used personally (Table 52.), is valued better in the reference buildings than in the IBs.** Among these is personal equipment, which can be operated also either through the interoffice network or with wireless technology, but still personally.

*Table 50. The end-user evaluation of office automation connected by network and used personally according to the office building types, the statuses of the workers and genders.*

| *The sample of the second phase of the IBs Survey, n=386.* <br><br> *An index from 4 to 10 (the best)* | IB *(n=174-121)* | Non-IB *(n=156-76)* | Men *(n=179-126)* | Women *(n=135-68)* | Executives *(n=44-30)* | Professionals *(n=154-94)* | Clerks *(n=81-47)* |
|---|---|---|---|---|---|---|---|
| Telephone | **9.1** | 9.0 | 9.0 | **9.1** | **9.5*** | 9.0* | 8.9* |
| Personal computer | **9.3** | 9.2 | **9.3** | 9.2 | 9.0 | **9.3** | **9.3** |
| Email | **8.6*** | 8.2* | 8.4 | **8.6** | 8.3* | 8.2* | **8.8*** |
| E-banking [2] | **6.6** | 6.1 | 6.5 | 6.5 | 6.6 | 6.1 | **6.8** |

[2] ≡ Those who use the device evaluate this device better than average (shown in this table) for working efficiency of the office worker; [*] ≡ a statistically significant difference; p< .05 (F-test); The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept.

The equipment connected via the interoffice network is a favourite among the female office workers (Table 50., Table 51., cf. also Section 7.1.4.2 about interoffice equipment and heavy travelling of the female executives). The end-user evaluation result of the personally used equipment has no special trend according to gender aspects (Table 52.).

Also, the status of the worker segregates the end-user evaluation result of the interoffice automation and network. The status of the worker has an effect on the

*Table 51. The end-user evaluation of office automation connected by network according to the office building types, the status of the workers and genders.*

| *The sample of the second phase of the IBs Survey (n=386).* *An index from 4 to 10 (the best)* | IB *(n=140-99)* | Non-IB *(n=112-75)* | Men *(n=150-124)* | Women *(n=93-64)* | Executives *(n=37-26)* | Professionals *(n=134-103)* | Clerks *(n=62-40)* |
|---|---|---|---|---|---|---|---|
| Telefax via local area network [2] | **7.8*** | 7.1* | 7.4 | **7.6** | 7.4 | 7.3 | **7.8** |
| Shared printer | **8.3** | 8.0 | **8.3** | 8.1 | 7.8 | **8.4** | 7.8 |
| Shared telefax machine[1] | **8.6** | 8.3 | 8.4 | **8.5** | **8.7** | 8.4 | 8.4 |
| Advanced telephone exchange | 7.3 | **7.5** | 7.2 | **7.6** | **7.8** | 7.1 | 7.4 |
| Safety (blocking, burglar alarm)[2] | 6.7 | **6.9** | 6.7 | **6.9** | **7.1** | 6.8 | 6.5 |
| Colour printer [2] | 6.5* | **7.0*** | 6.8 | 6.8 | 6.6 | **6.9** | 6.8 |
| Access control | **6.3** | 6.0 | 5.9* | **6.5*** | 6.0* | 5.8* | **6.7*** |
| Working time monitoring | **6.1** | 5.9 | 5.7* | **6.5*** | 5.4* | 5.8* | **6.6*** |

[1] ≡ The device can be either an interoffice system or run locally or by using wireless technology; [2] ≡ Those who use the device evaluate this device better than average (shown in this table) for working efficiency of the office worker; [*] ≡ a statistically significant difference; p< .05 (F-test); The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept.

*Table 52. The end-user evaluation of the personally used office automation according to the office building types, the statuses of the workers and genders.*

| *The sample of the second phase of the IBs Survey (n=386)* <br> *An index from 4 to 10 (the best)* | IB *(n=125-79)* | Non-IB *(n=101-58)* | Men *(n=131-85)* | Women *(n=101-64)* | Executives*(n=42-22)* | Professionals *(n=112-94)* | Clerks *(n=40-31)* |
|---|---|---|---|---|---|---|---|
| **Paging device** [1, 2] | 6.0* | **6.6*** | 6.1 | **6.7** | 6.4 | 6.3 | **6.8** |
| **Portable computer** [2] | **7.6** | 7.2 | **7.7*** | 7.1* | **7.8*** | 7.7* | 6.5* |
| **Mobile phone** [2] | 7.2 | **7.6** | **7.6*** | 6.8* | **8.1*** | 7.4* | 6.5* |
| **Answering machine** [2] | 6.7 | **6.9** | 6.6* | **7.1*** | **7.0** | 6.8 | 6.3 |
| Personal telefax machine [2] | **6.0** | 5.4 | **5.8** | 5.6 | 6.1 | 5.4 | **6.3** |
| Video, digital camera, etc. image handling [2] | 5.6 | **5.8** | **5.7** | 5.6 | 5.2 | **5.8** | 5.4 |
| Dictator [2] | 5.1 | **5.4** | 5.0 | **5.6** | **5.5** | 5.1 | 5.1 |
| Personal printer | 8.0 | **8.4** | 8.0* | **8.5*** | 8.2 | 8.0 | **8.7** |

[1] ≡ The device can be either an interoffice system or run locally or by using wireless technology; [2] ≡ Those who use the device evaluate this device better than average (shown in this table) for working efficiency of the office worker; * ≡ a statistically significant difference; p< .05 (F-test); The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept; The equipment important also for flexibility is marked with bold text.

personally used equipment's end-user evaluation. Executives like voice connections and safety, and clerical personnel services reached through computing (Table 52.), while the professionals can find hardly any such personally used equipment that could help them with their work. Professionals do not evaluate any equipment as very good in contract to the other groups of the workers.

#### 8.1.4.4 Office Automation Availability

The evaluators of the office automation were given three options concerning the respondent's status as an user of equipment: device in use, wish to have device for use, not using it. The end-user evaluations of those who are using a device and those who do not use it can be different (Lehto 1999f, Lehto & Karjalainen in Lehto et al. 1997, p. 181). **In general, the end-user evaluation is more favourable, if the evaluator uses the device.**

The IBs Survey could be analysed further by grouping the answers as follows: [a)] those who use, and those who do not have but wish to have, together, and [b)] those who do not use. That result would be more precise, than the one now available, which is including the end-user evaluation alternatives based on users' and non-users' opinion together.

There is no difference between those who use and those who do not in the case of the six devices, which were evaluated to be best for the work performance: a personal computer, a telephone, a personal printer, email, a telefax machine shared by LAN, and a printer shared by LAN. The personal telefax machine ranks seventh in the group of best equipment. There is a great difference regarding its' evaluation between those who have and use it, and those who don't use it. It is evaluated to be good (8.9) on the behalf of working efficiency among those who use it, but to be not so good (5.7) among those who do not use it. The rest four best pieces of equipment out of the eleven are a portable computer, a mobile phone, a telefax via LAN, and an advanced telephone exchange. In these cases, the worst grade is 7.4 and the best one is 8.5, on the scale of 4–10. The ranking order is the same according to the grades of the users' and those who do not use the device.

The difference in the end-user evaluation grades is between 6.3 and 7.8 in the next, not in anyway more remarkable group of five devices: an answering machine, a colour printer, e-banking, paging and security. The four least important systems for work performance are image handling, dictating, access control and work time monitoring. Image handling and dictating is evaluated better among those who use them (difference from 5,2 to 7.3). The access control and working time monitoring are the least important for working efficiency whether the evaluator is using them or not (difference from 6.0 to 6.5).

#### 8.1.4.5 Working Efficiency

Quite a large set of claims of the effects of the ICT on office work performance was presented and the respondents were asked if they agree, partly agree or disagree with them (from Table 55. to Table 56.). The claims included questions about usability of the new technology in the office, as well as questions about possibilities to concentrate to one's work, about interaction and communication and the effectiveness of office work. The following is based on the data of the second phase of the IBs Survey. Some differences between office building types was found on these matters.

The statistically significant difference between the building types is:

- The workers can partly telework (distant work) for example at home due to the technical equipment better in the IBs than in the reference buildings.

Remarkable differences between the building types are:

- The workers can better keep up with their goals by means of office automation in the reference buildings than in the IBs.
- New technology makes it easier to concentrate on knowledge work or thinking in the reference buildings than in the IBs.
- The use of technical equipment is more stressful for the workers in the reference buildings than in the IBs.

The statistically significant differences when the status of the workers and gender is in concerned are:

- working efficiency, while the clerks found more often than the other groups of workers that they can well keep up with my goals by means of office automation

- working efficiency, while the men more often than women found that the office automation has decreased the need of executives' secretariat

- possibilities to concentrate to one's work, while the men thought more often than women and the clerks found more often than the other groups of workers that they can partly telework (distant work) for example at home due to the technical equipment.

The office workers prefer their own ability to take care of their tasks to the efficiency of the office equipment (Table 53.). The clerical personnel's ability to take advantage of the office automation is exceptional in the terms of increasing working efficiency. In general, the new technology is experienced to be good for the working efficiency in the reference buildings, in particular.

Due to the new technology it is possible to decrease executives' secretary in the end-users' opinion and the amount of the clerical staff has decreased remarkable on the grounds of the differences in the amount of different groups of workers in the IBs and the reference buildings. In the IBs has happened the change from triangle organisation to the diamond one, because the number of clerical staff is smaller there than in the reference buildings. However, the option that the new office automation technology could reduce meetings was not true for very many of those who answered.

The lacks in the knowledge of and the difficulties with the use of the technical equipment are reported as well as the increase of the hurry, but not stress due to the use of new technology (Table 54.). Although the stress factor in general in not important, it is good to notice that the office equipment was found more stressful in the reference buildings than in the IBs, which might be due to the bigger number of women working in the reference buildings.

In the IBs, both because of the spatial solutions and due to the ICT, to concentrate on knowledge work is more difficult than in the reference office buildings.

*Table 53. The office workers opinion on the efficiency of the working environment.*

| Claim<br>*The sample of the second phase of the IBs Survey. Percentages (%) of the respondents, who fully or partly agreed on the claim of the question* | Mean *(n=285-343)* | IB *(n=166-191)* | Non-IB *(n=131-152)* | Men *(n=172-178)* | Women *(n=113-127)* | Executives *(n=41-46)* | Professionals*(n=150-166)* | Clerks *(n=66-76)* |
|---|---|---|---|---|---|---|---|---|
| IN GENERAL | | | | | | | | |
| New working environment has increased my working efficiency remarkable. | 63<br>15[1] | 61 | 65 | 67 | 60 | 65 | 61 | 60 |
| My working efficiency is dependent on my own not on the technical devices. | **91**<br>41[1] | 90 | 91 | 92 | 88 | 96 | 89 | 89 |
| OFFICE AUTOMATION | | | | | | | | |
| I can well keep up with my goals by means of office automation. | 72<br>18[1] | 68[2] | 78[2] | 72 | 74 | 69* | 66* | **84*** |
| The office automation has decreased the need of executives' secretariat. | 66<br>32[1] | 69 | 63 | **72*** | 59* | 71 | 68 | 60 |
| TIME MANAGEMENT | | | | | | | | |
| By means of office automation equipment such as mobile phone I can better than before manage my time. | 60<br>28[1] | 59 | 62 | 65 | 53 | 71 | 61 | 52 |

* ≡ A statistically significant difference, $p< .05$; [1] ≡ In this column of the mean values this second figure is the mean value of those who fully agreed with the claim.; [2] ≡ p= .09662 (Pearson Chi-square), p= .09497 (M-L Chi-square); The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept.

*Table 54. The office workers opinion on stress caused by and their skills to use the equipment.*

| Claim<br><br>*The sample of the second phase of the IBs Survey.*<br>*Percentages (%) of the respondents, who fully or partly agreed on the claim of the question* | Mean *(n=285-343)* | IB *(n=166-191)* | Non-IB *(n=131-152)* | Men *(n=172-178)* | Women *(n=113-127)* | Executives *(n=41-46)* | Professionals *(n=150-166)* | Clerks *(n=66-76)* |
|---|---|---|---|---|---|---|---|---|
| "COMPUTING SKILLS" | | | | | | | | |
| Part of the equipment which the company has purchased is there in vain because people cannot use it. | 67<br>15[1] | 64 | 71 | 66 | 68 | 62 | 67 | 69 |
| I am able to benefit only a minor part of the technical equipment available in our working environment. | 57<br>7[1] | 62 | 52 | 55 | 60 | 59 | 56 | 61 |
| STRESS | | | | | | | | |
| The use of technical equipment is stressful for me. | 19<br>4[1] | 17[2] | 22[2] | 15 | 22 | 17 | 16 | 26 |
| The increase in the technical office aid means the increase in hurry. | **74**<br>19[1] | 70 | 79 | 78 | 68 | 76 | 70 | 77 |

[1] ≡ In this column of the mean values this second figure is the mean value of those who fully agreed with the claim.; [2] ≡ p= .10274 (Pearson Chi-square), p= .09749 (M-L Chi-square); The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept.

However, the communication possibilities are better and the possibilities for personal contacts are appreciated in the IBs. It can be concluded further that difficulties in concentration concern the professionals and female clerks more than the executives and male clerks. These interesting differences are not, however, statistically significant.

#### 8.1.4.6 Flexi-working Possibilities

As mentioned earlier, the equipment in the IBs make the tele-working easily possible than that of the reference buildings. There is no difference between the workers of the IBs and the reference buildings in the importance of the portable computer's and the mobile phone's influence on work performance (Table 52.). This is natural, since these are separate devices, which do not have much to do with the quality of the building, although they influence working flexibility and the amount of business travelling.

Instead, gender's and the status of the worker's relevance is in this connection significant. **Men more often than women and executives more often than professionals and clerical personnel, and professionals more often than clerks prefer office tools that promote working flexibility** (Lehto 1998d, Lehto 1999f).

The evaluation gave higher grades for the quality of the fixed personal office equipment utilising interoffice networks in the IBs than in the reference buildings (Table 46. and Table 47.). In the reference buildings the ICT got higher grades when it is based on local use or wireless technology (Table 48.). The quality of fixed ICT equipment might be important in the IBs, because there people work long hours in their personal workrooms. Despite of this end-users' opinion, the installations of the fixed office equipment is neither better nor worse in the IBs than in the reference buildings (Lehto 1999f, Lehto 1998d), and for example the LAN is a standard in any studied office building.

The ICT's power is best for speedy communication and reaching people quickly. Of those who answered to the claims about the working environment, 95 per cent thought that "due to the new technology the information transfer is fast" and 90 per cent think that "mobile phones, emailing and answering machines have made it easier to reach other workers of the company" (Table 55.).

*Table 55. The end-user evaluation of the communication possibilities of the working environment.*

| Claim<br>*The sample of the second phase of the IBs Survey.*<br>*Percentages (%) of the respondents, who fully or partly agreed on the claim of the question.* | Mean *(n=285-343)* | IB *(n=166-191)* | Non-IB *(n=131-152)* | Men *(n=172-178)* | Women *(n=113-127)* | Executives *(n=41-46)* | Professionals *(n=150-166)* | Clerks *(n=66-76)* |
|---|---|---|---|---|---|---|---|---|
| OFFICE AUTOMATION | | | | | | | | |
| Need of meetings has been decreased due to the office automation. | 55<br>15[1] | 55 | 55 | 59 | 50 | 44 | 55 | 55 |
| Due to the new technology information transfer is quick. | **95**<br>63[1] | 96 | 94 | 97 | 94 | 96 | 94 | 96 |
| Due to mobile phones, email and answering machines it is better to catch up the workers of the company. | **90**<br>60[1] | 90 | 89 | 90 | 90 | 91 | 89 | 90 |
| OPEN SPACE | | | | | | | | |
| The open office space speeds up interaction and communication and decreases the need of meetings. | 66<br>22[1] | 67 | 64 | 67 | 64 | 66 | 66 | 60 |

[1] ≡ In this column of the mean values this second figure is the mean value of those who fully agreed with the claim.; The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept.

#### 8.1.4.7 Concentration on Work by ICT

The interplay between the possibility to concentrate at work and the possibilities of communication is a multidimensional issue, which was studied through several questions. More about it in the next sections. Next, the possibilities to concentrate at work are discussed from the ICT point of view.

The possibility to concentrate on knowledge work thanks to the ICT was tested with a claim. The evaluators were asked to either confirm or refute the claim. The bigger number of respondents thought that ICT also helps in concentration, not only in communication. A difference between the two office building types was found. **As mentioned earlier, the number of those who think that the new technology help concentrating at work is in the reference buildings bigger than in the IBs.**

No differences between men and women, and no statistically significant differences between worker groups of different status were found in the ICT's ability to aid in concentration at work. One exception was noted, however.

The evaluation of the clerical personnel shows some a difference to the other worker groups. A good number of the clerks thought that new technology helps them to concentrate on their work due to the ICT tools. The clerical personnel is relatively well educated, and the clerks are satisfied with their work (Sections 5.3.3.1, and 7.1.4.4), and further more they answered to other claims about the working environment effect on the work efficiency more positively than other worker groups of different status did. They also considered their abilities in keeping up with the aims of their work due to the office automation statistically significantly better than the other worker groups did.

The female executives are a mystery. Female executives who are working in the IBs find the new ICT office tools most effective for their working efficiency compared to the all other groups (Lehto 2000, Lehto 1997). They find also the possibilities to concentrate on their work better than all other groups (Lehto 2000).

#### 8.1.4.8 Interaction, Communication and Concentration on Work through Spaces

The interplay between the possibility to concentrate on work and the possibilities for communication is a multidimensional issue, which was studied through several questions. Next, the possibilities of interaction and communication are discussed from the point view of the spatial quality of the building.

Two claims were about open workspace and its effect on communication and the possibility to concentrate at work (Table 55. and Table 56.). The majority of respondents, two thirds of those who answered thought that the open workspace "speeds up communication and reduces the need of ordinary meetings" (44 per cent partly true, 22 per cent true), but even bigger majority almost three quarters of office workers claim that "too open a workspace disturbs my concentration at work" (27 per cent partly true, 45 per cent true). There was a consensus on these matters; no differences between office building types, status of the workers or genders could be found.

According to Brill (1985) the closed environment structure encourages communication. This is natural, because the need for communication must be greater than in an open area, and perhaps also because it is easier to communicate more freely in a closed space.

The type of workplace can tell if the space is a closed or an open structure. The closed work environment is a structural qualification. It can be found that the work areas in the IBs are more open than those in the reference buildings (Table 45, Table 17. and Table 18., Lehto 1999f).

Of the popularity either openness or closed space can be said, that too open workspace is disturbing, but it speeds up interaction and communication and decreases the need of meetings. Also is known of the room types that own workroom, which represents the closed one is a favourite, but the reason for that is unknown.

On the other hand, among the questions on adaptability was a question about the possibility to withdraw into a peaceful place for working and another one about the easiness of creating the needed connection (making eye or speech contact), which both reveal differences between the IBs and the reference office buildings (Lehto 1999c, p. 20). In the IBs it is more difficult to close up into a peaceful place for working, while creating the needed connection is somewhat easier there than it is in the other types of office buildings.

*Table 56. The end-user evaluation of the concentration possibilities of the working environment.*

| Claim<br><br>*The sample of the second phase of the IBs Survey.*<br>*Percentages (%) of the respondents, who fully or partly agreed on the claim of the question* | Mean *(n=285-343)* | IB *(n=166-191)* | Non-IB *(n=131-152)* | Men *(n=172-178)* | Women *(n=113-127)* | Executives *(n=41-46)* | Professionals *(n=150-166)* | Clerks *(n=66-76)* |
|---|---|---|---|---|---|---|---|---|
| OFFICE AUTOMATION | | | | | | | | |
| New technology makes it easier to concentrate on knowledge work or thinking. | 68<br>19[1] | 63[2] | 74[2] | 67 | 70 | 64 | 65 | 75 |
| I can partly telework (distant work) for example at home due to the technical equipment. | 41<br>17[1] | 47* | 34* | **56*** | 21* | 49* | 48* | **17*** |
| OPEN SPACE | | | | | | | | |
| Too open workspace disturbs my concentration on work. | 72<br>45[1] | 74 | 70 | 72 | 72 | 76 | 73 | 70 |

* ≡ A statistically significant difference, $p< .05$; [1] ≡ In this column of the mean values this second figure is the mean value of those who fully agreed with the claim.; [2] ≡ $p= .09497$ (Pearson Chi-square), $p= .09333$ (M-L Chi-square); The bold text is for the best or biggest values. Non-IB means reference buildings, which are not built according to the IB concept.

Disturbances affected mainly the female clerks' work, who had difficulties in closing up into a peaceful place for working (Lehto 2000c). There was no statistically significant difference between other worker groups and genders in the respect of the ability to withdraw into a peaceful place for working, but the executives both male and female, report their possibilities for concentrating on their work better than other worker groups (Lehto 2000c). On the other hand, it is the executives who found the open area work space disturbing.

According to Brill (1985) the bigger room size helps in communication. There are far smaller rooms in the IBs than in other offices. These facts create expectations about the different possibilities in communication between the two office types.

Brill has found also that the connection between fewer people in any given space experiencing higher ease of communication, and with higher densities of occupation there is less ease of communication (Brill 1985, pp. 70–71). He continues:

*"Where ease of communication is important, lower occupancy is beneficial."*

From the IBs Survey results in the Finnish offices of the end of 1980's and the beginning of the 1990's can be concluded that low occupancy is a desired spatial arrangement, but the reasoning behind this is unstudied and its connection to the communication unknown. Still, a cross-tabulation of the parameters of the IBs Survey could either strengthen or weaken the above mentioned Brill's conclusion of communication found in the American offices of the 1980's.

As mentioned earlier another effective mean for good communication is the new communication technology, which is mentioned in the results of the IBs Survey (Table 55.).

Furthermore, according to Brill (1985) the great amount of interoffice moving disturbs communication. It has been found that (Section 7.1.2.2, Lehto 1999c, cf. also Section 2.5.3) it is easier to move from room to another in the IBs than in other offices, which might have negative influence on the easiness of communication as well. The correlation between the amount of interoffice moving and the communications is unanalysed.

Good orientation due to the office layout helps in communication. The quality evaluation of interoffice orientation and signs was included in the study, but the data is still unanalysed in detail and undocumented. A first look at the preliminary results showed that the orientation and signs were not considered to be good in any of the studied office buildings.

## 8.2 Possible Reasoning behind the Power of Intelligent Buildings in Making a Difference in the Office

It is quite a common fact, that not very much attention has been paid to the meaning of the space in the profit making of the company or it has been generally underestimated (cf. Section 2.5.1). Accordingly, it is common knowledge that other factors of the working environment than those of the physical working environment influence the productivity of the occupant and the organisation, which is located in the building. Such factors can be organisational, economical and personal. The skills of management or leadership, the status of the business opportunities or the level of the operating income of the occupant of the building, as well as the personal characters of the tenants, such as sensitivity, level of stress, etc., can influence the productivity more than the building features.

Nevertheless, the physiological and mental response of the occupant to the quality of the building features has been studied (cf. Section 2.4). Within the indoor air research, its effects on the productivity of the worker have been studied (cf. Section 2.4.7.1). Especially, the factors of the sick building syndrome and their effect on the productivity have been studied more carefully.

Still, it must be concluded that studies, which cover several factors of the productivity simultaneously, both physical and non-physical, such as those of the ASHRAE measurements have not been carried out even in the area of indoor air research (cf. Section 2.5.5).

However, there are of course several studies of the feasibility of the buildings and the building economy. The Intelligent Building Study in 1992 (Anon. 1992a) is one of the studies, which has measured the influence of the IB concept to the productivity of office buildings. The ORBIT study (Duffy 1983) and the Office Tenant Study of the BOMA and the ULI (Anon. 1999) include post-occupancy studies of the IB features of office buildings, but their correlation with the occupants' productivity is missing.

Within the IBs Survey the possibilities to a find correlation between the post-occupancy evaluation and the cost effectiveness of the intelligent buildings has been studied (Pulakka in Lehto et al. 1997, pp. 226–248). The result was that the investment costs of the IBs were 50 per cent higher than the costs of the average Finnish office buildings (Pulakka in Lehto et al. 1997, pp. 239–240). The calculation is done per office floor area (the gross $m^2$). This is due to the extra IB features of the IBs, which often are totally missing from the average office building. The savings of the operation costs are 1.0–2.5 per cent, which are due to savings in the costs of business trips, office supplies and labour costs.

It was impossible to find numerical correlation between the effect of satisfaction to the building features and the office equipment and their costs. The cost was compared to the level of the end-user evaluation, whether it is high, not so high or low. The end-user satisfaction was different in different cases of costs. The benefits of the investments can be found to be dependent on operation conditions, such as the need of changes of the spaces, the frequency of the contacts of communication systems, or the number of marketing or training events. In general, it can be concluded that in many cases the end-users gave high grades to building features with relatively high investment costs (Pulakka in Lehto et al. 1997, pp. 229, 231). The show-room in the glass roofed lobby is an example of such a case. Despite of the high investment cost of the IBs, the effectiveness of the outcome on the basis of the end-user evaluation results of building properties and the possible savings due to the use of IB features made the building economy from the cost effectiveness perspective reasonable.

The occupants productivity can be dealt with using two types of indicators: those which measure the workers' efficiency, and those measuring businesses' profitability, which may or may not support each other. In the IBs Survey, the amount of trips and the indoor air quality indicate the office work efficiency as well as the productivity of the business of the company located in a certain office space.

### 8.2.1 Influence of the Organisation

Many other factors of the working environment besides the physical working environment, in other words the interior and the building with the working equipment, have an effect on work performance. Such factors can be organisational, due to business culture and management styles or they can come from the economical situation of the line of business in which the company of the building occupant operates. They can be originated from the working methods or the quality management system of the company, as well as from the selected environmental and human capital policies.

There is little if any scientific evidence of how much various types of factors of the working environment affect the work performance. As mentioned earlier (Section 5.3.5.11), Farshchi and Fisher (in Clements-Croome 2000, p. 60) claim that no unified theory of environment and behaviour has as yet been formulated. The author however has had the change to make study proposals with a national and an international research group (2002) on the separation of the organisational, economical and physical factors of the working environment from each other. This separation should concern the theoretical identification of the various factors, as well as the methods used to recognise these factors in working environments. The meaning of the physical environment for a successful business is growing along with the growth of the importance of the property management as an investment on an active asset of any business, and not only a that of the building industry.

In the IBs Survey the focus is on the physical working environment. The other types of factors of the working environment have of course influenced the results. No clear separation between the physical environment and the other environmental factors can be done, in such a case study as the IBs Survey. The only method for achieving such a separation has been the phrasing of the questions of this post-occupancy study. All questions ask the office workers to evaluate their building, space, equipment, and services on the basis of their influence on the working performance. Similarly, for example in the Office Tenant Survey of the BOMA and the ULI the office occupants have been asked to evaluate the office features and amenities on the basis of their importance to the organisation of the occupant and to the level of satisfaction of the occupant (Anon. 1999, p. 77).

How much the respondents of the IBs Survey have reflected the quality of other environmental factors besides that of the physical environment is not known. However, it is known that the work satisfaction of the respondents as well as their satisfaction to life in general are good (Section 7.1.4.4). It means that the respondents do not reflect their dissatisfaction with work to the evaluation result. On the other hand, it must be concluded, that eventually in real business life the providers of the physical working environment will face this inaccurate situation of the lack of separation of the various forms of influencing factors anyway.

The purpose of the post-occupancy studies often is to serve the companies' business interests, as it was the case in this study to begin with as well. However, the focus on a certain factor – the work performance – served the scientific purposes to such an extent as it was possible.

### 8.2.2 Environmental Sensitivity of the Occupant

Finally, the personal characteristics influence the end-user evaluation results. Some people are far more environmentally sensitive than others. The sample was relatively large, over 530 office workers, which guaranteed that the influence of a few very different people does not affect the total result.

Nevertheless, in some cases the small group can be very effective as was the case with the female executives of this sample. There were only ten of them, but the sample was so statistically coherent, that their opinion showed statistically significantly differing results. Style of personal orientation, ability to concentrate and communicate, nature of work, possibility and amount of telework, style of clothing or semiotic indicators are factors which measure phenomena with small amount of comparative previous information (Sections 8.2.7.4, 8.2.7.5, 8.2.7.8, 8.2.7.10 and 8.2.7.11). They can easily turn up to give the opinions of small groups too.

The correlation between the end-user evaluation result and some factors has been checked. Such factors are the health symptoms, the working hours and the overtime work. Among them there is not any appreciable environmental sensitivity, because on the basis of those characteristics no differences between the IBs and the other office buildings were found.

In this study, the status of the worker describes to some extent also the nature of the work, although this factor has not yet been analysed thoroughly.

### 8.2.3 Nature of the Information Intensive Work

The result, which is gained from the analyses done so far, highlights the importance of the status of the worker and the gender in the end-user evaluation of the building qualities. The nature of the work could have an effect on the end-user evaluation results. However, no statistically significant differences between the groups of workers (executives, professionals and clerical staff) could be found in the nature of the work, whether it is autonomous, group work or controlled. The same goes for the length of the workday. In Finland it is very common to work full time. Accordingly in this sample, the share of those who worked full time was a significant majority (Over 90 per cent of all groups of workers worked full time). Also distant work was very exceptional. However, in the type of overtime work there are differences between different groups of workers, and it is a feature which is related to the nature of the work, which have influence on the differences between the two office building types. Other factors, such as for example the national work culture, may influence on the result, which is not verified during this study to any extent.

However, according to scientific literature the results of the IBs Survey reflect very accurately two phenomena, which are important factors of the work in the information age or society. One is the correlation between the change of the workload from the clerical staff to the professionals. That is why the working organisations in the IBs seem to be similar to the knowledge work organisation on the basis of the working organisation's diamond structure. Second is the correlation between the gender differences and the use of the office work environment. They are typical, at least, for the information intensive work, if not for the knowledge work.

Although the results of the IBs Survey show the gender differences according to the tests of the total quality of spaces and equipment, it is good to remember that for example according to Goleman (1997) the differences between genders cannot be found in all social indicators. However, also often when separately evaluated building properties are concerned, the differences between the genders appear in the results of the IBs Survey. Goleman (1997) says too, that men and women think, communicate and feel in a different manner, when reacting emotionally. The many differences in the opinions of the different genders might be due to the phrasing of the questions, which highlights the building features importance to the work efficiency, not their influence on anything personal such as emotions.

When referring to the results of the IBs Survey, the differences between genders are very concrete. When talking about male and female needs and wishes and the possible reasoning behind the gender differences, the author does not mean that the reader should take these words literally. The author is aware of the androgyne person, and as found in the referred literature and from the results of this study, the female type needs – such as lack of time – are also present in the lives of men. The various results of the IBs Survey making a difference between women and men are simply reminding of the different occupant needs of the design of offices located in the intelligent buildings, which concern the spatial logistics and FM service assortment.

When talking about the female aspects of the building design also the needs of the children and those of family life will be covered quite unavoidably (cf. Section 2.4.10). This has been the case especially in the cases of workplaces with the majority of female workers. This type of concern benefits – naturally – the life of men also.

### 8.2.4 Personal Environmental Control

As mentioned earlier (Section 5.3.5.1), it is common knowledge among facilities managers that the possibility to influence one's work environment is one of the most important factors of the workspace design. It has been considered to be more important than any other of workspace property. A second can be the feeling that things are taken care of, either with some changes, repair, etc.

The first one was proved by the IBs Survey to be in better order in the IBs than in the reference buildings, if the possibility in participation in design is concerned. Next are discussed the results of the personal control possibilities which have been one of the key design criterion of the IBs, and which are good on the behalf of the spatial quality of the shared spaces, but not very good on the behalf of the spatial quality of the personal workplace and the control of the technology in the IBs.

*Table 57. Comparison of end-user evaluations of office space between the two office building types (Lehto 2000c).*

| FEATURE | RESULT |
|---|---|
| Space quality (all variables) | Better in the IBs than in the Non-IBs |
| Shared space quality | Better in the IBs than in the Non-IBs |
| Workspace quality | No better in the IBs than in the Non-IBs |
| Easiness to move | Better in the IBs than in the Non-IBs |
| Flexibility | Better in the IBs than in the Non-IBs |
| Adaptability of workspaces | Variables differ |

Non-IB means reference buildings, which are not built according to the IB concept.

*Table 58. Comparison of end-user evaluations of the office equipment between the two office building types (Lehto 2000c).*

| FEATURE | RESULT |
|---|---|
| Equipment quality (all variables) | Better in the IBs than in the Non-IBs |
| Room Temperature Regulation | No difference |
| Lighting Control | No difference |

Non-IB means reference buildings, which are not built according to the IB concept.

The IBs' power in performance over the reference buildings is apparent in the spatial flexibility besides the quality of spaces, when workers move into the building or within it (Table 57.). The good spatial flexibility is due to such building properties as [1)] the good chance for spatial expanding in the same building, [2] the possibility of changing the workplace in accordance with the changes in the company activities and tasks of the employees, and [3] the possibility to have extra workplaces for temporary use, as well as [4] the good possibilities for other changes (Lehto 2000c). The IBs' character as a good workspace to move in is due to moveable walls, easily plugged electrical installations, the ease in changing phone numbers, the ease in getting the interoffice network running and the computers connected after moving. These are all matters which concern the whole office building.

*Table 59. Comparison of end-user evaluations of office space and equipment between the two office building types according to genders (Lehto 2000c).*

| FEATURE | RESULT |
|---|---|
| Space quality (all variables) | Men prefer better than women |
| Easiness to move | Not tested |
| Flexibility | Not tested |
| Adaptability | Men prefer better than women |
| Equipment quality (all variables) | Women prefer better than men |
| Room Temperature Regulation | Men prefer better than women |
| Lighting Control | No difference |

The office workers' possibilities in influencing the technology and the space of their personal work environment can be concluded from the three variables of room temperature regulation, lighting control and adaptability of their workspace, which all are evaluated to be no better or worse in the IBs than in the reference buildings (Table 57. and Table 58., Lehto 2000c, cf. also Lehto 1997a, Lehto 1999c). However they are dependent on the gender and the status of the worker (Table 59.).

*Table 60. Comparison of end-user evaluations of office space and equipment between the two office building types according to the statuses of the workers (Lehto 2000c).*

| FEATURE | RESULT |
|---|---|
| Space quality (all variables) | Executives consider best, professionals next best and clerks worst |
| Easiness to move | Not tested |
| Flexibility | Not tested |
| Adaptability | Executives find their possibilities good, professionals neutral and clerks poor |
| Equipment quality (all variables) | Executives and clerks consider best and professionals worst |
| Room Temperature Regulation | No difference |
| Lighting Control | No difference |

Spatial adaptability is evaluated as good in men's opinion, who in general prefer the spaces better than women do. Adaptability is also dependent on the status of the worker (Table 60.). Executives evaluate adaptability as best and professionals as neutral. Clerical personnel evaluate it either as neutral or worst in all groups. The evaluation of the technology has no special trend either in the respect of the gender or that of the status of the worker.

### 8.2.5 Sick Building Syndrome and Healthy Building Concept

The comparison of the results of the IBs Survey in respect of the sick building syndrome and the healthy building concept helps to conclude the differences between the intelligent and the reference buildings (Table 61. and Table 62.).

The relations to various factors of the two building categories – the sick and the healthy one – work as a tool for summarising the buildings quality evaluations.

As mentioned earlier health symptoms have also been used in the IBs Survey as indicators of the building quality of the two office building types and for the comparison there after. As mentioned in section 2.5.5, the healthy building properties are not necessary in a building in order for it to be classified as an IB. Although the IB concept has targeted the healthy building properties, the IBs still resemble both sick and healthy buildings. This use of healthy building design criterion for the IBs describes the building quality in general rather than the building's success as an IB.

#### 8.2.5.1 Sick Intelligent Office Buildings?

The studied intelligent buildings still have three sick building syndrome factors: more effects on women, lack of control and poor indoor air quality (Table 61.). Positively however, the end-user evaluation result of the IBs suggests that the large building size should be taken off from the list of sick building syndrome factors, if sick leaves of the office workers are used as a criterion for judgement of the existence of the sick building syndrome. On the other hand, if the number of health symptoms is used as a measure of the existence of sick building syndrome in the IBs, the large building size correlates positively with the sick building syndrome also in the IBs.

In the terms of the status of the worker, the use of the IB concept or the existence of the knowledge work organisation seems to put the professionals at the same level as the clerical staff. Whether the quality of air-conditioning corresponds to the public sector was not tested in this study, as can be in the case of the sick building.

The factors Lorsch (in Clements-Croome 2000) has given for sick building syndrome are not studied in the IBs Survey. In any case, Lorsch mentions the building occupancy being higher than intended as a reason for the sick building syndrome (Lorsch in Clements-Croome 2000, p. 12). This was not the case of the IBs, but the occupancy was relatively high in the IBs, which also may indicate the tendency towards sick building syndrome.

*Table 61. The existence of the factors of the sick building syndrome in the studied intelligent buildings (relationship marked with a +)*

| FACTOR | RESULT FROM THE IBS SURVEY |
|---|---|
| Women | Women's control over the physical work environment and the indoor air was not satisfied; lack of information on the use of ICT tools (+). |
| Clerical workers | Professionals are suggested to take the position of the clerical workers as the ones of the office personnel who carry the majority of office work load (+). |
| Lack of control | No better or lack of control over the physical work environment (+). |
| Large office | The IBs are large but good in quality, workers are not much on sick leave there, but they have health symptoms. |
| Passive smoking | Only in one reference building was passive smoking a problem. |
| Air-conditioning | It was a standard in every building. |
| Speculative | IBs are not under financial speculation. |
| Public sector | Not tested |

#### 8.2.5.2 Healthy Intelligent Office Building

The studied intelligent buildings are related to four principal healthy building factors: the view out of the window, a good market value, good image and less sick leave among workers (Table 62.).

*Table 62. The existence of the factors of the healthy building concept in relation in the studied intelligent buildings (relationship marked with a +)*

| FACTORS | RESULT FROM THE IBS SURVEY |
|---|---|
| Personal control | Personal control of the IBs not working better than in the other office buildings and is not satisfactory for all groups of workers. |
| Fresh air | Indoor air of the IBs is not particularly good if not poorer than that of the reference buildings. |
| View out of the window | Both in the IBs and in other office buildings, occupants wish for a view of nature out of the window instead of busy areas, which is the fact in the IBs (+). |
| Daylight | Windows are compulsory in any Finnish offices. |
| Good work productivity | Less health symptoms means better work productivity but there are no less health symptoms in the IBs; good building quality can be understood to be a weak identification of good work productivity (+). |
| Good market value | Not actually included in this study, but the economical study of the IBs Survey proved better market value of the IBs (+) (Pulakka in Lehto et al. 1997, pp. 226–243). |
| Good image | Image is a more important factor in opting an IB business venue rather than in other office buildings (+). |
| Natural ventilation | Not used in any office building studied here. |
| Long life cycle | Not studied |
| Less health symptoms | As many health symptoms in the IBs as in the other office buildings |
| Less sick leave | Less sick leaves in the IBs (+). |

The studied IBs in the Helsinki metropolitan area which were built in the late 1980's and the beginning of 1990's have not succeeded in providing personal control and fresh air quality, although they have been included in the IB concept. This lack in quality is still giving the IBs the sick building status. The existence of good personal control but no lack of central control would guarantee the healthy building status in terms of control.

The good market value aspect is supported by the fact that the price is not the primer selection criteria when selecting the office space in the IBs. Work productivity in precise terms, length of the life cycle and natural ventilation are factors, which were not studied in the IBs Survey and this thesis.

It can also be concluded that the IB concept has to make progress in control matters, solving the problems of the professionals and the female workers (similarly as it has succeeded with the clerical staff), and increasing the indoor air quality.

It can be concluded that the intelligent building concept is working well in the respect of such areas as the building mass, view outside, and clerical workers; its market value and the selection of it for a workspace on non speculative grounds also speak for its favour.

### 8.2.6 In Comparison to the Literature

The differences between the IBs and the reference buildings turn out to emphasise three factors: the knowledge work, the status of the worker and the gender. There is not much literature on the knowledge work, despite of the wide literature of office environment and office work (Section 2.4).

It has been interested to find out that in the Finnish working organisations the status of the worker is so important. It can be understand as a consequence of the different nature of work. However, according to the findings of the IBs Survey that is not necessary the case. It can even be possible that still a part of the working effort is spent on taking care of the personal status instead of putting the whole effort on the tasks of the job. Instead of a job centered working orientation other matters count and the nature of work is not influencing the use of physical working environment. A more probable case is, that the end-user empowerment is not yet the leading principle in the working organisations and in the planning and the use of the working environment, but the meaning of the status of the worker is so obvious that its meaning is not recognised.

Due to the result of this thesis in this section the focus is on the literature of the knowledge work and gender.

The differences between the IBs and other kinds of office buildings can be based on several arguments:

- In the IBs there are more executives and highly educated workers than in other offices, and thus the summary of the end-user opinion can be more positive in the IBs due to the executives' and highly educated workers' ability to find cumulated knowledge and information, as Castells has argued, and further on their ability for using the available building properties.

- Although Korvajärvi and A-M. Lehto have found that haste and pressure is not due to the increased use of ICT tools but rather due to the lack of workforce and the new management routines, the results of the IBs Survey argues that the female professionals are unable to get the most out of the ICT, and that they are working longer hours with computers than other worker groups (Lehto & Karjalainen in Lehto et al. 1997, p. 177). Further, more overtime work seems to cause more health symptoms, with more sick leaves for female professionals and female clerks than executives and male professionals and clerks. Thus it can be argued that it is possible that both the heavy use of ICT tools and new management routines cause pressure on female professionals in office work.

- Furthermore it is possible that due to the economic recession during the period of data collection also the lack of workforce could cause haste and stress, which in turn causes health symptoms and sick leave among female professionals and clerks.

- Korvajärvi and A.-M. Lehto have argued the importance of social skills and customer relationships, and that of the backup of own organisation for success in knowledge work, thus it can be argued that the good end-user evaluation results of the interoffice show and meeting rooms in the IBs reflect the above mentioned needs in the knowledge work.

- It can be asked if the change from the pyramid organisation into the diamond type knowledge based organisation, which Goleman (1993 in Gouin & Cross 1986, p. 29) presented, turns the pressure from the clerical staff towards the professionals, who form the majority, and on whose work results the modern organisation most probably leans on. This can explain the not so good results of the end-user evaluation when the professionals' work efficiency is concerned.

- Friberg has found that women experience stress not only at home but also at work and both at professional and on clerical level, which could explain together with the above mentioned change in the organisation structure, the differences in the equipment end-user evaluation between men and women among professionals and clerical staff.

- Furthermore, as Korvajärvi and Lehto A.-M. have concluded, the fact that the gender equality plans remain unimplemented sometimes even in cases, when it is compulsory by law to have such plans, reflects the careless attitude towards the rights of women at work, about which Friberg has also concluded (Section 2.4.9.4) and which could be a source of extra stress among female office workers.

- Friberg's classification of three female styles[4] at work could be applicable in the analysis of the use of the ICT and IB features in offices. It can be asked, if the career life form is common among female executives and professionals, and how many have chosen the balancing life form. Is the career life form too laborious and does the executives' status mitigate this burden, or are those, who

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[4] The career life form is for well-educated women who place their occupations with all the inherent career possibilities first and try to adapt their family life to suit this. They do not want to miss having family life and have great ambitions for their children's lives and development. Women in the balancing life form do not have the same priorities; instead, they try to balance their working life and their family life, for example by working part-time when children are small, with the hope of developing their chosen fields of work when the children become older. These women have good job training and/or education. The women comprising the paid work life form most often have little or no job training and their position on the labour market is low. They work primarily to get money to support themselves, which does not necessarily imply that they do not like their jobs. They are family oriented, and in tight situations when the conditions on the labour market are not compatible with a reasonable family life, they can easily imagine working part-time or staying at home with their children. (Friberg 1990, p. 331)

have managed to get the executive’s position, those who are able to carry the heavy burden of the career life style? Also the chance to choose the balancing life style is possible, although almost all women in Finland participate in the working life full time, contrary to other European countries.

- Finnish studies on the female use of computers and media confirm Friberg’s results in the findings of the difficulties women have when they have chosen the career or balancing life form and combine the working life and housekeeping responsibilities. It seems obvious that the female office workers do not have the chance to learn enough about the use of the equipment, and it is not a question of a lack of interest in the use of computers. This problem is cumulating in the situation of the female professionals in the IBs, and to some extent in that of the female clerks in the IBs as well, where the status and the standard of the equipment is high.

- Puirava's finding about female novice computer users being afraid of showing their ignorance and wishing to have the chance to learn new skills in private, gives an interesting point of view to the results on the female office workers, who find that they do not know enough about the use of the office equipment and who most probably do not have as good a chance to work in private. This seems to be especially true, because the female executives get the most out the new office equipment and they do have the chance to work in private.

- Despite of the trend of outsourcing and concentrating on the core business become demanding in the point of view of the building occupant (company or worker) there are factors, which speak for the demand on the amenities in the office building. It is known: [1]from the findings of Marzano that there is lack of time and services in modern life style, [2]from Puirava's findings that there is lack of time to learn to use the computer at home, [3]from the results of this study that female office workers gave the low grades to the use of ICT, their poor teleworking possibilities or poor possibilities to influence one's work environment, despite of their equally large overtime workload with the executives, who work most overtime of all groups of workers, [4]from the findings of Tamminen that there is a problem of a lonely childhood of the children of two career families and [5]from Friberg's studies of the life styles of working women that the balancing between career and family is very common. As mentioned in section 2.4.9.4, the service assortment of the intelligent building has an influence on the productivity of the occupant, and several potential solutions are not yet applied to such an extent that it would be clear, which services are needed in the building and which not. The occupants have to be wise enough to be able to demand those services, which help their business. From the occupant's point of view also other services than those, which directly serve the core business, seem to be in a central role for the workers productivity, as has been found in this study on the behalf of the female professionals and clerks, as well as on the behalf of the male executives in comparison to their female colleagues. They are important for the success of the occupant company too according to the findings of Kostiainen (2002). Designing the intelligent office to be an operator in the logistics of the office worker’s every-day life operations and the utilisation of the remote services run by ICT could help the time budget of the family and thus make the office work even more effective. The old society was built around home or farm and the church (Figure 32.) and according to Finnish research the modern one is centred around transport network knots and shopping centres. To my understanding the core of life is still around the home and work. The offices are rising next to airports, because of easy access to business connections all over the world, but unused potential of the office, which helps the occupants to create a flourishing business, lies in the interests of the office builders, etc. in taking part in the planning of the logistic operations of the society in a whole to a greater extent than today. The male approach to planning of the working life operations is a very good half of the solutions. It should be maintained and developed further. Taking into consideration the needs of the female workers is an unused potential for the other half of the solutions of the productive office work.

- It seems that the result of the socio-economical factors of the IBs Survey is very similar to the results of Puirava, except on the behalf of women. Puirava has found that neither gender nor age, education or income can explain the attitudes towards technological development, when the consumer behaviour was studied. The effect of age should be checked against the life span psychology as mentioned earlier in section 7.1.4.3. According to Darian in Puirava the gender has an influence on the attitudes towards technological development.

- Brill (1985) highlights the meaning of the distinctiveness of the office design for the occupants, which could be comparable to the results of the IBs

Survey, which claims that the building type is a more important selection factor for the office building in the IBs than in the reference buildings.

- As Brill (1985) has found that the increases or decreases in occupancy do not affect job satisfaction, the summarising result of the IBs Survey also show the positive correlation between the good building quality of the IBs and both the big unit size and high occupancy.

- None of the executives wished to move to a shared room, but a handful of them prefer an open area workspace to a private workroom, which seems also to be a tendency in the new management styles. According to Brill, this direction is wrong since communication is not dependent on the openness, but more for instance on privacy. Further analysis on this argumentation is needed.

The two-edged issue of the transparency and trust (Section 2.4.9.2) in the knowledge work has not been studied in the IBs Survey. It can in the context of building also reveal important knowledge on the differences between various worker groups' evaluations of their working environment (Section 2.4.4).

Among others Ryburg (1993) has claimed that the presence of the office workers is and will be relatively low. He is estimating that in such a new type office as in a multisite office only 50–60 per cent of the workers will be in at once. Due to the result of the IBs Survey the future trend seems different in the IBs. Office workers spend quite normal working hours in the office space and meet the customers either in their own office building or even after the standard workday.

### 8.2.7 Need for Further Analyses

Due to the wide variety of factors in the physical working environment, the questionnaire is relatively long. Many very interesting factors still remain to be analysed. The future potential of the IBs Survey analysis is explained in this section.

#### 8.2.7.1 Intelligent Building Features

There are certain building features, which are connected to the application of the IB concepts. As described in the section 5.3.5, two questions concerning the needs for these features were included in the IBs Survey, but still remain unanalysed.

The assembly floor could have influence on the building flexibility and on the possibility to move equipment from place to place in the worker's personal workroom. The assembly floor may not correlate with the possibility of personal control of the work environment, which was revealed as poor in the IBs.

Movable walls is another structural IB feature, which separates the IBs from other office buildings. They may have a similar effect on the end-user evaluation as the assembly floor has.

The spatial flexibility and the possibilities to move equipment should be examined and tested using these two IB features (assembly floor and moveable walls) as reference parameters.

#### 8.2.7.2 Illumination

There are several unanalysed questions about the illumination, which deserve to be analysed, as their meaning in general for the work ergonomics is remarkable. The questions are about the type of lighting (direct or indirect, special arrangements of illumination, desk lamp), lighting control, influence of lighting on the worker's health condition, quality of intensity, reflections, contrast, etc., and whether or not eye glasses were used.

Illumination is becoming ever more important due to the complex design problem of the workspace caused by the display terminals of computers. The reflections caused by illumination and natural lighting influence the working positions – causing bad posture, which are tiring and can in worst cases cause disability to work. The illumination of the workspace with computers and video-displays is challenging, because for instance the display works best in shade and next to it can be other materials that need proper lighting, or the possible audience needs light during a video-conference and so on.

#### 8.2.7.3 Noise

There are several unanalysed questions about the voice environment, which deserve to be analysed, as their meaning for the information intensive work lies in the dual problem of concentration and communication (cf. Sections 5.3.5.2, and 7.1.2.3 and 7.1.2.4).

#### 8.2.7.4 Styles of Orientation towards Physical Environment

The way of orientation towards the physical environment was included into the questionnaire in a question asking about the style of perception of the worker, if she or he is making contact with the environment by thinking, feelings, audition, vision or outlook, by body motions or intuition – the classification derived from the Neuro-Linquistic Programming (NLP) (Bandler & Grinder 1975).

This question was intended to work as a background parameter for the other questions, but has so far been unused in the analyses. Its performance in judging the work environment qualities such as spaces and equipment should be tested. There is some doubt of its usefulness in the context of tracing the work environments' qualities, which best promote the knowledge work.

#### 8.2.7.5 Semiotics

There were a few questions about the signs and symbols of the building in the questionnaire, in the section on image of the building (Section 5.3.5.5), and two questions were set on the basis of the semiotic paradigm, asking about the feelings caused by the image of the building. These questions together with the questions on the colours and materials, and on the scenery outside of the workplace, form a good basis for a semiotic study of the symbols of the physical environment (cf. Section 2.4.8). The dependency of the other building properties on these matters can reveal much of the suitability of the IB concept for knowledge work.

In addition to the above mentioned semiotic related parameters, there was a question about the word pair TAKETE and MALUMMA[5], asking the office workers to express their "feeling" about the building with one or the other (cf. Davis in Clements-Croome 2000, p. 232). That question remains unanalysed. The analyse could help in understanding the answers of various worker groups.

#### 8.2.7.6 Environmental Psychology

A question about the best place for thinking and a question on the types of place (open or closed), where the worker enjoyed his or her stay the most was also included in the questionnaire. They are still unanalysed at this time.

#### 8.2.7.7 Image of the Building

The image of the building is an IB feature, which still remains partly unanalysed. The question about the possibility of the building details to reflect the business idea of the company or the values of respondent, or the atmosphere of the organisation is unanalysed. Further analyses of all the questions concerning the image of the building and the cross-referencing of the result with the questions on socio-economic factors is needed.

#### 8.2.7.8 Nature of Work

More detailed analysis of the working nature according to the respondents' work types (autonomous, group work (interactive), controlled), might reveal more of the needs necessary to the office working environment. The analysis based on the working types could also tell more of the differences between the IBs and reference buildings, and of the profitability of the IB features, especially those needed in information intensive work.

Still, there lie two interesting unanswered questions; [1)]why the clerical personnel, who are satisfied with the work and who have the least autonomous work, are more satisfied with the working environment properties than the

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[5] The words takete and malumma has been selected as a description of the feeling within the semiotic paradigm and they are not originated from any real language.

professionals are; [2)] and since the professonals' work is not that much less autonomous than that of the executives, why the professionals in the IBs, who are not especially dissatisfied with their work if not satisfied either, are not very satisfied with the equipment.

The conclusions of Leidner about the fact that the service type work is fixed with women and the sale and marketing with male workers (Section 2.4.9.4), offers an interesting starting point for further studies on the differences between the genders in the connection of knowledge work and the workers' position and the type of work.

#### 8.2.7.9 Working Hours

The working hours do reveal special differences between the work in the two different office building types. More detailed analysis of the working hours can reveal many interesting features of the knowledge work. For example, although there are not many professionals with fixed working hours, it would be fruitful to check their evaluation of equipment, while the fixed working hours might cause extra stress and rush, which makes it difficult to operate and learn how to use the equipment. On the other hand, new research may reveal the power of interoffice networking even more clearly than the results gained so far.

#### 8.2.7.10 Teleworking

Questions about the respondents' willingness to flexi- or telework were included in the questionnaire. In this context this part of the unanalysed information is especially interesting, because the data on the work-related trips has been gathered at the same time. It seems obvious, but remains unstudied, that work-related trips carry a greater potential in substitution of trips than teleworking, and that it is more obvious that it will be taken into use in a greater extent than the telework possibility. The possibilities of telework are well studied and perhaps its potential is better known, but other means of saving in business travelling should be also taken into consideration.

This material also gives good opportunities for analysing the telework potentials in the context of various knowledge professions, and the analysis based on different demographic and socio-economic situations.

#### 8.2.7.11 Clothing Physiology

The question on the clothing is unanalysed in this phase of the study. In addition to the importance of the subject itself, the results of the indoor air tests speak for a correlation of the clothing habits and indoor air quality. Because of problems with the indoor air in the IBs, and in the control possibilities of the indoor air – especially because of the gender differences, it would be necessary to check the influence of the clothing on these difficulties.

#### 8.2.7.12 Demographics and Socio-economic Factors

The effect of the socio-economic factors to the end-user evaluation results have been studied in some cases. However, the influence of the socio-economic factors to the grand total of the end-user evaluation result showed in the Table 11. is not done in this phase of the analysis.

Some tests have been carried out in order to find the most interesting factors. Those tests are mostly based on the second phase of the interview. The size of the second sample is 386 responses.

The gathered data makes a more detailed analysis of the correlation of the background information and the results of the *gender differences* possible. It is possible to find out:

- whether the family relationships affect the possibilities in learning at work or the amount of overtime work, which might be behind the need to learn more of the ICT-tools,

- if the nature of the work (autonomous, interactive, creative) is different for the genders,

- what kind of effect the possible differences in the nature of the work have on the amount of use of computers and other office tools,

- what kind of effect the possible differences in the nature of the work have on the end-user evaluation of the tools,

- if the family relationships, satisfaction with work, private life and salary have an effect on the gender differences in the evaluations of the office spaces of the IBs and that of the reference buildings, or if the difference is due only to the building characters,

- if the share of genders in the staff affect the evaluation of the spaces and tools, i.e. if in the male organisations women reflect their discomfort on the end-user evaluation of the tools and space,

- if gender differences exist in the possibility to have various tools, and if it differentiates men's and women's evaluation of tools, especially that of mobile phones,

- if the end-user evaluation of the space and tools is different between the genders in those buildings, where the ICT workers dominate the number of workers.

The effect of the *status of the worker* on the possibilities to control one's personal work environment shall be analysed more systematically and similarly as the gender factor (cf. Section 8.2.7.12).

As mentioned earlier (Section 7.1.4.1), the level of the education is higher in the IBs, and the level of the education is higher among female professionals and executives than among the male office workers in the whole sample, hence the level of the education of the female professionals and executives in the IBs is expected to be higher than that of the male professionals and executives. But, it is stated to be impossible to say if it is higher among female executives or professionals, or both, without statistics on the sample. This information could possibly explain the differences in end-user evaluation of the equipment among female executives and professionals (Lehto 1997a), if there is a difference in education. The findings on the knowledge workforce by Castells could be used for the analysis.

Some reasons for the good end-user evaluation results of the equipment among clerical personnel can be found from following three facts. Firstly, the education level of the male clerks is higher than that of the female clerks. Secondly the work satisfaction among male clerks is, together with the female executives, highest of all worker groups. Thirdly the number of clerks is as small as that of the executives. This all can reflect the ability of the clerical staff to manage better in a poorer working environment than the professionals can. If this is true, the evaluation result of the professionals reflects more the office buildings', and also that of the IBs', ability to fulfil the needs of the modern knowledge worker.

The need of further analyses of the *ages* of the office workers has already been discussed in section 7.1.4.3. The *education of the worker* seems to correlate to several end-user evaluation results with a statistically significant effect. If the analysis of the age is not that important because of the differences between the two office building types, the further analyses on the education of the worker are the more important particularly because of the building differences.

##### 8.2.7.13 Sick Building Syndrome and Healthy Buildings

Health symptoms form an indicator of the sick building syndrome. The data gathered on the health symptoms is partly unanalysed, especially the part, where the office workers were asked to analyse the reasoning of their health symptoms against the building properties and other possible reasons for the illness (cf. Section 8.3.8). As pointed out in section 2.6, the sick building syndrome is related to such factors as women, clerical workers, passive smoking, lack of control, large offices, speculative, public sector, and air-conditioning, which all have been studied within the IBs Survey. Many aspects of the possibilities of preventing health symptoms by using building intelligence can be scanned from gathered data by cross-referencing the building qualities with good end-user evaluation results and the parameters indicating the well-being of the tenants (cf. Section 8.3.8).

On the other hand, it is known that health is related to personal control, views out of windows, fresh air, daylight, and natural ventilation, good work productivity, long life cycle, good market value and the image of the building, of which data is available from the IBs Survey for further studies.

## 8.3 The Building Intelligence Framework

Defining the building intelligence with the factors derived from human intelligence causes quite a change in the idea of IB concept, which has not included the factor of intelligence.

The earlier definitions have actually been describing the intelligent buildings, not the building intelligence. They have defined its maximum performance, the shareholders, the focus on matching the stakeholders' interests or needs, and how the performance will be met. These are the tools for construction, use, maintaining and evaluation of the IB rather than the actual components of the intelligence.

### 8.3.1 Building Intelligence

This definition of the building intelligence is based on one approach to human intelligence and is the first attempt to combine these two phenomena together. The factors of the building intelligence will be developed further after the discussion on this new definition takes place. After that it might be possible to develop the parameters for these factors for testing or evaluating the intelligence of the building.

The building intelligence has been defined by the BIF in such a way that it differentiates the intelligent building from other modern building concepts, such as the Green Building. It also makes it possible to distinguish the intelligent building parameters, factors, characters or qualities from those of Facilities Management.

The building intelligence could be a similar classification as that of the stars marking the status of hotels. Still, to my mind the understanding of the diversity of the successful developments of natural phenomenon strongly argues against a fixed set of parameters for building intelligence.

On the basis of the present definitions of the intelligent building concepts some kind of ranking of the buildings based on their intelligent characters has taken place in the form of intelligent building awards, which is not a similar practise as that of ranking hotels with stars.

The understanding of the essence of the building intelligence preoccupied the author's mind with the hypothesis of the meaning of psychology, mental and social approach probably more important in the RTD than thought in general (cf. the author's IB definition in section 2.1.5). Still even after the findings of this study on the BIF a better understanding of the nature of the human abilities will reveal much about building intelligence (Figure 44.).

### 8.3.2 Importance of Correct Expression

As Korvajärvi and A-M Lehto (2000) have argued (Section 4.3.3.2) that competence in knowledge work is based on correct expressions of matters and one's personality, i.e. using correct explicit knowledge in the knowledge management of knowledge work. Furthermore, the information sharing and the personal social skills are important tools in knowledge work.

It can be argued that similarly the correct explicit knowledge in the knowledge management of intelligent buildings is based on correct expressions. As mentioned in the first sections of this thesis in the context of the IBs it is a need to express by explaining one's personal impression of the intelligent building concepts, before the message will be well understood. From now on, also the personal view of the building intelligence should be articulated with correct expressions.

### 8.3.3 Emphasis on Knowledge Creation

In the examination of the BIF, the author has kept intelligence and it’s role separate. That is not the case in the review of the human intelligence presented in section 4.3.3.1. It is not the case in the definition of the concept of ba presented in section 4.3.3.2.

End-user need orientation is a character of the intelligent building. The building intelligence's role is to allow the end-users to act according to their needs. End-user needs can determine what type of intelligence is needed in the building, but they do not have nothing to do with the intelligence, neither the human nor building intelligence. That is why the user connectivity has been taken as the model for the buildings' ability to contact other items, objects, creatures, etc.

The author's approach to the building intelligence highlights the importance of the tacit knowledge in the definitions of intelligence. Especially the concept of ba – of those approaches presented in the literature of intelligence – takes account the tacit and explicit knowledge. Furthermore, the author's approach to the building intelligence highlights the transformation of the tacit knowledge into the explicit one, and back to the tacit one again. The emphasis is in the knowledge creation spiral.

The author emphasises the role of intelligence in the creation of new knowledge, or rather, the role of intelligence in letting the tacit knowledge emerge in explicit form, which then is considered new knowledge although it might have previously existed for a long time in other than explicit forms. Clements-Croome (1999) uses in his IB definition the term 'transdisciplinary'. From the context can be understood that his emphasis is also in the creation of new knowledge. Not reviewing his theory in detail, it is difficult to argue for or against his definition of the IB concept.

The use of knowledge is one role of intelligence as well as creating new knowledge or learning from experience. In creating the building intelligence definition the roles of intelligence have not been in focus. They are understood to be elements of the intelligent buildings when the building intelligence is implemented or evaluated in building practise.

### 8.3.4 An Alternative Approach to the Building Intelligence

An individual approach to the human intelligence by Gardner (Gardner 1983 in Dryden & Vos 1996, pp. 120–123, Gardner 1991 in Dryden & Vos 1996 pp. 345–352, Gardner 1993 in Tuomi 1999, pp. 107–110, Gardner (1993) in Dunderfelt 1998, p. 28) has been selected as a starting point for thinking about generating building intelligence from the metaphor of the human and building intelligence. Another very useful approach to the understanding of the IB concepts is the collaborative cognition (Engeström 1995), where the use of tools developed for the production, the specialisation of the production, and the creation of the various forms of rules have been taken into consideration. The author understands Engeström's collective approach to human intelligence, such as highlighting the social nature of human intelligence, and its functionality.

If an analogy can be drawn between the information society (and the service age to follow) and the various forms of the rules of Engeström's theory (1995), it can be used for combining [1] the information society domain, [2] the use of the ICT tools developed to the production taken place in the IBs, and [3] the IB concept specifications for the IB construction, to the parameters of the IB concept and the human intelligence by Gardner (Gardner 1983 in Dryden & Vos 1996, pp. 120–123, Gardner 1991 in Dryden & Vos 1996 pp. 345–352, Gardner 1993 in Tuomi 1999, pp. 107–110, Gardner (1993) in Dunderfelt 1998, p. 28) (Figure 49.).

This approach produces a description of the IB concept, which separates the players of the interplay between various factors of the BIF. It ends with a description of the role of the intelligence in the construction of the information age, which the current IB concept definitions are also about.

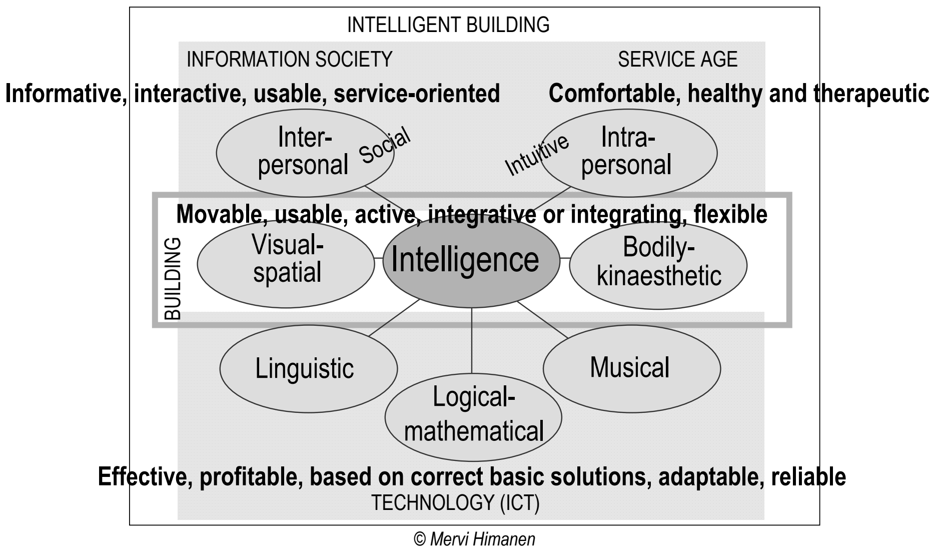


*Figure 49. Human intelligence and the intelligent building concept.*

This examination based on the collaborative cognition is fruitful for the implementation and evaluation of the intelligent buildings. The role of the intelligence of the intelligent buildings can be described from this starting point. However, the intelligence of the building is best identified, in the authors' mind, using the Gardner's definition of the human intelligence as a model for building intelligence.

### 8.3.5 Wide Variety of Intelligent Building Definitions

The existence of a wide set IB concepts has been questioned, because it has been pointed out that buildings have always been built intelligently. Who needs a specially defined intelligence or more intelligence than used in the construction process in any case?

This criticism can be argued against by placing it against the claim that the intelligent building concept has an internal stock of knowledge in addition to the explicit knowledge shown in the building documentation. As argued in this thesis this internal stock of knowledge is tacit knowledge of the IB concept, which is becoming more conscious than before, as it is transformed into the explicit form by the IB concept definitions. The unconscious tacit knowledge is spoken aloud and thus shared in a similar manner to the implicit knowledge. The construction experts express the tacit part of their expert knowledge by the IB definition. The existence of the wide variety of IB definitions is itself a proof of the fact that, this sharing of the tacit knowledge seems to be needed in the construction field. The IBs Survey also gives evidence of the lack of sharing of tacit knowledge in the construction field. This was shown by the evaluated quality of the personal workplace in comparison to the evaluated quality of the shared spaces (Section 7.4.3).

The variety of IB definitions has an important purpose in the construction field in presenting the tacit knowledge explicitly. The universal definition is a good target, but the process towards it seems productive, if the quality evaluation of the end products, the IBs themselves, are used as evidence for the efficacy of the IB concept in comparison to the situation, where it is not in use.

It can be claimed that the intelligent building concept parameters (described in the section on systems thinking (Section 4.2.1)) are a broader conscious approach to the construction industry, including descriptions of parameters, which has long been there and can be considered to be the same as "the good and healthy practise of building". Some IB concept definitions have also included the set of parameters, which describe the building product qualifications. Dr. So has presented the IBI, with which it is possible to implement and evaluate the IBs.

Because the tacit knowledge of the IB concept has been unknown, the IB concept definitions have included much information about the best construction practises. It has been difficult to differentiate the IB concept as a concept of its own. The understanding of the essence of the building intelligence, i.e. both the explicit and tacit knowledge of the IB concept gives the possibility to identify the IBs by the building intelligence, not by the expressions borrowed from other sectors of construction industry or other applied sciences.

Still, the author does not suggest focusing only on the intelligence in the construction of IBs. On the contrary, **a holistic multidimensional approach to the construction is needed in any building project. Each project benefits from the wide variety of solutions according to the needs of the stakeholders. It will not be discussed further within this thesis, but the author would like to mention, that the self-consciousness or self-knowledge of the stakeholder is an important key to a successful building project. It is not enough to be aware of the tacit knowledge of the construction expertise only in the connection of the IBs, but also the tacit knowledge of all the stakeholders involved (Section 4.3.5.3), their experience, targets, activities and needs.** This is an usually rejected factor in decision making.

**The building intelligence definition is a tool for further argumentation and empirical studies in order to increase knowledge of the IBs. It has in the first place a scientific purpose. It will have no use, if it is not implemented in practise (**Figure 51**.), because the building processes are continuous and they are based on a developing internal stock of knowledge of construction and buildings. For that purpose also a new sophisticated version of the IBI suggested by So could be a solution.**

### 8.3.6 The Number of Intelligent Building Features

The common first two questions about the intelligent buildings are: "How a building can be intelligent? Could we not call it by another name?" and "What makes the building intelligent? How many intelligent features are enough to give the right to call the building intelligent?". These are both good questions. In this thesis they have been answered. Even the Finnish term of the smart houses or intelligent buildings has been defined by the author together with the Finnish Centre for Technical Terminology. The term is 'älytalo' (Lehto & Jantunen 1993).

Still, those two questions also remain open. Next, the system theoretical analysis of the number of intelligent building features will be explained. The possible future features of the intelligent building will follow after that.

The question is, whether a system is intelligent on the basis of the existence of one element of the IB concept or the building intelligence, or if several are needed. If so, how many of the parameters of intelligence should be included in the system, before it is regarded intelligent. In practical terms, the same question can be how many intelligent apparatus make a building intelligent, or if an intelligent overall control system guarantees the building intelligence. This question has bothered the author’s mind in the system theoretical point of view, but remains still unanswered.

The implementation of the intelligent building criteria has been based on a selective set of intelligent properties. This is comparative to the definitions of human intelligence, where it is said that human intelligence is a generator of selective behaviour.

In this thesis, however, it has been suggested that there is most probably genuine need for more than one successful application of the IB concept parameters before the building will be functional enough from the end-users' point of view. In practise, this could mean the need for more than one of the intelligent subsystems. The level of technical competence of the intelligent subsystem influences over the functionality of the intelligent system.

This result of need for several intelligent subsystems is based on the technology, which was valid in the IBs in the beginning of the 1990's in Finland. That quality should not be any lower in particular than the quality of the IBs in other part of the world, in general. Even so, it might not reach to the level of the most progressively advanced projects, because the intelligent buildings of the IBs Survey were those, which are built as effective workspaces for profitable businesses by keeping the commercial purposes in mind.

### 8.3.7 The Building Intelligence Framework and the Intelligent Building Index

It seems obvious that, on one hand, the BIF and the Intelligent Building Index (IBI) (So 2001) are both results of the systems thinking applied to the intelligent building concept. In the IBI the human aspect is present in the background in many of the topics, but the BIF has taken it into account with the explanation of the metaphor between the human and building intelligence. Sustainability combines the BIF and the IBI together.

On the other hand, the IBI is also an attempt to solve the evaluation of the IBs, just as the IBs Survey in this study. There are similar components in the IBs Survey and in the IBI: space, comfort, culture, working efficiency, high-tech image, and cost effectiveness. Safety and security, as well as structural matters are not included in the IBs Survey. The IBI lacks such topics as flexibility, transport, efficacy or end-user empowerment (gender), and clothing, which are included in the IBs Survey.

During the creation of the IB concept definitions, the integrated buildings have been understood as being different from the intelligent buildings. It is even more clear on the basis of the IBI and the BIF, that the IB concept has been separated from the integrated building, as well as from the CIB (Computer Integrated Building), which seem to have components of the IBI, as well as components of the BIF on the basis of the metaphor between building intelligence and the logic-mathematics of the human intelligence.

In the light of the building intelligence, the results of the IBs Survey reflects the efficiency and efficacy of the intelligent buildings, but do not directly measure or evaluate the building intelligence. However, they reflect building intelligence indirectly. This is a fact also with the IBI.

### 8.3.8 New Design Criteria

Intelligence in buildings starts usually from cables and sophisticated building and office automation. Although its essence lies rather in new kinds of floor plans, open space design, active structures and new kind of building services such as in house tailored illumination. Integrating, flexible and interactive building design are important key words. Intelligent features improve real estate management, energy efficiency and operational economy. Comfort, social and mental welfare can also be aimed at.

Moving about is good for muscles and digestion, but it is also essential for thinking and creating new ideas. New ergonomics in offices might need even more flexibility, and new indoor air design criteria. The new indoor air design criteria can be found by choosing the nominal thermal load according to the walking office workers and that of the low energy equipment. Open office layouts – common in the IBs – are challenging, since walls are not keeping out unwanted air, heat and odours. The balance between the indoor air quality and the energy efficiency seems to be finer than what anyone ever thought. The old need of balancing the clothing and indoor air could turn out to be as promising. It is remembered that thermal comfort is a state of mind. It will be understood as a state of a more conscious mind in a healthy intelligent office for the knowledge work of the abstract organisations, such as tele- or flexi-work, imaginary organisations, hot desking, or mobile offices. The building intelligence determined within this thesis will follow the growth of humans in consciousness.

The implementation of the IB concept has yet to keep its promises in personal control either in the spatial flexibility or in the creation of adjustable apparatus. The correct design criteria make it possible to use space flexibly or adjust the building service apparatus. On the other hand, the needs of the occupant make the flexibility, easily movable furniture and equipment, and adjustable technology and building services work for the human benefit. The design criteria would be based on the building physics, and the physiological and psycho-sociological factors, which have been reflected from the socio-economic factors of the users for fulfilling also the needs of the interplay between work and private life.

One challenge in offices is to keep eyesight in good condition while working with computers, another is to prevent the worker from suffering from head-, neck- or backache, or electrical allergy. It is not only proper illumination and sophisticated ways of benefiting natural lighting without reflections from both paperwork and display terminals in the office, but also the conflict between the human body and the requirements of the computer aided work, which does not take into consideration the needs of the walking wise man.

Architecture is the mean for designing functional, aesthetic and psychologically satisfying environments, but it is also about the mental ergonomics of space. The progress in the cognition science both in human and artificial intelligence seems promising also on the behalf of the building design.

Efficiency counts in the quality of the workplace. Efficiency is traditionally understood as the cost benefit ratio. One cannot deny that the office is the factory of the information society. When the end-users of the buildings were asked the reason why a company moved into an office building, they replied in the IBs that after location the image of the building was more essential than in the reference buildings, where the price was more dominant. This made the author ask (Lehto 1997a), how long will mankind be interested only in being better off, with progress gained through the means, which are the cause of the cost benefit ratio, or with those which the cost benefit ratio is describing? Technology carries with it various values. Could it be possible to think that the performance of office technology is also described by 'fun to knowledge ratio', or 'positive experience to wisdom ratio' (cf. Cabanac in Clements-Croome 2000, pp. 45–46)? Benefiting from the material good gained might lead to the office becoming a fertile place for creative knowledge and skills, multiculturalism, or an energetic place for satorian insight. Enjoying one's work is different from being a workaholic although equally long hours might be spent in the working environment and equally good results gained. Enjoyment is based on success gained by recognising problems, not avoiding them.

The exception of the female executives working in the IBs has made the author ask, if their way of using local ICT and intelligent space and their skill in combining these resources into the mobile technology during the numerous business trips are the female themes to be discovered and discussed in the context of workspace design and the RDT of artificial intelligence as the new means of getting all of us, men as well as women, from the information era to the consciousness or knowledge era?

Are networking, imaginary organisations, female leadership utilising the IBs, hot desking or tele- or flexiwork showing positive thinking and using the harmonious, healed operations of everyone's own path and benefit? If so, how it could be expressed in the language of the workspace design.

# 9. Concluding Results

This thesis has been studying the differences between intelligent and other types of office buildings by measuring the performance of the building properties of twelve office buildings in the Helsinki metropolitan area. Among these office buildings, which were selected by the steering committee of the IBs Survey Study, were buildings, which have been designed using the Intelligent Building concept as a leading design criterion. The reference office buildings, which have not been designed according to the IB concept criterion, were selected to be comparable to the IBs. Thus the quality of all these office buildings is relatively high compared to the whole office building volume in Finland. The volume of the sample represents about 15 per cent of the average yearly built office building capacity in Finland.

The difference between the IBs and the reference buildings is proved by the quality evaluations of the end product. The end-user evaluations take place on such factors, which are either common to the post-occupancy studies of office buildings or which are included in the IB concepts, and which have been found from the literature of the IBs. The evaluations have been analysed statistically by using variance analysis (F-test), and the importance of the differences of the building qualities is based on these analyses. The importance of the factors studied by the IBs Survey for the identification of the IB has been ranked on the basis of their feasibility for the building quality.

The second criterion for the feasibility of the intelligent office work environment is the intelligence of buildings, which is based on the theoretical examination and the creation of the concept of the Building Intelligence Framework (BIF). It is typical for human intelligence to make artefacts, in other words products and also buildings. The ability of human intelligence to lend intelligence to an inorganic object, such as a building, is the key to the building intelligence. The BIF is derived from the argumentation of the related paradigms, such as the definitions of the human intelligence, the concept of ba, and concepts of knowledge management, as well as from such results of the IBs Survey, which seemed in the first place unclear and made a search for a clear reasoning necessary. Among possible definitions of the human intelligence the Gardner's seven forms of human intelligence have been selected as the starting point for the definition for the building intelligence (Figure 50.).

The BIF is the definition of the building intelligence, which separates the IBs from the other building concepts. It is not an answer for the lack of a universal definition of the IBs, which there are many and which define the IBs in a more general way with all kinds of good qualities of buildings.

Humans use their intelligence for satisfying their needs and to win their goals. That is why, for instance, Maslow's Need Hierarchy is frequently used in manufacturing industries in the R&D of products. The IB concepts define the IBs with the aid of needs and goals for which the intelligent building properties are made for. Their core message is not in the building intelligence itself.

The BIF defines the building intelligence according to how the IBs satisfy the occupant needs and make possible for the owners to reach their targets. The needs of the building's stakeholders are a reason for intelligent building and the intelligent buildings with all their advantages are the consequence of the use of building intelligence (Figure 51.). The importance of the parameters of by the IBs Survey for the identification of the IBs has been studied also in some extent on the basis of their feasibility for the building intelligence.

Because the difference between the building types is witnessed by the quality of the end product, i.e. that of the building itself by the end-user evaluation, the result actually reflects the efficacy of the building or the efficacy of each building property. How the working efficiency of the office workers is dependent on the performance of the office building is studied. In an empirical study like this, it cannot be prevented that the result reflects also the qualities of the used measuring instrument. Thus, on the one hand the primary result of this thesis on the buildings properties is due to the end-user evaluations, and on the other hand the result also describes the character of the used measuring instrument, in other words the characteristics of the evaluator. Some general remarks of the office work and working environment in the different offices are extracted as a by-product of this thesis.

The sample of the office workers of the IBs Survey is relatively numerous and the office workers represent very well the average Finnish office worker, and particularly in the IBs they actually represent knowledge workers.

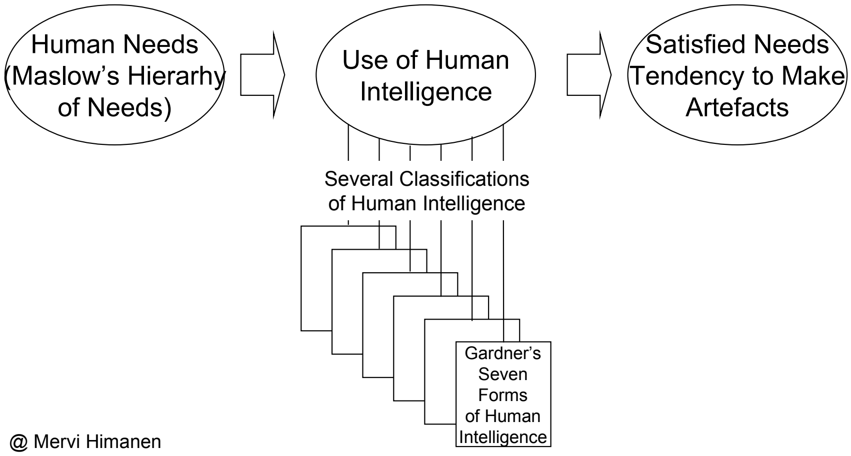


*Figure 50. Humans use their intelligence for satisfying needs, solving problems, etc. The human intelligence has the tendency of making artefacts. Technology can been seen as copying nature. Thus humans make things, manufacture products and build houses, which are of their kind.*

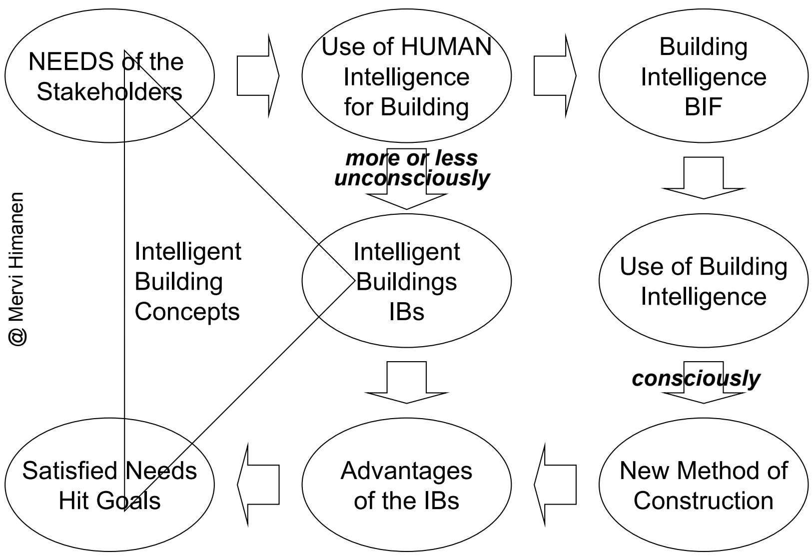


*Figure 51. The needs of the buildings stakeholders are a reason for intelligent building and the intelligent buildings with all their advantages are the consequence of the use of building intelligence.*

The final conclusions of the hypotheses of this thesis will be summarised in the last chapter. Because technical sciences and economics are by nature, applied sciences and disciplines and technology produces products, wherein the science produces knowledge, in this chapter will be concluded such results of this thesis which may have use in the design and implementation of the IB concept, and even in those of the office environment as a whole.

## 9.1 Summary of the Differences between Intelligent and Reference Office Buildings

The results of the IBs Survey have been summarised in the following tables (from Table 63. to Table 68.). The results have been grouped on the basis of the used parameters as follows: some general building properties, factors of the IB concepts from the IB literature and factors of the FM.

The path to the final proof of the existence of the IBs resulted from the relevant pieces of detailed information of the IBs and FM, which will be reported first and the BIF will be summarised that after. The building quality is the primary result of this thesis, but the by-product of the IBs Survey – the results on the quality of the office environment of knowledge work – will also be summarised briefly.

In the IBs Survey the office workers were asked to evaluate the impact of the working environment on their work efficiency. On the basis of the results of the IBs Survey, and those of the additional indicators, the feasibility of intelligent building technology or the efficacy of the use of IB concept shows the following features, which will be described in the next sections and which in general are beneficial for the use of the IB concept (Lehto 1999a). The efficacy of the IBs is better in comparison to that of the other types of high quality office buildings in terms of end-users' working efficiency.

### 9.1.1 General Building Properties

The *locations* of the studied office buildings were in the city centre of the capital of Finland, Helsinki, and in the technology parks, and in suburban areas of the Helsinki metropolitan area.

The IBs are somewhat bigger in size, their occupancy is higher. Both the big unit size and high occupancy of the IBs resulted in a good building quality (Table 63.).

The IBs are newer than the reference buildings, because after the application of the IB concept began it was not possible to find high quality reference buildings. Both new and old buildings are evaluated to have good and not as good spaces and equipment in both groups: in the IBs and in the reference buildings. Thus, the results of the IBs Survey are not building age dependent.

#### 9.1.1.1 Architecture

The style of the building (overall impression, mass and form) seems more important to the end-user than the total building size, or such details of the building as colours, materials and facade structure (Table 63.). This need not to be a sign of the lack of importance of the above mentioned architectural features, but of the success of the office architecture of the studied office buildings. It was expected that the smaller, "human scaled" size of the office building would be more popular than the massive ones. That was a fact with the reference office buildings. They were smaller in size than IBs, and their size was evaluated better than that of the bigger IBs. However, the other features made the IBs in general better than the reference buildings. Many of the big ones were office hotel type buildings, which might fulfil the human scale in their own way.

#### 9.1.1.2 Workspace Size and Occupancy

The personal work space is smaller in the IBs than in the reference buildings (Table 63.). On the other hand, the shared spaces are more spacious in the IBs than in the reference buildings. In all, the occupancy of the IBs is not as high as it is in the reference buildings. In the IBs the spatial effectiveness is based on the compact workplace size, but the shared spaces per worker are bigger than those in the reference buildings. There is the need to express the occupancy with two separate values: the occupancy of the workers' personal working area and that of the shared spaces, so that the real meaning of the space sizes can be understood in building design.

*Table 63. The differences between the two building types on the basis of building properties.*

| PROPERTY | IB | NON-IB |
|---|---|---|
| **Age of the building** | 3.8 years | 5.4 years |
| No dependency. | | |
| **Size of the building** | 67 300 $m^3$ | 35 000 $m^3$ |
| Dependency:<br>The bigger size of the IBs acceptable because of the good overall impression of the building and the good mass and form of the building.<br>The small size of the reference buildings favourable. | 270 occupants | 123 occupants |
| **Size of the personal workspace** | 2.6[1] | 2.9[1] |
| Dependency:<br>The compact workspace of the IBs is evaluated to be worse than the bigger one in the reference buildings.<br>The bigger shared spaces of the IBs are evaluated to be better than the smaller ones in the reference buildings. | 27.9... 87.6 $m^2$ / worker | 29.8 ... 105 $m^2$ / worker |
| **Occupancy** | | |
| No dependency.<br>More room per worker gives better grades for the spatial quality.<br>Less room per worker gives better grades for the quality of the equipment. | | |

| Number of the IB features | 3.75 installations of equipment<br><br>3.50 spatial specialities | 2.43 installations of equipment<br><br>0.86 spatial specialities |
|---|---|---|
| Dependent on the number of features; the bigger number of them in the IBs and the better quality of the building than that of the reference buildings. No dependency vice versa.<br>The good quality is independent from the number of the IB features; a good result can be gained also by a stripped down solution. | | |

[1] ≡ An index from 1 to 4 as follows: 1≡less than 5 $m^2$, 2≡5–9 $m^2$, 3≡9–13 $m^2$, 4≡over 13

In general, the larger the workspace the better the evaluation result. Consequently, the shared spaces of the IBs are valued better for the working efficiency than those of the reference buildings. However, the smaller personal work spaces of the IBs are valued as good as the larger workspaces of the reference buildings. It seems obvious that the numerous spatial IB features of the IBs can mitigate the lack of space. Brill (1985) has found that the increases or decreases in occupancy do not affect job satisfaction.

Professionals have as small office rooms as clerical staff, but more demanding work. Still, their evaluation of the personal workspace is quite the same as that of clerks. Women have more often smaller personal work space than men do, and they give lower grades to the personal workspace than their male colleagues. It is unstudied, but seems obvious, that women who are longer hours present at their desks than men, have more spatial demands than men (Table 64.).

The executives are satisfied with their big rooms, and the professionals and also clerical staff are in need of bigger rooms. There are even some weak signals of executives who might be satisfied with a smaller office and who might like to move to the open area office space. According to Brill (1985) this handful of executives who prefer an open area workspace to a private workroom are making a mistake, since communication is not dependent on the openness, but more, for instance, on privacy.

*Table 64. The different use of the two office building types.*

| PROPERTY | IB | NON-IB |
|---|---|---|
| **Presence**<br><br>Dependency:<br><br>Less time is spent in shared spaces in the IBs than in the reference buildings.<br><br>More time is spent in personal workplace and out of office in the IBs than in the reference buildings. | In personal workplace 64 per cent of the working time.<br><br>In shared spaces 22 per cent of the working time.<br><br>Out of office 14 per cent of the working time. | In personal workplace 61 per cent of the working time.<br><br>In shared spaces 28 per cent of the working time.<br><br>Out of office 11 per cent of the working time. |
| **Work load**<br><br>Dependency:<br><br>34 minutes longer working days in the IBs than in the reference buildings.<br><br>Dependent of the duration of the attendance in the space; the longer attendance the poorer evaluations and vice versa. | 329 minutes in personal workplace,<br><br>86 minutes out of office.<br><br>Longer attendance in the personal working space than in the reference buildings. | 319 minutes in personal workplace<br><br>62 minutes out of office.<br><br>Longer attendance in the shared spaces or in the workspace of the colleagues than in the IBs. |
| **Flexi-work**<br><br>Dependency exists. | The office automation encourages to work especially in the office and out of office. | Personally used equipment is good and portable equipment got good grades. |

Ryburg (1993) among others has claimed that the presence of the office workers is and will be relatively low. He is estimating that in such a new type office as in a multisite office only 50–60 per cent of the workers will be in at once. Due to the result of the IBs Survey the future trend seems different in the IBs.

Office workers spend quite normal working hours in the office space and meet the customers either in their own office building or even after the standard workday.

The typical ideas of the beginning of the 1990's in office design were: high density space planning, workspace sharing, free address workstations (or non-individually assigned desk allocation practise such as that of Digital Future Office in Helsinki), working at home, working in the customer's office, and innovative physical design. Hood (1993) had found that non-individually assigned desk allocation practices (free address workstations) have proven successful from financial, employee satisfaction and productivity viewpoint when the approaches are productivity rather than cost driven.

According to this sample the high density space planning and working in the customer's office (and also at home) have been successfully carried out in the Finnish IBs. The workspace sharing seems not very obvious because the personal workspaces are occupied for relative long hours. Offices with free address workstations or hot-desking were not studied within the IBs Survey.

#### 9.1.1.3 Quality and Suitability of Spaces and Equipment

The total qualities of spaces and equipment of the IBs are better to those of the reference buildings. The meaning of the status of the worker seems to have quite a strong effect on the evaluation of the quality of the physical working environment (Table 65.).

Executives give the spaces and equipment highest grades. In the opinion of the professionals and the clerical personnel the spaces are of quite the same quality. Executives share the good end-user evaluation of the equipment with clerical staff, while the professionals form a worker group finding the effect of the equipment worse to their working efficiency compared to the other groups. Thus, the modern office equipment is suited better to executives' and clerks' work than that of the professionals. The modern office space is more suitable for the executives' work than it is for professionals' and clerks' work. The IB concept has had an effect in the creation of a good working environment, but the differences between worker groups have remained as well as the gender differences.

The occupants of the IBs are members of typical knowledge work organisations more often than the office workers in the reference buildings. This means that there are working a greater number of professionals than clerks, more often supervisors than representatives of other office worker groups, more often male than female office workers, and the workforce is better educated in the IBs than in the other offices.

Because in the IBs there are more executives and highly educated workers than in other offices, and the end-user opinion can be more positive in the IBs due to their ability to find cumulated knowledge and information, as Castells has argued, and further on their ability for using the available building properties.

The overtime work is common among academic knowledge workers in Finland in general. The working hours in the IBs are half an hour longer per day than in the reference buildings. Under the circumstances, the workers in both types of buildings seem to spend quite the same time in their personal workspace.

The overtime hours do not explain either the satisfaction of the executives nor the dissatisfaction of the professionals and clerical personnel with the office building properties, because the differences in overtime work between worker groups occur in such cases of overtime work, which is taking place somewhere else than in the office building. Thus, the differences are rather due to the differences between the qualities of two building types.

Work satisfaction correlates with the positive end-user evaluation of the equipment in the IBs. However, work dissatisfaction does not explain the low end-user evaluation from the professionals' side in the IBs. The same goes with the critical female evaluations. They are not reflections of poor work satisfaction.

*Table 65. The differences between the two building types on the basis of end-user evaluation.*

| PROPERTY | IB | NON-IB |
|---|---|---|
| **Spaces** | 7.8[1] | 7.3[1] |
| Dependent on the spatial quality; it is evaluated to be better in the IBs than in the reference buildings. | | |
| **Equipment** | 7.9[1] | 7.5[1] |
| Dependent on the quality of the equipment: it is evaluated to be better in the IBs than in the reference buildings. | | |
| **Personal workplace** | 7.9[1] | 7.8[1] |
| No dependency. | | |
| **Shared spaces** | 7.8[1] | 7.2[1] |
| Dependency: better share space quality in the IBs than in the reference buildings. | | |
| **Indoor air quality** | Thermal comfort 3.3[2] (difference from target value 2.3[2]) | Thermal comfort 2.6[2] (difference from target value 1.6[2]) |
| Independent from the other indoor air quality factors except the thermal comfort, which is worse in the IBs than in the reference buildings. | | |

[1] ≡ An index from 4 to 10 (the best); Non-IB means reference buildings, which are not built according to the IB concept; [2] ≡ scale from (1) pleasant to (7) unpleasant.

#### 9.1.1.4 Shared and Personal Work Spaces

The personal work space is not found to be exceptionally good in either types of office buildings (Table 65.). In the reference buildings the work time outside own workspace is spent mostly in other spaces of the office building, but in the IBs these working hours include meetings out of the office. The shared spaces of the IBs are valued better for work efficiency than those in the reference buildings. It seems that the numerous spatial IB features of the IBs are working well in the shared spaces but they are not good enough for the needs of the personal work space to make the offices in the IBs better in quality than the reference offices.

The flexibility and the easiness of moving are one of the strengths of the IBs. They are the properties of the whole building. The control possibilities of the personal work space are not that good in the IBs despite of the fact that the personal control possibilities have been targeted according to some IB concepts.

In the IBs the architecture and interior design (such as new floor plans, flexibility, active structures, materials) of the shared spaces are good, but that of the personal workplace not so good. The meeting room, show-rooms and lobbies are highly evaluated because of their effect on working efficiency although the working time spent there is not long or it is shorter in the IBs than it is in the reference buildings.

Korvajärvi and A.-M. Lehto (2000) have argued the importance of social skills and customer relationships, and that of the home organisation for success in knowledge work, thus it can be argued that the good end-user evaluation results of the interoffice show and meeting rooms in the IBs reflect the above mentioned needs in the knowledge work.

Both Hood (1993) and Joronen (1993) has claimed that not only the actual workplace, but shared spaces such as meeting rooms, restaurants, sport halls, parking, etc. are important in improving work or office space quality. If the fit is good, there can be significant gains in productivity, profits, innovation and morale.

The small personal workplace with short visits to shared spaces are preferred and get high grades in end-user evaluations. In other words, the total workspace quality (end-user evaluation) is high if the quality (end-user evaluation) of the shared spaces is high, although the small personal workplace alone is not a preferred solution. The highly evaluated bigger workspaces in the other offices cannot substitute for the lower quality evaluation of the shared spaces, especially when workers tend to spend their time there. Both shared and personal workplace has to be well designed.

On the basis of the high grades given to the shared spaces for the working efficiency of the office worker, it can be concluded that the social needs of the office work in the IBs are better fulfilled than the individual ones, and the poor grades given for possibilities to concentrate on ones work confirm this result.

Earlier the social values dominated in the society. Today individualism – individual rights and responsibilities – are seeking their position in the society. The march of individualism does not delete social relationships. The attitude of international business towards cultures in various societies needs to rely on the company culture for a good atmosphere of co-operation and on company values for good customer relationships. The roles of the core businesses, as well as the roles of the workers and society are both becoming important.

The sophisticated spatial solutions and the new ways of using space can influence the productivity of the workers and their spatial experience (comfort or discomfort).

#### 9.1.1.5 Indoor Air Quality and Energy Efficiency

Indoor air quality of the IBs makes a not so good exception as could be expected and the indoor air quality evaluation show inconsistent results, although some cases give proof of the possibility for good indoor air quality in the IBs.

There is not enough evidence of the better energy efficiency of the IBs in comparison to the reference buildings, the energy saving potential of the use of the IB concept seems undoubtable.

It is possible to guarantee a good indoor air climate with high energy consumption as well as with low energy consumption. The good indoor air and the energy efficiency in the sense of saving energy are not necessarily in conflict when applying the intelligent building concept.

### 9.1.2 Intelligent Building Features

The major issues related to the built environment and also some key elements in the construction of the IBs in the turn of the decade from 1980's to 1990's were: accommodating personal privacy on an as-needed basis, ergonomics, personal environmental control, life cycle economics, problems with interfaces (building to furniture, furniture to equipment, user-interface, etc. and environmental problems.

The whole 1990s have been a period of constant change in working life. The variations of sharing space between personal workplace and shared office spaces have followed each other, aiming to solve the problem of balancing a peaceful personal work environment and the need for space for communication.

Innovative new technology and structural and spatial solutions seems to make the IB concept work (Table 63.). Spatial design of the IBs requires careful planning (and extra installations of equipment and structural innovations) to give effective result.

The emphasis on the good spatial intelligence of this sample of Finnish IBs seems to endorse So's view that intelligent buildings in Europe depend on meeting the user's requirements rather than just on the technologies (So 2001, pp. 4–6.).

In the IBs, there are a bigger number of special installations of equipment per building, and the difference between the two building types of the number of spatial specialities is even bigger. These numbers correlate to the end-user evaluation result of the building qualities.

In examining the installations of equipment, structures and spaces of an individual building, which are not composed of several IB features, and

*Table 66. The meaning of the parameters of the intelligent building concepts from the literature to the separation of intelligent buildings from the reference buildings according to the result of the IBs Survey.*

| | FACTORS OF THE IB CONCEPTS FROM LITERATURE | RELEVANCE | FACTORS OF THE IB CONCEPT STUDIED IN THE IBS SURVEY |
|---|---|---|---|
| $z_1$ | End-user need orientation | 👂 | End-user need orientation |
| $z_2$ | Level of integration | 👂 | System integration |
| $z_4$ | Space flexibility and utilisation[1] | 👂 | Spatial flexibility |
| $z_5$ | Movable space elements and equipment | 👂 | Moving |
| $z_7$ | Comfort | 🤲 | Indoor air quality |
| $z_8$ | Convenience | 🤲<br>🤲 | Concentration on work<br>(Work satisfaction) |
| $z_{10}$ | Working efficiency | 👂<br>👂 | Working efficiency<br>Flexi-work |
| $z_{11}$ | Image of high technology | 👂<br>/<br>🤲 | Image of the building (values and types of buildings), Space selection criteria |
| $z_{16}$ | Information intensity | 🤲<br>🤲<br>👂 | Control and regulation (HVAC)<br>Office automation<br>Paperless office |
| $z_{17}$ | Interaction | 👂<br>🤲<br>👂<br>👂 | Among occupant companies<br>Communication<br>Awareness of the use of ICT<br>Participation in design |
| $z_{18}$ | Service-orientation | 🤲<br>🤲 | Building amenities<br>User interface |
| $z_{19}$ | Ability of promoting health (therapeutic) | 🤲 | Health symptoms |
| $z_{20}$ | Adaptability | 👂 | Adaptability (Adjustable) |

[1] ≡ Included in also such the parameters of the questionnaire as occupancy and room size; 👂 ≡ has an influence on the difference between the IBs and the reference buildings; 🤲≡ has no influence on the difference between the IBs and the reference buildings.

comparing the set of solutions to the end-user evaluation result, it can be found that good results can also be gained with a stripped-down solution.

This result of the IBs Survey (from Table 63. to Table 65.) means on the behalf of the IB concept factors that the following factors have a role in the separation of the two building types: end-user need orientation *($z_1$)*, level of integration *($z_2$),* space flexibility and utilisation *($z_4$)*, movable space elements and equipment *($z_5$)*, working efficiency *($z_{10}$)*, image of high technology *($z_{11}$)*, interaction *($z_{17}$)*, and adaptability *($z_{20}$)*.

The end-user orientation and the work efficiency are not separately studied with particular questions in the questionnaire of the IBs Survey, but they are a part of the research arrangement.

The correspondance between the factors, which separate the two building types can be expressed by the Equation 5. as follows:

$$\textit{Equation 30. } BQ_{Difference} = f\,(z_1, z_2, z_4, z_5, z_{10}, z_{11}, z_{17}, z_{20}).$$

Interestingly, all the factors which separate the two types of buildings from each other are also those, which have been successfully carried out in the IBs.

#### 9.1.2.1 Image of the Building and Values

The IBs are described to be of advanced progressive development, while the reference buildings are described rather as traditional and reliable.

The office building does not reflect the office workers' own values but rather those of the company.

One out of four of the office workers thought that the building quality had influence on their choice of workplace, and this was found more often in the IBs than in the reference offices. This result might be valuable in a situation where the employers are competing for the insufficient markets of ICT professionals.

#### 9.1.2.2 Moving, Spatial Flexibility and Adaptability

The IBs' power in performance over the reference buildings is apparent in the spatial flexibility besides the quality of moveable workspace (moving).

The flexibility of spaces in the IBs allows easy moving from one workplace to another; this makes the office space elastic for changes in the number of personnel according to the needs of the business. However, Brill (1985) claims that the big number of interoffice moving disturbs communication.

If the IBs are good for moving and in spatial flexibility, that is not the case with the adaptability of their workspaces. Neither the IBs nor the reference office buildings are particularly good or bad in adaptability of workspaces. Both moving and spatial flexibility concerns the whole building or shared spaces. The adaptability concerning the workspaces is not evaluated to be higher in quality in the IBs than in the reference buildings. Brill (1985) claims that the layout of a workstation with greater suitability for the work at hand, correlated with greater ease of communication. This is a reason for improving the adaptability of the personal workspace.

The adaptability is sensitive to the gender. Men find spatial adaptability better than women do. In all cases of fifteen factors female workers find the workspace adaptability worse than their male colleagues do, except in one case when they have more or less the same opinion.

The effect of the working status on the adaptability is similar to that on the spatial work environment properties. The executives find their possibilities in adaptability better than the other worker groups, and the professionals find them better than the clerical personnel, who find them worse.

#### 9.1.2.3 Control and Regulations

Occupants do not have much personal control of their workplaces in general. If they have they also evaluate the quality of the spaces and equipment better.

According to the end-user feedback the indoor air control is a challenge for the designers of the demanding working environment of the IBs.

#### 9.1.2.4 Communication or Interaction

The ICT power is best for speedy communication and reaching people quickly. For the best working efficiency one need everyday office tools: a personal computer, a telephone, a printer, a telefax and email.

The satisfaction with work mates is the only factor of work satisfaction, which is statistically significantly better in the IBs than in other office buildings. Also, the increased possibilities for personal contacts in the IBs are appreciated in communication with other occupant companies at personal level.

The location, which allows the same location with the cluster of the companies to which the occupant company belongs, is important for occupants of the reference buildings.

Female executives who are working in the IBs find the new ICT office tools most effective for their working efficiency compared with the all other worker groups. In the intelligent buildings the female executives form an interesting special user group concerning ICT also, because they evaluate the office automation high, but do not like mobile phones and paging. Female executives working in the IBs find their possibilities to concentrate on their work best of all worker groups.

Friberg's (1990) classification of three female styles at work could be applicable in the analysis of the use of the ICT and IB features in offices. It can be asked, if the career life is common among female executives and professionals, and how many have chosen the balancing life form. Is the career life form too laborious and does the executives' status mitigate this burden, or are those, who have managed to get the executive's position, those who are able to carry the heavy burden of the career life style? Also the chance to choose the balancing life style is possible, although almost all women in Finland participate in the working life full time, contrary to other European countries.

Brill (1985) has found the connection between fewer people in any given space experiencing higher ease of communication, and with higher densities of occupation there is less ease of communication.

*Table 67. The differences between the two building types on the basis of the parameters of the IB concepts.*

| PROPERTY | IB | NON-IB |
|---|---|---|
| **Image of the building** | On 32 per cent of respondents it had an effect on the choice of the workplace. | On 26 per cent of respondents it had an effect on the choice of the workplace. |
| Independent from the reflection of the values.<br>Dependent on the choice of the workplace among the small group of tenants. | | |
| **Moving (whole building)** | ~ 40–50 easy moves | ~ less than 30 easy moves |
| Dependent on the easiness of movings, which got higher grades in the IBs than in the reference buildings. | | |
| **Spatial flexibility (whole building)** | ~ 8[1] | ~ less than 7[1] |
| Dependent on the flexibility, which got higher grades in the IBs than in the reference buildings. | | |
| **Adaptability (personal workplace)** | 5.1[1]–7.1[1] | 4.9[1]–7.1[1] |
| Independent from the building types. | | |
| **Control and regulation (room temperature and lighting)** | 6.2[1]–6.7[1] | 6.3[1]–6.7[1] |
| Independent from the building types. | | |

| | | |
|---|---|---|
| **Communication among occupant companies**<br><br>Different communication styles between occupant companies in the IBs than in the reference buildings. | The personal relationships more important in the IBs than in the reference buildings. | The location with the companies belonging to the same cluster more important in the reference buildings than in the IBs. |
| **Health symptoms**<br><br>Independent from the type of building.<br><br>Dependent of the co-effect of gender and status of worker. Various correlation between building properties and health symptoms.<br><br>The health symptoms correlate to good equipment evaluation, which means that the health symptom rate is reflecting more the heavy use of the equipment than dissatisfaction to it, and also rather the work load of the knowledge work resting on the shoulders of the professionals. | Female professionals and clerks have exceptionally high health symptom rates and there are as much sick leaves among female professionals as those are among female clerks in the reference buildings although the sick leaves are not common in general. | |
| **Systems integration**<br><br>Dependent on the building quality, but independent from the number of the IB features. | | |

[1] ≡ An index from 4 to 10 (the best); Non-IB means reference buildings, which are not built according to the IB concept.

However, this fact was not found in the IBs Survey, because the communication possibilities were better in the IBs, where the occupancy was relative high. The result would be better comparable to the findings of Brill (1985), if the comparison would be done between two IBs with different occupancies.

#### 9.1.2.5 Concentration – Open versus Closed Workspace

The work areas in the IBs are more often open than those in the reference buildings are. The majority of office workers believe that open plan area offices and the use of the ICT speed up communications, but an even bigger majority consider that the open planning disturbs their personal workplace and it was more difficult to concentrate in the IBs, than in the reference office buildings.

Difficulties in concentration concern professionals and female clerks more than executives and male clerks. Disturbances affected mainly the work of the female clerks, who had difficulties in withdrawing to a peaceful place to work.

Both male and female executives reported their possibilities to concentrate on their work as better than other groups of workers. Female executives who are working in the IBs find the possibilities to concentrate on their work best of all groups of workers.

The type of workplace can tell if the space is a closed or an open structure. The private workroom is a current workroom type and a favourite in the future in comparison to the other workspace alternatives of a shared room, an open area workspace with partitions and an open area workspace without partitions. Shared room is not a favourite, but the open area office space as an personal workplace seems not to be good either on the basis of the future wishes.

According to Brill (1985) the closed environment structure encourages communication. This is natural, because the need for communication must be greater than in an open area, and perhaps also because it is easier to communicate more freely in a closed space.

#### 9.1.2.6 Systems Integration

Because LAN and building automation were standard in any office building in the late 1980's and the beginning of the 1990's in Finland, neither the building automation nor the local area network installation differentiates the IBs from the reference buildings within this sample. However, it can be found on the basis of the end-user evaluations that the interoffice network integrating the personally used office automation equipment works better in the IBs than it does in the reference buildings. The quality of intelligent subsystems must ensure that the elements of which they compose form effective systems which respond to changing user needs.

The personally used equipment without any interconnection between them are more often used in the reference buildings than in the IBs, and the end-user evaluation of them has no special trend, which could differentiate the two office buildings from each other.

Adding intelligent subsystems without taking care of their reliability, the quality of installations and the pre-settings, and without a well designed overall plan, seems more likely to be an effective tool for causing problems and for giving a wrong image of the building for the tenant. To build a good intelligent building needs good engineering practice and thinking according to the intelligent building concept rather than assuming that digital control systems will guarantee building intelligence.

The end-user can stand some unsatisfactory factors in the working environment, but if they are many, the building quality is experienced as poor. The criteria for the use of the Intelligent Building term will be best fulfilled, if the building design is based on more than one of the elements of the IB concept, and if the quality of intelligent subsystems rests on knowledge of high standard engineering for the correct technology needed in each subsystem, and finally if the elements of intelligent buildings (or those of building intelligence) form a functional combination which responds to changing user needs.

An assembly floor, which is one of the concrete structures to enable integration, seems to have a positive correlation with the good end-user evaluation result of the quality of the IBs, but two examples out of five are proving that good or average building quality can be achieved without an assembly floor, and thus its influence on the building quality is uncertain. The spatial flexibility and the possibilities to move equipment, which are better in the IBs than in the reference buildings, should be examined and tested using the two IB features (of assembly floor and moveable wall) as reference parameters.

Movable wall is another structural IB feature, which separate IBs from other office buildings and they may have similar effect on the end-user evaluation as the assembly floor has.

The equipment connected via interoffice network is a favourite of the female office workers.

### 9.1.3 Facilities management

The variety of new type services available in a modern office building is considerable, and their number is growing. Due to the concept of outsourcing, these services are increasingly brought from outside the office building.

#### 9.1.3.1 Selection Criteria and Location

The location of an IB is an important aspect as a selection criterion of an office building, together with the image of the building of any office building.

The building type counts when selecting an office building on the bases of the building type, which is important in the IBs. The price and the building used as an investment are dominant when selecting an office space in other types of buildings than in the IBs.

Brill (1985) highlights the meaning of the distinctiveness of the office design for the occupants, which could be comparable to the results of the IBs Survey, which shows that the building type is a more important selection factor for the office building in the IBs than in the reference buildings.

A location either in the middle of nature or in the city centre is best in the tenants' opinion for an office building in the Helsinki metropolitan area. Office buildings are different in different locations. Also, the lines of businesses and the type of occupant can differ according to the location. This type of "product" variation could be a tool in FM.

According to Hood employees respond well to bright, modern, functional surroundings, resulting in greater productivity and greater synergy between groups. Such popular elements in the studied offices in the IBs as green interior design, view out to the nature from the office room and glass roofed lobbies are confirming Hood's findings.

#### 9.1.3.2 Business Travelling, Possibility of Paperless Office and Flexiwork

The existence of the potential for substituting work-related trips (business trips) by means of the ICT and IB features can be noticed. Men experienced the diminishing effect more often than women. About two thirds of the office workers (who regularly make work-related trips) had not noticed any impact of the use of ICT on work-related travelling. Because they are also using ICT in their office work, it can be stated that the majority felt that there exists a complementarity between ICT and travelling.

Office workers' experience on the influence of the use of ICT on work related trips, was different in the two different office building types. This was related to the number of business trips which from IBs to abroad are three and a half times more than from the reference buildings. This difference is due to the trips made by the executives and professionals, both male and female.

Until 1994, portable equipment and video conferencing were not frequently used. Phone, mobile phone and portable personal computer are most important for executives and less important for clerical personnel. Usually men prefer mobile phones and portable personal computers to other office automation more often than women do.

In 1994, telefax, email and mobile phones were the office automation devices, which were ranked most powerful in diminishing the number of business trips. Telefax and email are more effectively used for that purpose in the IBs than in the reference buildings. They belong to those ICT tools of the office which in general got better grades in the IBs than in the reference buildings. When avoiding trips abroad women use conference calls more often than men, although in general men have conference calls more often than women.

In general, it cannot be presumed that the high quality office or building automation can substitute, affirm, compensate or mitigate lacks in the spatial quality of the building. The realisation of the paperless office might change this argument after the office automation is made as suitable for paperless office work in regard to the work of executives and professionals as it is for the work of the clerical staff today. Although the paperless office has not been realised despite of the increased use of ICT, there is new hope for it because of the popularity of the green office concept applications.

The workers in the reference buildings trust more the paging device, the answering machine and the mobile phone than the workers in the IBs, who take care of the flexi-working situations with the portable computers better than their colleagues in the reference buildings. The equipment of the IBs allows best interoffice working conditions and in the IBs more work is done both out of the office and in ones personal workplace than in the reference buildings. The equipment suitable for spatial flexibility of work and the paging device and the answering machine got higher grades in the reference buildings, where workers spend more time in their colleagues' rooms. There work also more women than in the IBs, and female office workers prefer the paging device and the answering machine better than their male colleagues.

It can be presumed from the results of the IBs Survey that the mobile technology (in 1994) might not be technically good enough for the requirements of the knowledge workers, especially men, who work a lot out of office, if the portable computers are not counted in.

Women can take advantage of the interoffice work equipment better than men do, because their working methods prefer working at the office more than the male work style does. The chances for tele-work at home are better for men than for women.

Human contacts seem inevitable due to many reasons, despite of the growth of the computerised information sources. 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 to keep up close relations and prevent loneliness, etc. by meeting. Although the limitations of the technology cannot be denied in substitution of face to face contacts, human engineering, usability studies, etc. try to develop more user-friendly technical solutions, that could also decrease prevent travelling. The use of ICT is growing rapidly – much faster than travelling. In spite of the apparent complementarity, invisible substitution probably exists. Actually, we do not know how big the growth of travelling would be without telematically aided information exchange.

It seems true, what already in the beginning of the 90's Hood has concluded, that behaviour can be improved with well-implemented facility solutions, and investment in high quality communication systems is vital to assure the effectiveness of the work force in the future.

#### 9.1.3.3 Amenities, Service Mode and Skills to Use New Technology

The differences between the two office building types of the needs of building amenities were favouring neither the IBs nor the other buildings. The analysis of the parameters of the primary building amenities reveals, that they are more important for the work performance of the female workers than for that of the male workers.

The building management is the most important personal service, which the office workers wanted to have as a personal service instead of a machine helping them with office tasks.

The highly educated office workers do not know all the properties of the technical facilities they are using. Female workers and clerical staff are most in need of guidance, and executives the least. Lack of education and guidance is a significant reason for the poor knowledge of the uses of technology in the IBs.

Puirava's finding about female novice computer users being afraid of showing their ignorance and wishing to have the chance to learn new skills in private, gives an interesting point of view to the results on the female office workers, who find that they do not know enough about the use of the office equipment and who most probably do not have as good a chance to work in private. This seems to be especially true, because the female executives get the most out the new office equipment and they do have the chance to work in private.

Finnish studies on the female use of computers and media confirm Friberg’s (1990) results in the findings of the difficulties women have in balancing the working life and housekeeping responsibilities. It seems obvious that the female office workers do not have the chance to learn enough about the use of the equipment, and it is not a question of a lack of interest in the use of computers. This problem is cumulating in the situation of the female professionals in the IBs, and to some extent in that of the female clerks in the IBs as well, where the status and the standard of the equipment is high. In many Finnish IBs the building amenities have been planned but unbuilt. Amenities would make the workforce even more effective. In the world of androgyne humans and increased number of singles this problem concerns not only families or the female sex.

#### 9.1.3.4 Participation in Design

Regardless of the status, it seems that those who have had good chances to influence their working environment are also satisfied with their office and its influence to their working efficiency.

In the IBs this possibility has been better and the workers' ideas have been realised well. This has been true especially in the case of female executives and clerical personnel of the IBs. They also gave the equipment good grades for their work performance, but are not as satisfied with the spatial solutions.

Men in the IBs are in the best position to influence the office design of their workplace. Women cannot participate in the design as often than men do, but their expectations about the beauty of the environment are higher than those of men.

Satisfaction with the designer and her or his awareness of the spatial needs of the respondent was significantly better in the IBs than in the reference buildings. Women are not as satisfied with the design and the designer of their work environment as men are.

Hood has emphasised the importance of the executives' involvement in the design. Management involvement is essential for setting correct expectations and for consulting with the employees, and the focus must not be on cost reduction as the sole objective. It alone seems not to be enough. Actually Brill

*Table 68. The differences between the two building types on the basis of the factors of facilities management.*

| PROPERTY | IB | NON-IB |
|---|---|---|
| **Location** | | |
| Different types of buildings in different locations.<br>The two best locations can be found in the middle of nature and in the city centre are. | | |
| **Selection criteria** | Building type counts. | Price or rent and the investment possibility count. |
| Independent from the location and the image of the building.<br>Dependent of the type of the building and the price or rent and the use of building as an investment instrument. | | |
| **Number of building amenities** | | |
| No dependency. | | |
| **Manual or automated services** | | |
| No dependency. | | |

| | | |
|---|---|---|
| **Business travelling**<br><br>Differences in the business travelling habits between the workers in the IBs and the reference buildings.<br>The potential of the use of ICT to diminish and mitigate the expanding business travelling. | 3.5 times more trips abroad in the IBs than in the reference buildings. | Local trips. |
| **Possibility of paperless office**<br><br>Independent from the building types in general.<br>Possibility of paperless office concept could be true for the clerical personnel in the IBs. | | |
| **Participation in design**<br><br>Dependency: in the IBs the possibility to influence is better and taken better account than in the reference buildings.<br>The possibility to participate correlates positively with the good evaluation of the spaces. | 45 per cent had had the chance to participate. | 30 per cent had had the chance to participate. |
| **Awareness of the use of ICT**<br><br>No dependency.<br><br>The knowledge of the use of ICT is poorer in the IBs than in the reference buildings. | Lack of education and guidance is a significant reason for the poor knowledge. | |

Non-IB means reference buildings, which are not built according to the IB concept.

(1985) points out that the office workers certainly know more about their work than facility managers and designers, and probably more than their executives and that analysis of needs of work environment during programming and the designing of it should utilise workers expertise. Results of the IBs Survey confirm these conclusions.

Not very many would like to design the environment themselves, but workers would like to choose the furniture and materials themselves, or pick one from several design alternatives for themselves, or to tell the designer about their wishes. The possibility to bring small things of their own to the workplace was also quite important, which is parallel to what Hood has notified about the importance of the ability to personalise one's workplace.

### 9.1.4 Office Work in Intelligent Buildings

#### 9.1.4.1 Knowledge Work

The working organisations in the IBs seem to be similar to the knowledge work organisation on the basis of the working organisation's diamond structure (Section 5.3.3.1). In intelligent office buildings well educated, male executives are employed more than elsewhere, but the educational level of the female worker in general, taking in account all worker groups, is better than that of their male colleagues in any office. The executives and the professionals in the intelligent and reference buildings can be presumed to be knowledge workers.

Most of occupants work in companies either from the services sector or from the knowledge management industries. The companies of the service sector both in the intelligent and the reference buildings are in technical and commercial services. In the IBs the knowledge work was largely in communication technology whereas in the other offices the knowledge work tended to be on other sectors.

The sample of the IB office has workers from the information sector (ICT-workers) more than that of the reference buildings, although several different fields of businesses are also represented among the workers in the IBs. However, the diversity of the lines of businesses is wider in the case of companies located in the reference office buildings.

#### 9.1.4.2 Workload

The workload of the office workers in the IBs is heavier than that of the workers in the reference buildings. The work satisfaction and the nature of work have no influence to the end-user evaluation of the differences between the two office building types. On the other hand, such human and organisational factors as the status of the worker and the gender have an influence on the end-user evaluation of the differences between the two office building types.

The overtime work is as common among female professionals in the IBs as it is among male and female executives in general, who as a group work most overtime.Women spend more time in their personal work space than men and they work outside the office less than men do. The long working hours in the building correlates to the critical female opinion of the quality of the space. The long working hours at their personal workplace correlates with the poor spatial end-user evaluation more generally than only among the women. The good spatial quality of the IBs seems to correlate with the male executive status and the possibility to work outside the office in addition to long hours at the office.

#### 9.1.4.3 The Status of the Worker

In the studied offices in the Helsinki metropolitan area the status of the worker is a more dominant factor than the nature of the work or the gender.

Different working conditions are needed for different types of work. The executives, professionals and clerical staff value differently various building properties. Executives like the current space best. Professionals and clerks share the not so good opinion of the current spaces. Executives and clerical staff like the equipment best, while professionals cannot get most out the office equipment. A reason for that is the fact that in the knowledge work organisations the heaviest working load rests on the shoulders of professionals, who are the heaviest users of the computers of all groups of workers. Professionals form a demanding client group of the office automation.

All highly educated office workers (half of them having an academic degree) do not know all of the possibilities to use the office automation and other ICT aided working methods well enough to get the best out of them. The possibilities to learn how to use new equipment are not good in the organisations of the IBs.

In all, executives like their working conditions best, professionals next best and clerical staff least. It seems that this fact is not only a reflection of the nature of work, but in particular that of the status of the worker. It probably tells of the possibilities to influence one's working environment.

The opinion on the office automation is somewhat dependent on the education. Those who have a middle level education have no special evaluation trend, they can be either for or against office automation or ICT. Those with a high academic education had developed a critical attitude towards office automation.

#### 9.1.4.4 Gender

Women work equally long hours as the men, but they travel for business less than men, if the female executives are excluded. It seems that it is more typical for women to work at their personal workplace with the interoffice equipment than it is for men, who work (likely with mobile phones and portable computers) out of office more than women.

The fact that women work less hours outside the office than men do explains also the fact, that the women do not evaluate the mobile phones and portable computers as highly as men do from the working efficiency point of view, because probably they simply do not need them as much as the men do, who are more out of the office.

Women are in general active in the information intensive work, and in the intelligent offices they work longer hours with the computer than their male colleagues. All female office workers trust more on the interoffice equipment than men, who work more out of office and need portable equipment. It seems that women and men need different working environments, because their working methods are different.

Gender affects the evaluation of the building properties. Men prefer the spaces better than women and women prefer the equipment better than men. Women

*Table 69. The differences between the two building types on the basis of the socio-economic parameters.*

| PROPERTY | IB | NON-IB |
|---|---|---|
| **Status of the worker**<br>Dependency: the executives prefer the space best, the professionals next best and the clerical staff worst, and the executives and clerical staff prefer the equipment best, and the professionals prefer it worst. | More executives. | |
| **Gender**<br>Dependency: men prefer the space better than women do and women prefer the equipment better than men do. | More men. Female executives prefer the equipment best. The male clerks prefer the equipment worst. | More women. The male clerks prefer the equipment worst. |
| **Age of the occupant**<br>No dependency. | | |
| **Work satisfaction**<br>No dependency.<br>Workers do not reflect their possible other dissatisfaction to the physical working environment. | Good | Good |
| **Nature of work and working hours**<br>Nature of work not tested.<br>Same working hours. | Full time and flexitime hours. | Full time and flexitime hours. |

Non-IB means reference buildings, which are not built according to the IB concept.

are more demanding on spaces than men, but do not have as good chances to influence their work space as men have.

Friberg (1990) has found that women experience stress not only at home but also at work and both at professional and on clerical level. It could explain together with the change of office work organisations from the pyramid organisation into the diamond type knowledge based organisation (Goleman 1993 in Gouin & Cross 1986, p. 29), the differences in the evaluation of equipment quality between men and women among professionals and clerical staff.

In general women have a large number of health symptoms, they work more often in the reference buildings and their evaluation of spaces is poor. It was also found that the female executives are the heavy travellers among the office workers, although the male office workers travel more in general. Female executives work effectively with the equipment at the office and travel a lot for business.

Female professionals who work in the IBs have smaller working rooms. Their rooms are the smallest of all groups of workers. Still, their evaluations of the spaces and equipment are better than those of female clerical personal, but worse than those of female executives. It seems that the gender is not as dominant a factor as the status of the worker in the Finnish offices, when evaluating the quality of the building. The status of the worker is even more important than the nature of the work in these Finnish offices, which were studied in 1994.

It would be presumable that the nature of work would count in design of new knowledge work environment. Social skills have been also appreciated as a factor of success of knowledge work. Social skills are personal, and thus gender related either culturally or biologically. They cannot be underestimated in the work environment design. Status is a reflection of the hierarchy, which is also an important tool of a working organisation.

The office design criteria which either focuses only on adults without children or does not pay any attention to the worker's family life, can be categorised as the employees' interest seeking. Not only the roles of the core businesses, but as well the roles of workers and society are both becoming important also in workspace design. To be able to design according to the needs of society can become a competitive weapon, which separates the spaces from each other.

Earlier the social values dominated in the society. Today individualism – individual rights and responsibilities – are seeking their position in the society. The march of individualism does not delete social relationships. The attitude of international business towards cultures valied in various societies needs to rely on the company culture for a good atmosphere of co-operation and on company values for good customer relationships. The director of Nokia Communications, Sari Baldauf, is convinced that company culture and values are growing in importance; especially if cultures will separate people – as it does seem since September 2001 – even in greater extent than earlier. In a win-win-type society and company, both-and are the keywords, not either-or.

#### 9.1.4.5 Work-satisfaction

Regarding of the space quality the status of the worker rather than the type of building correlates with work-satisfaction, the number of health symptoms, and to the time which is spent in ones personal workplace. The work-satisfaction has no correlation to the differences of the evaluations either of genders.

Women are more critical with the spaces than men, but they are more satisfied with the equipment than men are. The long hours in ones personal workspace and the heavy usage of equipment rather than the work satisfaction or gender might be the reason for demand for good working environment and equipment. Female executives in the IBs are exceptionally satisfied with their work. That is, also, the case with the male clerks in the IBs.

#### 9.1.4.6 Health Symptoms

The work-satisfaction and the number of health symptoms of the evaluator seem to have no influence on the differences between the end-user evaluation results of the IBs and the reference buildings.

However, the work-satisfaction and heath symptoms reveal something about the knowledge work, in Finland. The higher the status the greater the work-satisfaction, the smaller the number of health symptoms, the shorter the time which is spent in the personal workplace and the longer the time spent out of office. The working hours which need to be spent out of office concern especially the executives.

Despite the fact that office workers have more health symptoms in the IBs than in other types of offices the staff is not out of office on sick leave in the IBs more often than it is in the other types of offices. The female professionals are the only exception of this rule.

The reaction in the two buildings types is different among the professionals and the clerks. The diamond structure of the knowledge work organisation can explain this difference. The relatively heavy workload of the professionals in the IBs is a reason for a strong reaction in health symptoms among female professionals, who work in a knowledge work organisation. In the reference buildings, where the work organisation is not as typically of diamond structure as in the IBs, the workload is heavier among the clerks, and especially female clerks, who have health symptoms and take sick leaves. In the IBs the situation of the clerks is far better and they do not have health symptoms and do not take sick leaves, which is the case even among the male clerks in the reference buildings more often than in the IBs.

It has been found in social studies that female workers do not find their work environment best in male organisations, which might be a reason for the fact that health symptoms and sick leaves occur among female professionals more in the IBs than in the reference buildings, where there are less male supervisors than in the IBs.

As Korvajärvi and Lehto A.-M. have concluded, the fact that the gender equality plans remain unimplemented sometimes even in cases, when it is compulsory by law to have such plans, reflects the careless attitude towards the rights of women at work, about which Friberg (1990) has also spoken and which could be a source of extra stress among female office workers.

Although the clerical personnel gives the spaces lowest grades of all groups of workers, they do not so when the equipment is concerned. Even the high number of health symptoms among the clerical personnel does not make them evaluate the equipment poorly. Neither they dislike their equipment because of their poor work-satisfaction. The health symptoms are most obviously due to the heavy usage of the equipment than indicators of poor quality.

### 9.1.5 The Additional Indicators of the Intelligent Buildings Survey

If anything can be said on the basis of the small sample of the energy efficiency study and that of the indoor air quality measurements, it can be concluded:

- that although there is not enough evidence of the better energy efficiency of the IBs in comparison to the reference buildings, the energy saving potential of the use of the IB concept seems undoubted, and

- that the indoor air measurements are not speaking for the good implementation of the indoor air design criteria in the intelligent office buildings of the sample of the IBs Survey.

The additional indicators of the IBs Survey support the results of the post-occupancy study on the behalf of the indoor air quality. However, the results of the indoor air quality of these both studies do not support the final result of the IBs Survey, which was favourable to the quality in total of the IBs. Furthermore, there is no evidence of the better energy economy of the IBs either.

However, because of the quality differences and the energy consumption differences of the few buildings in this sample, it can be concluded that the potential for the good indoor air quality and good energy efficiency exists.

The study of the impact of ICT on the business travelling proves:

- that the majority of the office workers think that they have not experienced a possibility of diminishing business trips due to the use of ICT, and

- that there are the differences between the IBs and the reference buildings in the possibilities of using ICT instead of travelling, and in the IBs, workers more often report the diminishing effect.

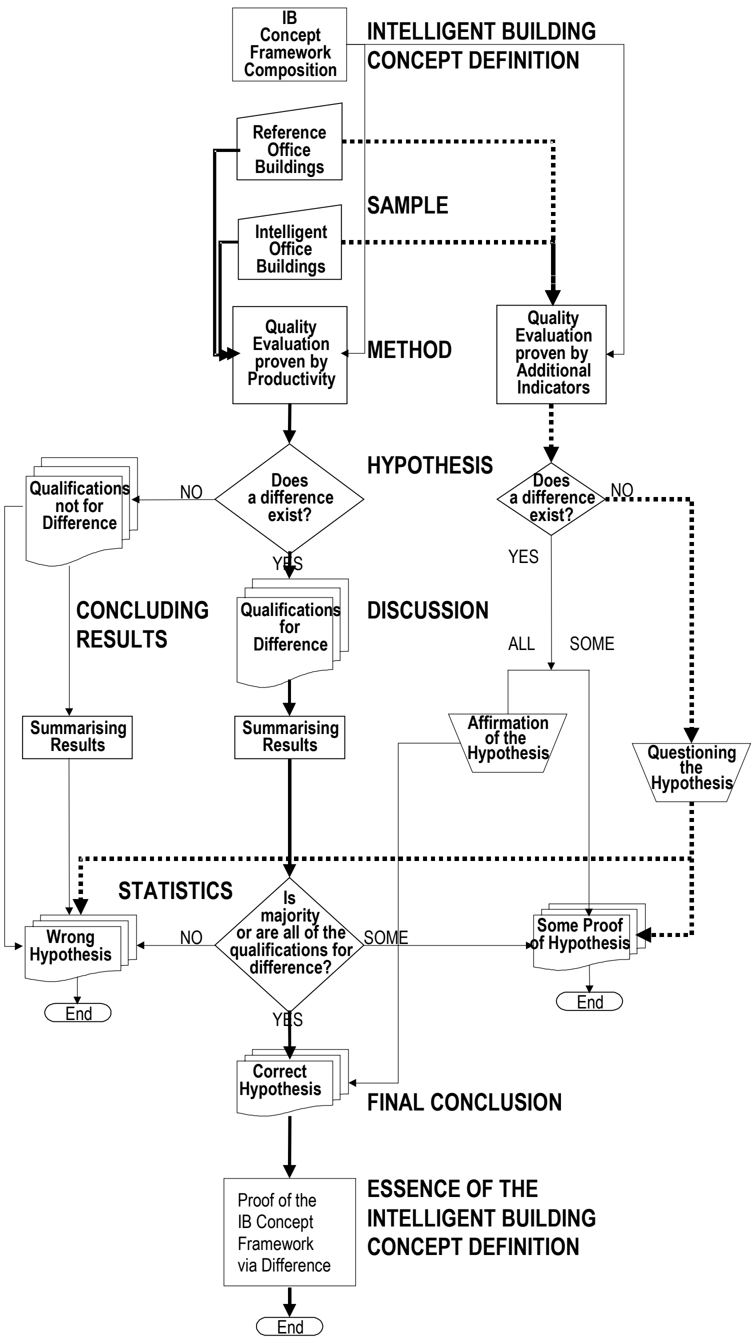


*Figure 52. The effect of the results of additional indicators to the result of the IBs Survey. The final result marked with bold and dash lines.*

It can be concluded that despite of the fact that the possibilities of diminishing the number of business trips by the use of the ICT are unused, the potential for this exists. It is also probable, that an invisible diminishing effect exists, because it is difficult to imagine the current volume of modern business life without the latest ICT. The study of the saving potential of the business trips supports the result of the IBs Survey, because the differences between two office building types are favourable to the IBs (cf. Figure 52.).

### 9.1.6 In Comparison to Design Criteria

Those features, which were especially targeted in the design of the studied buildings (Section 2.6) came true as shown in the Table 70.

*Table 70. The IB features of the studied buildings and their realisation according to the IBs Survey.*

| ENERGY SAVINGS. | POTENTIAL EXISTS. |
|---|---|
| Increase in office work productivity: | |
| – workers save time from unnecessary routines for creative work, | Unanalysed. |
| – need of interoffice everyday-life-related services, | Fulfilled partly. |
| – building is able to answer the future challenges of the end-user needs by flexibility and ability to change, | Fulfilled. |
| – the nature of the technical installations is service oriented, they are not in a dominant position, | Fulfilled as far as studied. |
| – the interoffice network does not limit the selection of the office equipment, and the freedom of interior design according to the desires of the end-users preferences, | Selection of the equipment not studied. Freedom of interior design not the best possible. |
| – the visible and functional part of the building intelligence is able to take into account the requirements of interaction and individualism. | The interaction is completed but all of the individual needs are not satisfied. |

| | |
|---|---|
| Decrease in building maintenance costs. | Not studied. |
| Increase in rental incomes. | True. |
| Increase in the return on capital of the investment. | True, not reported in this study. |
| Need of flexibility and changes:<br>– the future occupant is not always known during the design and construction,<br>– more seldom the same occupant uses the building during its whole life cycle,<br>– in addition to the changing occupants, the needs of the same occupant changes,<br>– the occupants do not necessary know their own needs,<br>– the occupant activities change,<br>– the office tools develop and regenerate, new innovations emerge. | These difficulties might be a reason for the lack of personal flexibility in the offices. Flexible enough for the needs of the occupant companies when there activities change or when they have to move. |
| The influence of human factors on the design of the IB features is taken account:<br>– a person is able to top performance repeatedly, if she or he has the possibility for full relaxation after the performance,<br>– different personal needs,<br>– the work efficiency and productivity is dependent of the possibility of keeping up connections, making new acquaintances and the possibility of stimulation and inspiration. | <br><br>Fulfilled partly.<br><br><br>Not fulfilled.<br>Fulfilled. |

## 9.2 The Building Intelligence Framework

It has been difficult to differentiate the IB concept as a concept of its own, because the IB concept definitions have included much information of the best construction practices. The BIF gives the possibility to identify the IBs by the building intelligence.

The building intelligence definition is a tool for further argumentation and empirical studies in order to increase knowledge of the IBs. It has in the first place a scientific purpose, whereas the IB concepts fulfil the technical purposes.

In this thesis the following statements of the building intelligence are made:

- The current intelligent buildings are dated to the information age, which is the time between the period of industrialism and the future wisdom age. The roots of the IBs are in industrialism, in other words in automation, which transformed the hand made artefacts into manufactured products.

- Intelligence is not the same as wisdom, the time of which in implementation of technology is still to come. It is still mostly tacit knowledge, if and how human wisdom will appear in the products of building industry.

- The intelligent buildings can be understood as an embodiment of tool creation by the human intelligence.

- The human intelligence has generated the IB concepts that enable an intelligent human being to act in its environment according to its capabilities and needs. The IB concepts are distinctions of various kinds of IBs. That has also been the purpose of several IB concepts, and in it they are very accurate. They do not separate the IBs from other types of buildings, because the IB concepts include parameters, which are also common to other types of building concepts.

- The process of clarifying the IB concept has not achieved the point where socially shared conceptual knowledge could be possible, although efforts to that direction have taken place in various parts of the world in the form of various IB concept definitions. The knowledge of the IB concept has been articulated in the form of the buildings, and the knowledge of it has thus become interpersonal and socially shared. However, it is not yet explicit enough for agreement on the universal definition to emerge.

- The intelligent building design has its own internal stock of knowledge, which has not yet emerged in the form of the explicit or verbal knowledge, but has emerged in the form of the building, that is, in the form of the tacit, focal and articulated.

- Despite of the fact that the internal knowledge is unknown in terms of conscious knowledge management, it becomes more conscious by the IB concept descriptions and the BI definition. The articulation of the knowledge of the IB concept in verbal form makes it explicit.

- For separating the intelligent building as a concept of its own, the copying of nature would be understood in such a way that the lending of the human knowledge to the building means more than integration, which so far has been a keyword in the IB concepts. The human intelligence is merged into the building rather in the form of embedded systems than integration. The word combinativity is suggested to be used for this type of integration.

- The end-user orientation does not identify intelligent buildings and other intelligent systems, although the factor of user orientation in the IB concepts can be considered as a weak signal of the desire to find the metaphor between human intelligence and building properties. Furthermore, the application of the results of the cognition science rather than usability are the key factors in the development of the intelligent buildings.

- The end-user is connected to the man-made objects ina way which is called connectivity. The user connectivity includes the user interface – a connection to human physiology which is made of an arm, a switch, a mouse, etc. This user connectivity can be broaden to include intellectuality, mentality and spirituality between man and machine in addition to human behaviour or psychology, which are included in usability.

- The human intelligence is merged into the building rather in the form of embedded systems than integration. The human skill causing the knowledge integration is the human logic. It is suggested to use the word combinativity for the embedding new knowledge into the building.

- Gardner's psychological paradigm of human intelligence corresponds to the building intelligence, which is based on the intelligent building concepts. It encourages deriving the essence of the IB concepts from the human intelligence defined by Gardner (Gardner 1983 in Dryden & Vos 1996, pp. 120–123, Gardner 1991 in Dryden & Vos 1996, pp. 345–352, Gardner 1993 in Tuomi 1999, pp. 107–110, Gardner (1993) in Dunderfelt 1998, p. 28) with the components of the BI as: 1) building connectivity (speaking and speech recognition including music and linguistics; user-connectivity and either personal, organisational or automatic control), 2) building self-recognition (building knows the state it is in, growing in consciousness), 3) spatiality (a more conscious understanding of the spatial expression of the architecture, structures, interior design), 4) building kinaesthetics (a sense of change, active structures, moveable structures, furniture and equipment, adjustable technology or building services), and 5) building logic (the embedded follow up of the occupants' daily activities, combinativity).

- The interplay between the stakedolders and the building is called the Building Intelligence Framework. The intelligence of the end-users or the object agents becomes a part of the BI via the feedback data bases used for the creation of new design criteria and through end-user participation in design. The human knowledge of designers, building owners, property managers, etc., that of the subject agents and the knowledge of technology have transformed into the IB. The building developers' and designers' and the experts' of facilities managers ability to understand, interpret and decode the end-user information into the design criteria form the user-connectivity between the user and the building.

- It can be claimed that an explicit universal concept of building intelligence is valid for a certain period, but the change of its essence seems inevitable.

- During the last three decades, it has become obvious that products come and go, and markets get reshaped, which is true especially for manufactured products. Therefore strategy cannot be based on outputs of the industrial system. It has to be based on the internal capabilities that make those outputs possible. The development of IB concepts and the IBs Survey as well as other post-occupancy studies are on the internal capabilities that make the IBs (outputs of construction industry) possible. The study of the definition of the BI and the BIF study knowledge-based competence of the IBs. The time for strategy researchers has come.

- The development of IB concepts and the even the definitions of the BI and the BIF are rather on the internal capabilities that make the IBs (outputs of construction industry) possible. The time for strategy researchers to study knowledge-based competence of the IBs is to come.

## 9.3 The Building Intelligence and Intelligent Buildings

My instinct has lead to trying both theoretical and empirical ways of understanding the intelligent building phenomenon. Within the empirical data there are some end-user responses, which may explain the theoretical analysis of the intelligence's role within the IB concepts. The role of the intelligence in the IB concepts is needed in order to understand how the information and knowledge will be formed in the end product, i.e. in the IB, and also in the design process of the IB.

### 9.3.1 Concept of ba

The concept of ba talks about the knowledge conversation modes. From the IBs point of view, the transformation of the tacit knowledge into explicit knowledge is interesting because of externalisation. In this thesis, the difference between intelligent buildings and buildings, which are not built according to the IB concept, is the same as externalisation. It is the proof of the existence of the IB concept, but it is also a proof of the existence of the building intelligence.

In this thesis the following statements of the building intelligence and the end-user evaluation results of the IBs Survey are made:

- According to the concept of ba, the combination of the human intelligence into a building can be considered as the combination, which converts a form of knowledge to another form of knowledge. This concerns rather the embedding of the intelligence to the building than integration of it to the building.

- The difference between the two compared office building types, proved by the IBs Survey, is in this case articulation of the different embodiments of the knowledge before the combination and after the combination. One is without the combined intelligence and the other one has the combination of building and intelligence.

- The IBs have been built according to the IB concepts, which do not include explicit information of building intelligence. However, on the basis of the differences between the end-user evaluation results of the two office building types it seem obvious that the knowledge of the building intelligence exists there, because the way how the IB concepts have been implemented in the IBs cannot explain all the differences of the end-user evaluation results. Evidence of the articulation of this tacit knowledge of the building intelligence in the IBs can be found from the quality in total of the equipment of the IBs, but also to some extent in that of the spaces, when the result of the end-user evaluation is compared to the building qualifications.

- It can be argued that the four forms of knowledge transformation of the concept of ba has no relevance only in the terms of current IB concepts but also in the terms of building intelligence. This is true, because it has been proved above that [1]the intelligent buildings can be understood as an embodiment of tool creation by the human intelligence and [2]the fact that IBs can become integrated parts of our thinking, and finally [3]we live off the human intelligence stored in the buildings as models of world, and guided scientific and philosophical thought. The role of the intelligence in the context of the building has relevance, when the combination can refer to rather to embedding than integration of conceptual knowledge.

- The end-user evaluation of the spatial parameters represents the mode of knowledge conversation, where the tacit knowledge changes into explicit, and thus it has relevance to the BIF, which is a verbal articulation of the building intelligence.

### 9.3.2 The Existence of Intelligent Buildings Measured by the Building Intelligence Framework

For the correspondence between factors of the IB concepts and the BI (Sections 7.3.4, 7.4.2 and Table 44.) all factors of the BIF are not studied within the IBs Survey. There is the correspondence between the differentiating parameters of the IBs Survey and the IB concepts (Section 7.3.3). Building self-recognition (the building knowing the state it is in, growing in consciousness) and spatiality (a more conscious understanding of the spatial expression of the architecture, structures, interior design) are factors of the BIF, which have no relation or they are very little related to the IBs Survey and any additional proof of the IB concept cannot be found on their basis.

In the IBs in the Helsinki metropolitan area such factors of the building intelligence as building connectivity, the building kinaesthetics and the building logic are explicit on the basis of the end-user response of the IBs Survey. The building self-recognition was measured with such parameters of the questionnaire of the IBs Survey as control and regulation (HVAC), office automation and the paperless office. Only the possibility of a paperless office turned out to show a weak signal of the differences between the IBs and the reference offices.

According to the result of the IBs Survey:

$$BIF_{IBs\ of\ the\ IBs\ Survey} = f\,(z_{12}\ ,\ z_{17,}\, z_{4}\ ,\ z_{5}\ ,\ z_{14}\ ,\ z_{20},\ z_{2},\ z_{21},\ z_{23})\ or$$

$$The\ explicit\ BIF_{IBs\ of\ the\ IBs\ Survey} = f\,(bi_{1},\ bi_{3},,\ bi_{5}).$$

The building self-recognition and the spatiality are tacit in the studied IBs or the IBs Survey could not recognise them.

Three factors out of five of the BIF have been studied to certain extent in the IBs Survey, although it is not by any means a study of the feasibility of the building intelligence. It can be concluded that these three factors are favourable to the result of this thesis on the existence of the IB concept application of the IBs surveyed within the IBs Survey.

The building intelligence enables to select a high quality or set of spatial factors, systems and equipment for the building. The role of the building intelligence is to perform as a system, which will meet all of the principal needs of the various end-users.

*Table 71. The correspondence between factors of the intelligent building concepts and those of the Building Intelligence Framework.*

| BIF | RELEVANCE | IB CONCEPTS |
|---|---|---|
| ($bi_1$) Building connectivity (speaking and speech recognition including music and linguistics; user-connectivity and either personal, organisational or automatic control) | ?<br> | culture ($z_{12}$)<br>interaction ($z_{17}$) |
| ($bi_2$) Building self-recognition (building knows the state it is in, growing in consciousness) | | information intensity ($z_{16}$) |
| ($bi_3$) Spatiality (a more conscious understanding of the spatial expression of the architecture, structures, interior design) | | |
| ($bi_4$) Building kinaesthetics (a sense of change, active structures, moveable structures, furniture and equipment, adjustable technology or building services) | <br><br>? | space flexibility and utilisation ($z_4$)<br>movable space elements and equipment ($z_5$)<br>long term flexibility ($z_{14}$)<br>adaptability ($z_{20}$) |
| ($bi_5$) Building logic (the embedded follow up of the occupants' daily activities, combinativity) | <br>?<br>? | level of integration ($z_2$)<br>reliability (stabile and accurate) ($z_{21}$)<br>correctness of basic technical solutions ($z_{23}$) |

≡ has an influence on the difference between the IBs and the reference buildings; ≡ has no influence on the difference between the IBs and the reference buildings; ? ≡ not studied.

The quality evaluation of the system is dependent on the use of several high quality subsystems simultaneously. The existence of one subsystem is no guarantee for good quality. The end-user can adapt to and experience some unsatisfactory factors in the working environment, but if there are too many the building quality becomes poor. Ultimately, the successful use of IB concept is based on the several successful subsystems and the prevention of several false or inoperable subsystems for the end-user.

The IBs Survey also shows that the building quality is also dependent on both the way in which the intelligent overall system has been put together, and the quality of each subsystem or the system components' quality.

### 9.3.3 Need for Intelligent Building Concepts and the Building Intelligence Framework

The BIF will have no use, if it is not implemented in practise, because the building processes are constant and they are based on a developing internal stock of knowledge of construction and buildings, despite of whether the knowledge of the building concepts is or is not converted to explicit knowledge.

The need for explicit knowledge is the engine for the clarifying process of the IB concepts. It can be parallel to the interest in the strategic thinking of the utilisation and development of internal stocks of knowledge. The IB concept means to make the tacit knowledge work in the designers' conscious minds, i.e. to make it work in the form of explicit knowledge, in the form of communication spoken, written, drawn, filmed, etc. This is done also, because conscious ideas are more understandable in thinking and thus can be submitted to scientific examination.

The author does not suggest focusing only on the intelligence in the construction of IBs. On the contrary, the holistic multidimensional approach to the construction is needed in any case of a building project. Each project benefits from the wide variety of solutions according to the needs of the stakeholders. It will not be discussed further within this thesis, but the author would like to mention, that the self-consciousness or self-knowledge of the stakeholder is an important key to a successful building project. It is not enough to be aware of the tacit knowledge of the construction expertise only in the connection of the IBs, but also the tacit knowledge of all the stakeholders involved, their experience, targets, activities and needs. This is an important, usually rejected factor in decision making.

The task of the construction field is to adopt and integrate or merge the ICT to the building in such a manner that the end-user can use her or his intelligence (cognition, senses, feelings, etc.) in accordance with the building intelligence. Furthermore, this embedding will follow from the creation of the building intelligence independently, without focusing only on the adoption of the knowledge of the ICT. Building intelligence becomes from the emerging of the human intelligence in the building just as the intelligent information and communication becomes from the emerging of the human intelligence in the ICT. The IB is not the same as the adoption of the ICT into a building. Building intelligence can be very similar to the ICT intelligence, and they both can follow same tacit or focal knowledge, but the articulation of the intelligence of those two will be totally different, while the ICT consists of bites, micro-ships, etc. and the building of bricks, steel, glass, etc.

# 10. Conclusions

In the literature several descriptions of the intelligent building (IB) concepts can be found. A certain set of the factors of the IB concepts have been studied in twelve office buildings in the Helsinki metropolitan area in order to conclude, if the IBs differ from the other high quality buildings in quality, and which of the factors of the IB concepts are influencing the difference.

Furthermore, the essence of the intelligence behind the IBs has been studied and the Building Intelligence (BI) has been defined with the Building Intelligence Framework (BIF). The BIF is the interplay between the built environment in the intelligent buildings and the human intelligence. The BI is the definition of the intelligence of buildings, which makes the buildings fulfil the requirements, which have set for the IBs by the IB concepts. The correlation between the factors of the IB concepts and the forms of the defined BI has been examined.

## 10.1 The Existence of the Intelligent Office Buildings in the Helsinki Metropolitan Area

The existence of the use of IB concept in the office buildings in the Helsinki metropolitan area was studied by comparing the quality of two office building types; intelligent and other high quality office buildings as reference buildings. According to the building end-user evaluation carried out for this doctoral thesis the intelligent office buildings are better in quality than reference buildings. Those who work in the studied offices have been the evaluators. The efficacy in terms of the end-users' working efficiency in the IBs is higher than in the reference buildings. The factors of status of the worker and gender affect the end-user evaluation of the buildings and the workspace – the spatial needs and requirements of equipment of the knowledge working environment. The information of the status of the worker and gender give valuable information also on the office workplace in general.

The dependency of the differences between the intelligent and reference buildings on such human and organisational factors as the status of the worker and gender speak for the user need orientation of the office buildings. In other words, various office buildings, intelligent ones or those built according to other building concepts are needed for different user groups, and thus for different type of work.

The intelligent buildings are better in terms of the space and the technology as a whole, when summarising all the spatial and technical factors. If the factors of the building quality are examined separately then in some cases the intelligent buildings are better in quality than reference buildings, but in some cases reference buildings can turn out to be better. It requires a very sensitive analysis to be made in the future to reach a thorough outcome of the yield of the IBs Survey which can serve as data for further analysis.

The IBs Survey examined the office buildings on the behalf of the following factors of the IB concept found from the literature of the IBs: end-user need orientation, level of integration, space flexibility and utilisation, movable space elements and equipment, comfort, convenience, working efficiency, image of high technology, and information intensity, interaction, service-orientation, ability of promoting health (therapeutic), adaptability.

**Of these, the level of integration, space flexibility and utilisation, movable space elements and equipment, image of high technology, interaction and adaptability proved to have influence in the separation of the IBs from the reference buildings in the Helsinki metropolitan area. All of these factors turn out to be significantly, remarkable or to certain extent better in the IBs than in the reference buildings. The end-user need orientation and working efficiency were included in the research arrangement via the phrasing of questions in the questionnaire. The end-user evaluation of building properties' influence on the working efficiency of the office worker was asked.**

**The spatial quality of the IBs turns out to be good, which is due to the many spatial IB features of the office buildings. The spatial quality is evaluated particularly good on the behalf of the shared spaces. The quality of the equipment in the IBs is also better than in the reference buildings although the technical installations of the two building types do not differ very much. Accordingly, the difference is not as significant as it is in the case of spaces.**

On the basis of the IBs Survey the criteria for the use of the Intelligent Building term will be fulfilled best, if the building design is based on more than one of the elements of the IB concepts.

## 10.2 The Building Intelligence Framework

The IB concepts describe the IBs, but not the intelligence of the building. Using the scientific paradigms of human intelligence – such as the tendency of the human intelligence to produce or fabricate and the ability to lend intelligence to the building – as a first estimation have generated the metaphor between human and building intelligence can be defined on the basis of Gardner's psychological paradigm of human intelligence, which defines the intelligence of the IBs in accordance with the Gardner's classification of the human intelligence.

From the knowledge management theory has derived that the intelligent building design has an internal stock of knowledge, which has not yet – before the definition of the building intelligence – emerged in the form of explicit or verbal knowledge, but it has emerged in the form of the building, that is in the form of tacit, focal and articulated knowledge. Despite of the fact that the internal knowledge is unknown in the terms of conscious knowledge management, it becomes more conscious by the IB concept descriptions and the definition of the BI, and thus more comprehensible. The articulation of the knowledge of the IB concept in verbal form makes it explicit.

**The concept of Building Intelligence (BI) is originated from the human intelligence of subject agents – the professional stakeholders of building sector. The components of the existing IB concepts from the IB literature and the results derived from the end-user evaluation of the IBs Survey encourage deriving the essence of the building intelligence as the forms of the BI as: 1) building connectivity (speaking and speech recognition including music and linguistics; user-connectivity and either personal, organisational or automatic control), 2) building self-recognition (the building knowing the state it is in, growing in consciousness), 3) spatiality (a more conscious understanding of the spatial expression of the architecture, structures, interior design), 4) building kinaesthetics (a sense of change, active structures, moveable structures, furniture and equipment, adjustable**

**technology or building services), and [5] building logic (the embedded follow up of the occupants' daily activities, combinativity).**

**The BI has been defined with the Building Intelligence Framework (BIF). The interplay between the stakedolders and the building is called the Building Intelligence Framework. The intelligence of the end-users or the object agents becomes a part of the BI via the feedback data bases used for the creation of new design criteria and through end-user participation in design. The human knowledge of designers, building owners, property managers, etc., that of the subject agents and the knowledge of technology have transformed into the IB. The building developers' and designers' and the experts' of facilities managers ability to understand, interpret and decode the end-user information into the design criteria form the user-connectivity between the user and the building.**

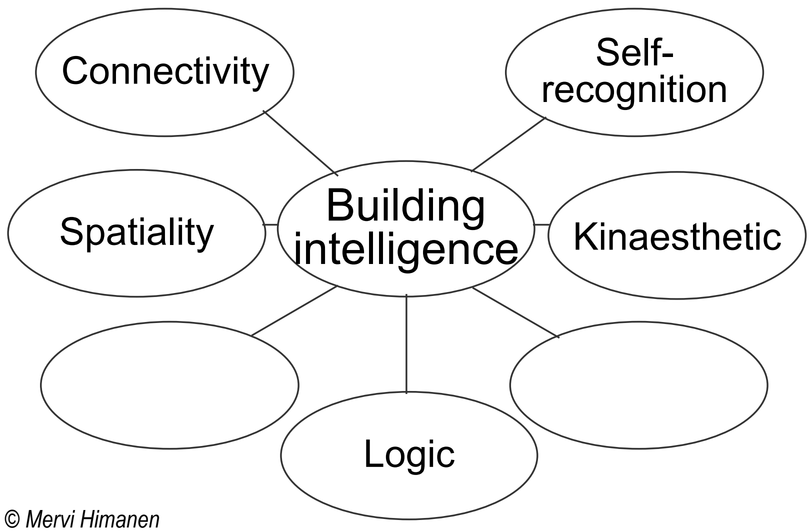


*Figure 53. The forms of the BI.*

The clarification of the IB concept is not achieved to the point where the socially shared conceptual knowledge could be possible. The knowledge of the IB concept has been articulated in the form of the buildings, and the knowledge of it has thus become interpersonal and socially shared. However, it is not yet explicit enough for agreement of the universal definition.

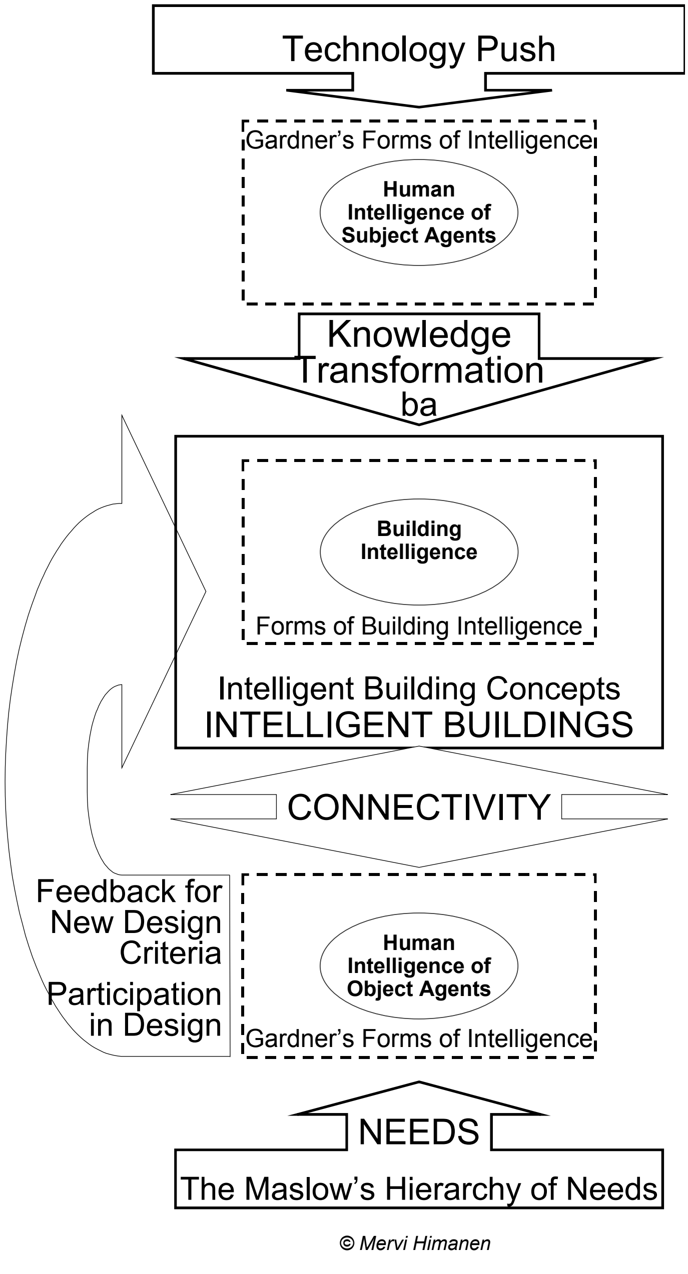


*Figure 54. The BIF is the interplay between the built environment in the intelligent buildings and the human intelligence of both the object agents – the end-users – and the subject agents – the professional stakeholders of building.*

The intelligence of the building as defined by the BIF is the first attempt to define a verbally explicit expression of the building intelligence, which so far has been in the form of tacit knowledge or in the form of knowledge articulated by the man-made product – the building.

**Any explicit universal concept of building intelligence is valid for a certain period, and inevitably that concerns the BI and the BIF as well. The intelligence of the building will change according to the change in human intelligence. The forms of knowledge or intelligence change, but the metaphor between the human and building intelligence remains, because objects symbolise the tendency of the human intelligence to fabrication, hence the intelligent buildings can be understood to be the embodiment of the creating force or a model of the world of the human intelligence. As far as buildings exist, we live off the human intelligence built and stored to the building.**

## 10.3 The Intelligence of Intelligent Buildings

The BIF defines the intelligence of buildings on a more general level than the results of the IBs Survey. The metaphor between the building intelligence and human intelligence and knowledge management is the basic hypothesis of the BIF, which has been, however, partly proved by the results of the IBs Survey.

The difference between the two compared office building types, proved by the IBs Survey, is in this case an articulation of the different embodiments of the knowledge before the combination and after the combination. Ones – the reference buildings – are without the combined intelligence and the others – the IBs – have got the combination of building and intelligence.

The IBs have been built according to the IB concepts, which do not include defined explicit information of building intelligence, but the correlation between the factors of the IB concepts and the BI can be found. The forms of BI are related to the factors of the IB concepts as follows: *building connectivity* is related to culture and interaction; *building self-recognition* is related to information intensity; *building kinaesthetics* to space flexibility and utilisation, movable space elements and equipment to long term flexibility and adaptability;

*building logic* is related to level of integration, reliability (stabile sand accurate) and correctness of basic technical solutions. *The spatiality* has no articulation among the IB concepts.

The IB concepts cannot explain all the differences between the two office building types. The building itself is an articulation of the building intelligence, and this is tacit knowledge by nature. The end-user evaluation articulates also such intelligent building features, which have not been defined or described by the IB concepts. For example, the end-user evaluation results of the quality in total of the spaces and the equipment of the studied buildings are an articulation of the building intelligence. The end-user evaluation of the spatial parameters represents the mode of knowledge conversation, where the tacit knowledge changes into explicit, and thus the BIF has relevance as a new verbal articulation of the building intelligence.

On the basis of the differences between the end-user evaluation results of the two office building types the explicit building intelligence exists there in the forms of building connectivity, building kinaesthetics and building logic, and the tacit one in the forms of building self-recognition and spatiality.

The end-users are in need of knowledge how the intelligent buildings serve them. The knowledge transformation from tacit to explicit is needed not only among the professional operators or stakeholders of building sector but the knowledge of intelligent building should be shared with the end-users and occupant organisations. Such means as education, user manuals or presence of the building managers could help in taking advantage of the new technology and spatial solutions. The good connectivity between the building and the end-user and well operating facilities management will most probably be of good advantage for office working environment.

The possibility to influence to and control on the physical working environment is important. A system of end-user feedback in construction could be useful. It could be the source of new design criteria. The success is often obtained via corrections of mistakes and the data gathering of the end-user feedback needs the understanding of this fact of life in construction. Courage in facing the feedback as soon as possible counts. It has to be faced anyways, sooner or later, after the building is in use.

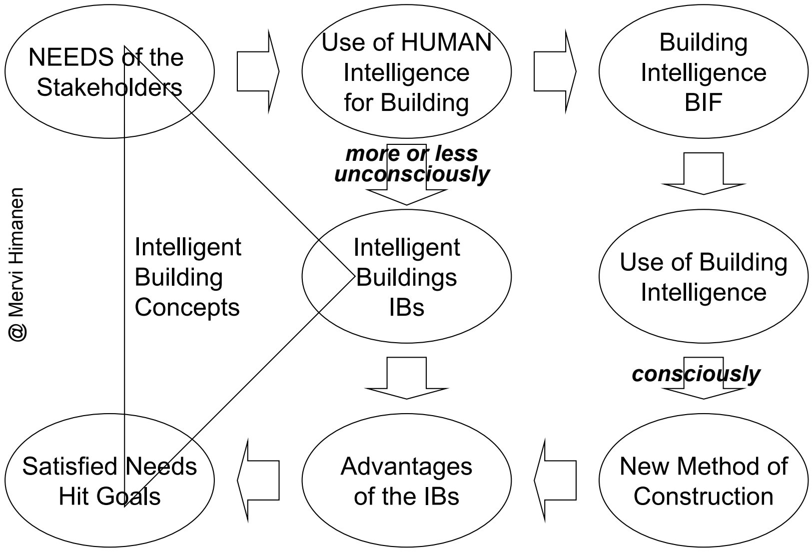


*Figure 55. The definition BIF makes the knowledge of intelligent buildings explicit.*

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# The Intelligence of Intelligent Buildings

## The Feasibility of the Intelligent Building Consept in Office Buildings

Abstract

Building of the IBs (Intelligent Buildings) is based on the IB concepts, which are very accurately defined for the practical purposes. The lack of universal definition of intelligent building has encouraged to study the knowledge-based systems for the definition of building intelligence. The BI (Building Intelligence) turned out to be a function of human intelligence, which the building professionals lend to the building through knowledge transformation. The forms of the BI are: building connectivity, building self-recognition, spatiality, building kinaesthetics and building logic.

The BIF (Building Intelligence Framework) describes the interplay between the building stakeholders and the building intelligence. In this interplay the focus is in the human-building connectivity, which is defined also in the thesis. Also end-users lend their intelligence to the building if they have the opportunity to give feedback of the design or the building.

The definition of the BI is done on the grounds of the IBs Survey, which is comparing five IBs and seven reference buildings in the Helsinki metropolitan area with a questionnaire of 417 parameters, to which was got 534 responses. The difference of the two building types proves the existence of the successful implementation of the IB concepts in the office buildings. The office workers' productivity has been the measurement of the building efficacy. Rich result of the quality of knowledge work environment and the end-user requirements of it have been gained. The end-user requirements of knowledge work environment do not differ only on the basis of the quality of technology and spaces, but the working environment design should offer different solutions according to the status of the worker and it should be different for women and men.

Keywords
intelligent buildings, building intelligence, office buildings, building concepts, integrated facilities management, ICT, working environment, workspace, information society, office automation, quality, post-occupancy study, user connectivity, building connectivity, building self-recognition, spatiality, building kinaesthetics, building logic, combinativity, building automation, indoor air, energy efficiency, business travelling, smart buildings

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