Smart Homes and User Values -

Long-term evaluation of IT-services in Residential and Single Family Dwellings

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Greger Sandström

In December 2009

ABSTRACT

Do residents find value in smart home functions? How should these functions be designed to offer user benefit? These were the governing questions of this study that involved nearly 200 families in three different housing projects during five years of occupancy. The housing units were equipped with advanced smart homes solutions, electronic and digital devices to control them, and a set of functions to increase comfort, safety and security in the homes.

The evaluations of the residents' use and benefits were accomplished in two different phases, i) evaluation of the user expectations' before and direct after occupancy and ii) long-term experiences after 3-5 years. A third phase of the study represents a radical shift in view. Issues related to innovation and organisation of service delivery were brought into the fore.

The research is founded on the multiple case-based methodology. Literature studies were effected. Data acquisition was based on interviews and questionnaires. Theoretical models from different research areas were used in order to analyse observations and to arrive to grounded conclusions.

Important conclusions include the fact that smart home functionalities must be developed as close as possible out of the users' genuine needs as experienced in their daily lives. Failure to attain accessibility to a certain function will cause disappointment and will be forsaken. To gain and over time preserve the user's trust in smart home functions or in a system as a whole is conclusive for their use. Another conclusion is that a viable business model for smart homes must include the occupancy phase. Surveillance and maintenance of smart home systems must be secured over time. It is argued that the failure of establishing a viable long-term service to homes to the benefit to the user depends highly on the market's ability to supply the homes with appropriate services over time. Possible ways to mediate revealed shortcomings are outlined and what role and responsibility the housing construction industry has to consider with the further development of smart homes.

Keywords: *accessibility, developer, dwelling, construction process, evaluation, home, housing, information technology, intelligent building, long-term, model, post-occupancy evaluation, resident, service delivery, smart home, trust, usability, usefulness, user, user evaluation, user experience, user value*

APPENDED PAPERS

This thesis is based on the following five appended papers.

Paper i) Sandström, G., Werner, I. B. and Keijer, U. (2003). Smart Homes Evaluated. *Open House International*, Vol. 28, No. 4.

Paper ii) Sandström, G., Gustavsson, S., Lundberg, S., Keijer, U. and Junestrand, S. (2005). *Long-term Viability of Smart Home Systems – Business Modelling and Conceptual Requirements on Technology*. Proceedings of the Home-Oriented Informatics and Telematics (HOIT) 2005 Conference, York University, UK, April 13-15, 2005.

Paper iii) Sandström, G. and Keijer, U. (2007). Integrated Systems in Single-Family Houses – An Incomplete Innovation. In Sandström, G. and Keijer, U. (eds.) *Smart Homes and User Values.* The Urban International Press, Gateshead, UK.

Paper iv) Sandström, G. and Keijer, U. (2007). User Values of Smart Home Functions in Residential Living. In Sandström, G. and Keijer, U. (eds.) *Smart Homes and User Values.* The Urban International Press, Gateshead, UK.

Paper v) Sandström, G. and Keijer, U. (2009). Smart Home Systems – Accessibility and Trust. Accepted for publication in *Open House International.*

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1 INTRODUCTION

This opening chapter begins with some points of departure and offers an overview and background to the Smart home concept, which is the central theme of the presented study. Summaries of appended papers are presented. The structure of the thesis is outlined.

1.1 THE HOME AS A STUDY OBJECT

Architecture as a discipline is about design, chiefly design of artefacts composed of spaces, starting from a general understanding of what to achieve with a multitudes of possible solutions, by an ordered process successively reducing a large number of degrees of freedom, and ultimately ending up with a viable solution, while during the whole process preserving some governing design idea. It is natural that architectural research applies a similar approach: i.e. formulation of some relevant question, establishment of a research site or artefact, and by some convenient method carrying out the planned investigation, compiling the results and making conclusions. In the end the posed question may be answered. A topical example of this approach in the research field to which the present study belongs was carried out by the architect Stefan Junestrand (2004). The subtitle of his thesis was *An architectural perspective on video mediated communication in smart homes*. Here the researcher had the opportunity to occupy a three-piece flat and equip it with a variety of IT devices and further to decorate it as a home-like space in order to study human behaviour using the equipment in this particular environment.

Architecture is a broad discipline, though, and, consequently, so is architectural research. Beside the design of buildings and other structures and urban planning, the research discipline spans a vast domain from architectural theory and philosophy to technically oriented issues related to spaces and use of spaces (Ekholm[1], 1987; Mo, 2003). In Sweden there is a long tradition of studying the functioning of spaces, not least the functioning of homes, which goes back to the break-through of modernism in the late 1920s and the beginning of the 1930s. Later from 1950s and on, this led to more precise studies of how homes are actually used and how spaces and various domestic equipment are deployed and utilised, e.g. Boalt and Holm[2] (1966), Cronberg and Sangregorio[3] (1979) and Cronberg[4] (1987). The present thesis should be regarded as a contribution to this latter area of architectural research, however with a specific contemporary point of departure in mind.

A new forceful artefact, which could be labelled *Smart home functionalities*, is now about to be introduced into our homes influencing our daily living. Many attempts to design and try out new devices and systems in homes or home-like setting have been initiated in Sweden and elsewhere. However, most if not all published research relate to special housing for disabled or elderly people who cannot remain in their ordinary homes due to physical or cognitive frailty (Sandström and Keijer, 2007). Similar devices and systems were applied to make it easier for the elderly to stay longer in their homes, so as to postpone, at least for a while, the need for relocation (Keijer[5], 2007). As yet however, studies on use and acceptance of smart homes functionalities by ordinary families in ordinary housing seem to be generally lacking, apart from occasional studies of particular individual homes.

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[1] In Swedish.
[2] In Swedish.
[3] In Swedish.
[4] In Danish.
[5] In Swedish.

Three unique large development projects in Stockholm were launched around the turn of the millennium. Considerable amount of smart functionalities were introduced into the homes, preceded by serious requirement specifications based on a close analysis of user needs. The technical development was backed by major Swedish industrial enterprises. The research presented in this thesis is based on the abovementioned prerequisites as the starting point and it took this unique opportunity to investigate the users' perspective of living in smart homes with their expectations and revealed experiences compiled over several years.

1.2 THE SMART HOME CONCEPT

1.2.1 The home as a place for development

The home, as we know it, has developed over centuries. Now and then at certain times major novelties were introduced to the home, principally depending on new technology break-troughs finding their applications also in homes. Radical changes cover such diverse things as the introduction of fixed fireplaces and, later, stoves, water faucets and toilets, central heating, electricity, from start providing light and improved cooking facilities, later facilitated the introduction of broadcasting, television and much more in the latter part of the 20th century. Another major step was the telephone connection to most homes, which spread quickly when it once started more than a hundred years ago. The development in Sweden was roughly in parallel with other countries in Europe and the USA, and in some areas, e.g. the telephone network development, well ahead of most other countries. The examples display that the home develops over time both as a structure in its own right, and as a service provider to its inhabitants.

The *Smart home*[6] concept represents an important step in this evolution, emanating from the all permeating information and communications technologies, ICT. In this thesis ICT will generally be named Information Technology, abbreviated IT. This evolution was and still is driven by the rapid progress in the IT field. The smart home as a concept has been around for more than 30 years. It is nevertheless fair to say that it has not, so far, taken off commercially on a wider basis, in spite of many optimistic forecasts over the years. Here smart homes will be spelled with lower case initial letters.

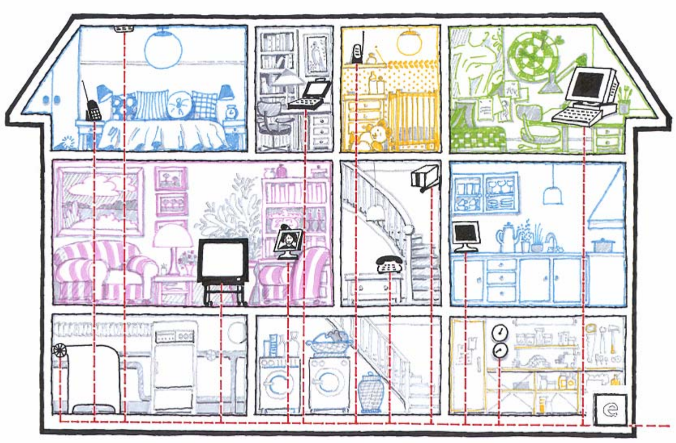

Figure 1. The vision of a connected home (e2-Home, unpublished).

[6] The term *Smart Home* is defined in appendix 1.

In the early 1990s *Information highways* such as the Internet (wired and wireless communication) emerged and enlarged the perspective for added value services to – and from – the home. The technological progress, and the increasing number of IT based products and services for the home, made it possible to imagine, promote and realise more *connected homes*. These homes offer an increased connectivity with the outside world through *home gateways*, and also within the home through *home networks* connecting a variety of home appliances and by that extending their functionality (Junestrand, 2004). Figure 1 depicts schematically a smart home, with sensors, appliances, connected communication devices and a central control system.

1.2.2 The intelligent building and the smart home

In the 1970s, big office buildings and other commercial establishments with electronic systems for controlling the operation of the facilities were introduced, predominantly in Japan, the UK and the USA (Abramson, 1995; Lindqvist[7], 1995). In the beginning they were labelled *intelligent buildings*. Monitoring security, alarms and the operation of energy consumption and HVAC (heating, ventilating and air conditioning) and similar functions were in focus. Large – and costly – real estate automation systems were offered on the market. Predominantly, they were aimed to decrease energy consumption and increase the efficiency of facilities management (Carlsson[8], 1987; Harrison, Loe and Read, 1998). Some early examples of technically advanced buildings were the TRON building (Lindqvist, 1995), Toshiba Headquarters and NTT Twins in Japan (Harrison et al., 1998), the HK Bank Building and the Lloyds Building in London, UK (Clements-Croome, 2004). Concurrently, especially in the USA, a similar development took place in the market of private homes, the *smart home* (Carlsson, 1987). In Europe and Japan the development in the home market emerged to a large extent from concerted actions by national and municipal authorities on the one side and the industry on the other. The development was mainly directed towards flats in multi-storey buildings. This was especially typical in France, where the notion *domotique*[9] (Ewerman[10], 1992) was introduced in the 1980s, but elsewhere as well, then usually named *intelligent house* or *intelligent home*. During the 1990s the token *smart homes* was generally adopted, together with other expressions like c*onnected home, home of the future*, etc., however, not always representing exactly the same concept.

In the end of the 1980s, the future market for smart homes was regarded to be immense. If the common technology standard issue once was solved, there would be, only in the USA, a market for 25 million households by the end of year 2000 (Carlsson, 1987). Several organisations addressed real estate automation at that time, aiming to create a common communication platform for real estate automation. Organisations like Echelon and EIBA (European Installation Bus Association) together with associations of suppliers of lighting, heating and ventilation control, passage- and alarm systems, surveillance programs etc. tried to bridge the traditional entrepreneurial boundaries. Many pilot projects were developed around the world. An overview of different technologies and communication standards for smart homes is given in appendix 4.

In the early 1990s the development for real estate applications of the IT was directed towards working life and office applications. Gradually, during the latter part of the decade, a refocusing took place. The market for smart homes was forecast to show a rapid growth in many countries. In Sweden, a multitude of projects with different aims and of different complexity was launched just before the turn of the millennium. Major actors in the field, the telecom and the household

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[7] In Swedish.
[8] In Swedish.
[9] Domotique (French) is a fusion of the words domus/***domo*** (Latin for home) and automa***tic***, i.e. Home Automation. The corresponding English word is domotics, however less frequently employed.
[10] In Swedish.

appliances industries, the construction and housing sectors, and many research institutions were involved in research and development of domestic application of the IT. However, the economic setback at the beginning of the 21st century hit the IT industry in particular, and at least temporarily weakened the activities in the field.

The development of the smart home concept, from 1980s and on, did not originate from an analysis or statement of wants or needs expressed by potential consumers. There was a strong element of "technology push" from the general development of IT and its application in most societal sectors. But, market considerations also made smart homes attractive to many firms and even motivated state support in some countries for the development. The enthusiasm was caused mainly by the fact that smart homes pointed to a new set of products that could win new markets. In the longer perspective, smart homes might bring producers to add value to a wide range of existing domestic technologies by incorporating new electronics into traditional appliances. Further, as soon as the smart home technology was established in the homes, prospects for other products, as yet unknown, were most likely to be developed which could take advantage of the new network infrastructure. If accepted by end users[11], smart homes could ultimately prove to be very profitable for a whole range of producers.

1.2.3 Swedish initiatives

An early pilot project with IT installations in homes was undertaken by Svenska Bostäder, a big housing company owned by the City of Stockholm, together with Ericsson and KTH in Vällingby (Hunhammar[12], 1998). In 1999 the housing company Poseidon in Gothenburg renovated a multi-family house, the "IT-house" (Hagström[13], 2000). The project was seen as a knowledge project and coined as the first upgraded house in the world (Kjellström[14], 2000). The upgrading referred to all new installed IT functions. Other municipality owned housing companies who joined the development were Markvärden in Gothenburg ("Bo ljust och smart i skogen", 2000)[15], Gavlegårdarna in Gävle (Höglund[16], 2000) and Marks Bostads in Skene (Gustafsson[17], 2001).

Two developers, JM and Selmer, the latter later acquired by Skanska, began 1999 to plan their own smart home projects. Three specific projects were launched, i.e. Vallgossen, Ringblomman and Smart Living[18]. At the same time the telecom company Ericsson and the household appliance company Electrolux initiated a joint-venture company called e2-Home, with the purpose to develop and market products and services for the smart home. e2-Home developed and installed the smart home system in both Vallgossen and Ringblomman[19].

1.2.4 How to define smart homes

Attempts were made during the 1980s and 1990s in order to define the smart home concept, e.g. Carlini (1988), Kroner (1988), Lustig (1995), van Berlo (1999), but no common definition was agreed. In 2007 the Smart Home Association in the Netherlands defined smart home technology

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[11] *End user* is defined in appendix 1.
[12] In Swedish.
[13] In Swedish.
[14] In Swedish.
[15] In English "Dwell smart in sunny forest".
[16] In Swedish.
[17] In Swedish.
[18] See chapter 2 for a more detailed description of these three projects.
[19] The history of e2-Home and the commitment of its parent companies is described in appendix 2.

as the integration of technology and services through home networking for a higher quality of living at home (Bierhoff, van Berlo, Abascal, Allen, Civit, Fellbaum, Kemppainen, Bitterman, Freitas and Kristiansson, 2007). Today the smart home concept encompasses all kinds of homes, single-family houses, residential housing and institutional living, e.g. for older persons and for people subject to rehabilitation.

The principal idea behind the smart home concept is to use networking technology to integrate appliances, devices, and services within the home in an effort to control and monitor the entire living space. In this thesis, the smart home concept is used in close connection to the specific system developed specifically for two of the studied housing projects. The system was marketed under the name Home Network. This commercial name must not be confused with an ordinary computer network. Although the homes were equipped with a broadband network, there were many other IT functions in the system that made the system unique compared to other ventures at the time. A detailed description of the Home Network is presented in section 2.2 and in appendix 2 and 3.

A concept close to the smart home is the *digital home*. Traditionally home entertainment was the domain of separate devices in the home such as TVs, DVD players and Hi-Fi/Stereos. Now, the digital home as a concept aims foremost at merging technologies for home entertainment, personal computers, networks and broadband into a seamless entity.

In this thesis the smart home concept is a collective term for information and communication technologies applied in a home, where the various components are communicating via some kind of local network. Typically, the smart home technology should allow for automatic communication with the surroundings of the home and its inhabitants, as well.

After all however, technology is not the end. It is often the beginning. The end is the user and his or her use and benefit of the technology. This is the main purpose and the theme of this thesis, i.e. "smart homes and user value". The term *user value* is not and could not be defined explicitly in advance. As will be seen, its meaning develops during the course of the thesis and is understood as an integrated construct encompassing technological solutions, systems and services related to users' needs, demands and desires when the users are at home or refer to their homes.

1.3 THE STRUCTURE OF THE THESIS

The thesis presents results from both pre- and post occupancy evaluations conducted with residents living in smart homes. The research objects were all located in or nearby Stockholm. Findings of success and failures from these studies were utilised for further investigations on organisational requirements for offering viable sustainable smart home facilities to the residents. The research was divided in three phases. The first phase treated the residents' expectations and first experiences of their smart home system. The second phase handled the residents' experiences after some years of use. Results from phase one and two showed that if smart home systems will offer user value in the longer perspective issues regarding maintenance and upgrading must be addressed. In the third phase the thesis makes a distinct turn and changes its view. Organisational aspects get in focus together with a deeper analysis from various points of view how to preserve over time user' values of their smart homes.

Chapter 1, Introduction, locates the work in an architectural context and further offers an express overview of the smart homes concept and its development over the last decades. It illustrates the evolution of the smart home concept and ends with workable definition of the concept. A structure of the thesis is given and summaries of appended papers are presented.

Chapter 2, First phase – Pre-occupancy and early post-occupancy[20] *studies* – starts with a discussion regarding general questions about smart homes and some specific questions and delimitations for the first phase. Essentially, this part of the thesis is based on work presented in an earlier licentiate thesis by the same author, Sandström[21] (2003).

The housing projects Vallgossen, Ringblomman and Smart Living are presented. It is followed by the theoretical framework and the choice of methods which then underpin the empirical studies of users' preferences before and after moving into their new smart homes flats. The chapter ends with chief findings and some conclusions. Implications for the second phase of the study are brought forward.

Chapter 3, Second phase – The long-term view – Now the flats have been occupied for two-three years. Some modified research questions are introduced and discussed, followed by a presentation of an additional study object. The applied methods and results from interviews and a postal survey are presented. The chapter ends with a summary of major findings and conclusions leading further on.

Chapter 4, Third phase – Smart home systems and long-term viability – introduces a radical change of view, based on the findings of the previous chapters, regarding the direction of the research. Organisational issues come into the fore. New questions are formulated. The adoption of new technology and innovations are put into the forefront, as well as the prerequisites for the building industry to take the responsibility for the development of smart homes as a component of their production range. The results are discussed in view of the introduced theoretical models.

Chapter 5, Discussion and Conclusions – discusses, i.a., the requirements on smart home systems and viable service delivery in a long term perspective to the benefit of the user in his or her home. Closing conclusions are made. Some ideas for further research are outlined.

1.4 SUMMARY OF APPENDED PAPERS

The appended papers are presented in chronological order in order to elucidate how the results added up during the course of the research. All papers are written with one or several co-authors. The co-authors contributions are limited to mainly methodological advice for the studies and the editorial reviews before submission. The author of this thesis planned and executed all empirical studies, carried out the subsequent analyses including the statistical parts of it, ploughed throw a variety of material of potential value for different phenomena encountered during the course of the study, and finally brought the work and its findings together in writing. This pertains to the individual papers as well as to the present thesis.

Paper i) Smart Homes Evaluated.

The paper describes a pre- and post occupancy evaluation of the smart home system in the Vallgossen project. The first turn of interviews was conducted before the residents moved into their new flats. The purpose was to investigate the respondents' expectations about the smart home system. The second interview study was conducted two months after the residents had moved in, with the purpose to review the respondents' early experiences with the smart home systems just taken into use.

[20] *Pre-occupancy* and *post-occupancy*, see appendix 1.
[21] In Swedish.

A typical conclusion was that installed functions in the smart home system either increased the residents' safety and security, saved time or added comfort were more appreciated than minor things offering little benefit. Further, it became clear that a user perspective was indispensable when designing the different smart home functions.

Paper ii) Long-term Viability of Smart Home Systems – Business Modelling and Conceptual Requirements on Technology.

Many parties are involved in a typical housing construction process, figure 2. The arrows indicate the direction of control. Only actors relevant for smart homes development are included. The responsibility for the proper function of the building rests with the developer with a two-years warranty. This period of time is based on a long tradition within the building industry. However, for complex structures, like smart home systems, such a limited warranty was considered insufficient and for the Vallgossen project, for example, the warranty period of the smart home system was extended over another three years. However, it became obvious that this extended warranty did not remedy the problem. In essence, it only postponed the problems for the residents a few years.

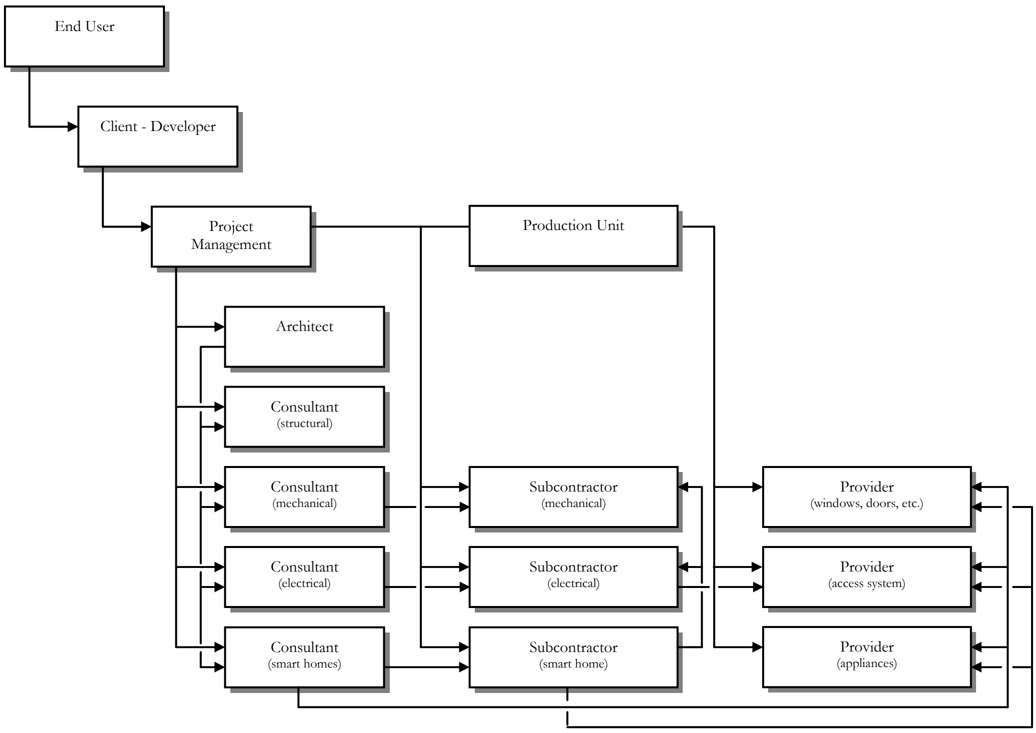

Figure 2. Co-ordination and dependencies in the construction process in Vallgossen.

The developer of the smart home system was the only economically strong body who had enough knowledge of the system, a fact which became very unfavourable. The running cost, also for minor changes of the functionality of the system, turned out to be high and prohibiting for the residents. Also the contracted regular maintenance required access to unique – and costly – competence.

In 2005 the system developer announced a replacement of the smart home system with a simpler one based on the Internet. Business models for the installed smart home systems should have included the occupancy phase, which to date were neglected. A crucial issue is who will and can assume the long-term responsibility for surveillance, maintenance, and added functionalities over time. Paper ii) discusses some principal questions and prerequisites regarding business viability in relationship to smart home systems, and its significance for business modelling.

Paper iii) Integrated Systems in Single-Family Houses – An Incomplete Innovation.
During the construction phase of a housing project issues regarding future maintenance and running cost are often disregarded in early stages, except perhaps energy conservation matters. Correspondingly, the long-term issues in Smart Living (one of the three studied cases of this thesis) were, by and large, neglected during the planning phase, including the important issue of maintenance of the smart home system. This paper discusses questions regarding the upkeep and upgrading of smart home systems, with the Smart Living project as an illustrative example. The different roles[22] during the construction process are mapped in figure 3.

The first interviews with residents in the Smart Living project were carried out in 2003. The purpose was to get a grip on how residents initially had conceived the technology and to what extent they had begun to use it. The second interview series followed in 2005. The purpose this time was to understand how the residents' behaviour with regard to the technology had changed over time and to discern possible emerging new habits.

The smart home system installed in the Smart Living project was found to be useful for the residents. It offered increased safety and comfort. This kind of technology requires a high degree of reliability, accessibility and availability as it is controlling vital functions in people's life at home, i.e. electricity, heating, water and the ability to lock and unlock the front doors.

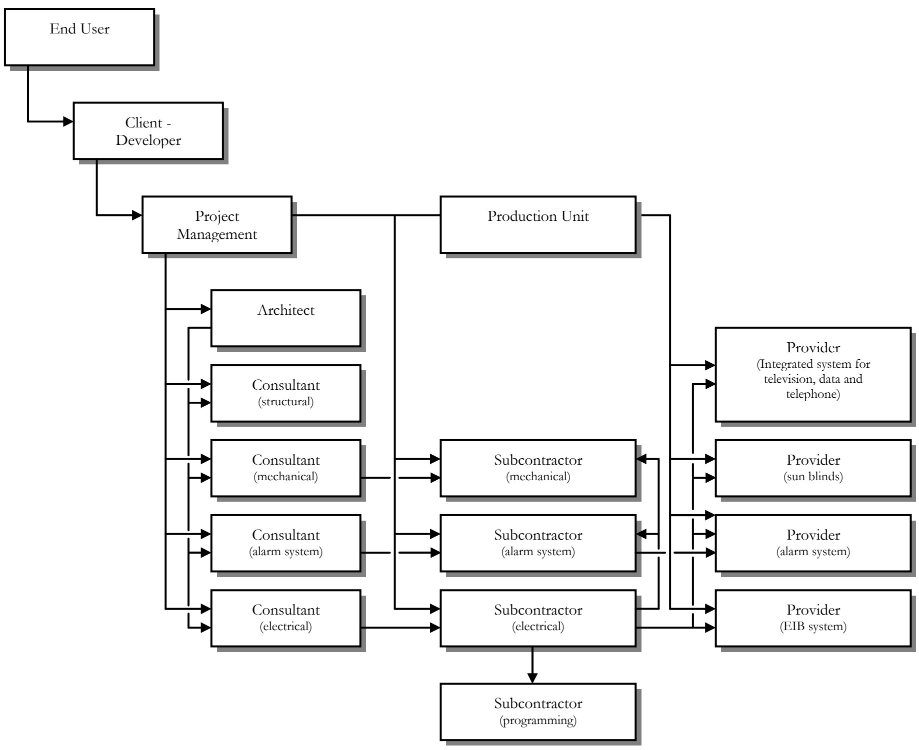

Figure 3. Co-ordination and dependencies in the construction process in Smart Living.

[22] *Role*, see appendix 1.

Malfunction is not accepted if the residents cannot obtain immediate help. It became obvious that two roles/actors are missing in the business structure, 1) a central operator, remotely taking care of the first-hand support of the smart home system, and 2) a local technical service provider, taking care of the second-hand support on site. As long as the residents cannot maintain the smart home system on their own, some combination of these two roles has to be fulfilled by market actors accessible to the residents.

Paper iv) User Values of Smart Home Functions in Residential Living.
A user benefit model is generally applied to evaluations of IT functions in the home environment, see figure 4. The model includes three central concepts, *usability*, *usefulness* and *accessibility*. Usability uncovers when a product is used. Usefulness characterises the ability of a product or a service to support the user in fulfilling a task or satisfying a need. Usefulness and usability are easily confused. A product or a service can be demanded by a user and appear useful to him or her at first sight. Still in practice it remains useless. It may depend on the fact that the user does not understand how he or she is supposed to use the function. It can also be out of order or not available when asked for; or rather the function is not accessible. Accessibility is supplementary to usability in order to attain usefulness.

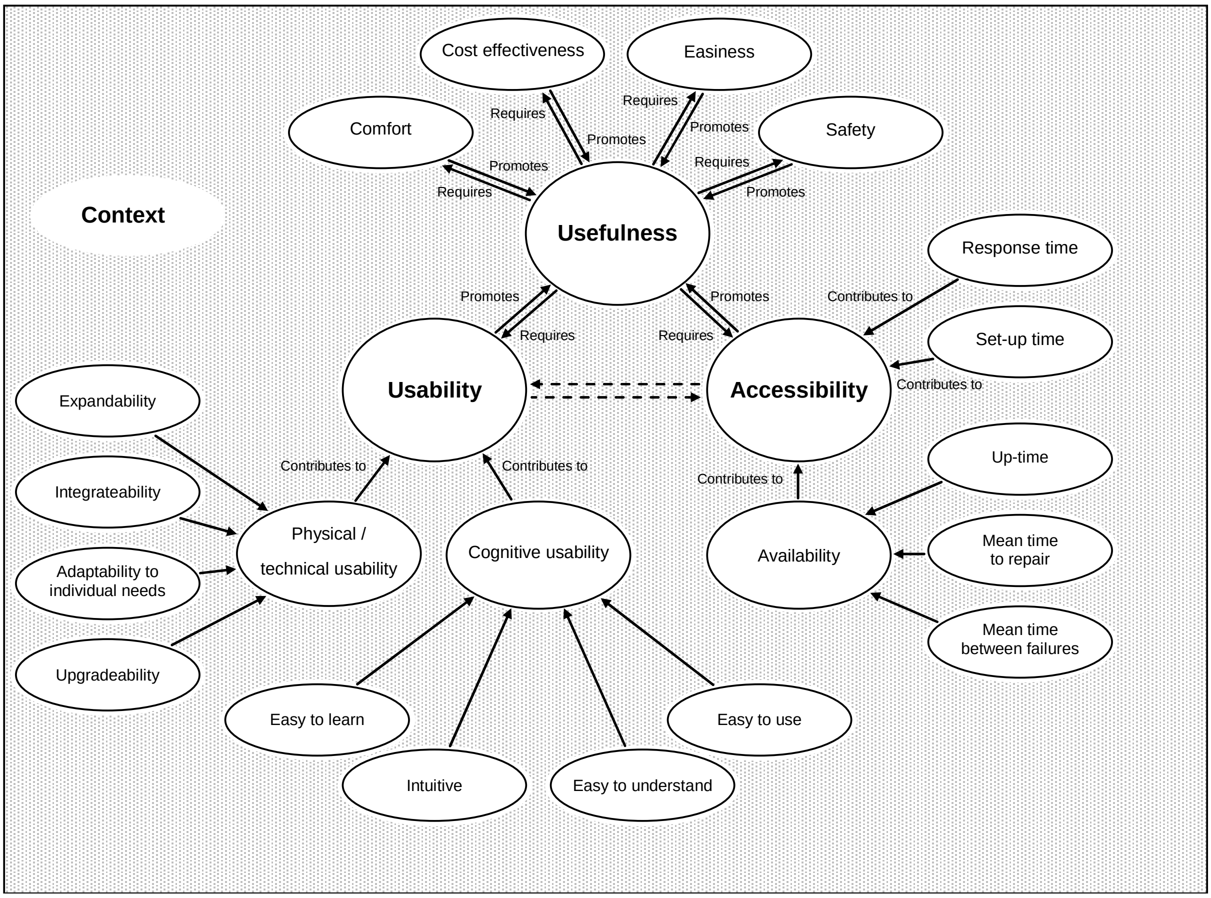

Figure 4. The Evaluation model – a mapping of the relationships between usefulness, usability and accessibility when evaluating smart home systems.

The empirical results are based on a series of interviews in Vallgossen and Ringblomman at two distinct occasions with an interval of about two and a half years. The evaluation monitored the residents' short-term and long-term use of the installed IT functions in their homes. Although the IT functions were not found to be a conclusive reason for buying a particular smart home flat, they still had a specific value for the residents. Functions contributing to increased safety and security (e.g. alarms) and to saving time (e.g. booking of common facilities) were the most appreciated functions.

However, the residents' revealed opinions showed the importance of the usability and accessibility in order to attain usefulness. It is not enough only to fulfil the users' demands or wishes expressed in terms of functions, equipment and services. The usefulness of the matter, in its full range, has to be considered.

Paper v) *Smart Home Systems – Accessibility and Trust.*
The paper explores the resident's attitudes towards and the acceptance of Smart Homes. The results are based on surveys to the residents in two housing units Vallgossen and Ringblomman equipped with advanced smart home systems, practically of the same kind.

The smart home systems installed in these two housing projects, totally 185 flats, were not installed elsewhere formerly. Tests of the system were performed only in laboratory settings prior to the site installations. As a consequence, not all possible faults and errors were detected in advance. The residents were to find them. Coping with a new and unstable technology is not the best environment for imposing trust between the user and the system.

Trust in information is an attitude directed toward a technological artefact. An integrated definition of trust recognises it as the union of three elements: 1) a *trustee* (the function) to whom (or to which) the trust is directed, 2) a *confidence* that the trust will be upheld, and 3) a *willingness to act* based on this confidence.

The results show that a system should function from an early point of time in order to gain and maintain trust and to be included in the daily routine as a regular service at home. Small differences in design of a smart home system, affecting accessibility and trust were shown to make large differences in usage. From a pure technical point of view most solutions function. But from the user's point of view also minor differences determine if a system will be used or not.

2 FIRST PHASE – PRE-OCCUPANCY AND EARLY POST OCCUPANCY STUDIES

The original research questions for the first phase of the study are introduced. The study objects are described followed by a presentation and analysis of three central concepts, viz. usability, usefulness and accessibility. The applied methodology and the accomplishment of the interviews with the residents-to-be of smart homes and their first few months of experience when using them are described. The results of the studies are presented and discussed.

2.1 BACKGROUND

During the 1990s, an increasing interest in *smart homes* became successively more apparent in different industrial sectors, among them the telecom sector, the household appliances and the housing industries. Optimistic prognoses indicated a new several million-dollar market only in Sweden. Also developers and real estate enterprises felt that they, too, had a role to play in the race. Buzzwords like "future living" and "connected homes" were aired everywhere. The developers' interest was based primarily on the assumption that homes equipped with the newest technology would be easier to market in the "dot.com" euphoria holding sway in the last years of the 20th century. The smart home technology would either be installed from the beginning in dedicated flats or offered as an option to potential customers according to their desires.

The real estate business operating housing units identified an option to lower their administrative costs by new technology and, in addition, to be able to let their flats more easily. At the time another argument was around, saying that a real estate company would earn increasing goodwill as an environmental-friendly enterprise by offering energy measurement on an individual basis on their premises.

As mentioned above, in 1999-2002 three specific housing projects equipped with a number of IT functions were developed in Stockholm, with all necessary characteristics for denoting them as smart homes. The projects were named Vallgossen, with in all 126 flats, Ringblomman, 59 flats, and Smart Living, the latter comprising six single-family detached houses. The governing idea was to offer the residents a secure and comfortable living by equipping their homes with smart functions. Typical IT based functions were alarm systems, individual measurement of energy consumption, lighting control, security camera at the front door, electronic keys, the opportunity to book common facilities, e.g. the common laundry room, and reception boxes.[23] Regarding scope and content these three projects were very similar; however, they differed slightly in design, a difference which turned out to be of significance for the conclusions drawn from the whole study.

The availability of the technology defined largely the selected IT functions of the three sites. At the time limited knowledge was available about the consumers' opinions and their perceived value of smart home functions. In order to gain further experience and knowledge about the potential residents' appreciation of different IT functions, a research project coined "Smart Homes – Buying Motives and User Values" was started (Sandström, 2003). The objective of the study was to evaluate and analyse user values of different technologies installed in real homes, what kind of technology the residents would like to have and what demands the residents put on IT solutions, their design and functionality.

[23] The projects and the installed smart home systems are explained in detail in section 2.2.

2.1.1 *Initial research questions*

Whose perspective?

Smart homes can be perceived from different points of view: that of the resident, the construction company, the housing company, or from the society's point of view. Many different aspects arise from society, taken in its widest meaning. Reducing the energy consumption in homes and buildings would decrease the influence on the environment (Miljövårdsberedningen[24,25], 2000; Boverket[26,27], 2002). Other opportunities are offered by telecommuting and interactive participation in public matters from your own home. Quick alarms on fires and burglaries in order to initiate swift action are other societal benefits, see further Vilhelmson and Thulin (2001) and Kring[28] (2003). Another topical issue related to smart home is the prospect that technology would enable old people to stay longer in their own homes postponing a move to residential care (Bowes and McColgan, 2007; Fisk, 2007).

From the resident's point of view, well designed functions in a smart home can offer an increased feeling of safety, lower costs for housing by reducing the energy consumption, and increase the quality of life by saving time or by being able to remain in one's home when sick or old. The application of this technology, at least in the short perspective, might result in problems for the resident. If the developed technology is inadequate it could make the home more complicated. Some people even fear the use of new technology in their home (Bierhoff and van Berlo, 2007).

Obviously, there is not only one single relevant actor. The resident, the construction company, the housing company and the society, all have important questions to formulate regarding smart homes. However, with the rapid progress on the housing market experienced during the last ten years, it seems most relevant to start from the resident's point of view. Ultimately, it is the resident who lives with and pays for the new technology.

For construction and housing companies, both working in a fiercely competitive market, it would be beneficial if they were able to offer homes equipped with services and products appreciated by most customers or tenants. If the technology allows them to offer their products at a competitive price, lower their vacancy and, at the same time, decrease their operating and maintenance costs their initial interest in smart homes is easy to understand. However, these statements were open at the time.

Governing questions

By putting the end user, the resident, in the forefront of the study, the discussion so far leads to the following governing questions of the first phase of the study:

- do residents find specific user values with smart homes functions?

- and if so, what demands do residents put on smart home functions regarding design and functionality?

[24] The Environmental Advisory Council.
[25] In Swedish.
[26] The National Board of Housing, Building and Planning.
[27] In Swedish.
[28] In Swedish.

2.1.2 Delimitations

The first phase of the study presented in this thesis examines 1) the individual residents' expectations on smart homes and their functions and 2) their early experiences of using these functions. No consideration will be paid to the effects from working with smart homes in the construction company, in the housing company or in the society in general.

Further, the research will not investigate what technology is to be preferred, nor what technology may be most favourably positioned for a commercial future.

Questions regarding the integrity of the individual and the "big brother society" will not be debated here. These issues, however, should not be disregarded in a wider context of smart homes.

The residents' willingness to pay for smart home systems and associated services was not examined in the study. The *willingness-to-pay* is of course an important question for the further development of the smart homes concept and its aptness for reaching the market; however, it requires another comprehensive treatment, which is out of scope of the present work.

2.2 RESEARCH OBJECTS

2.2.1 Vallgossen

The residential housing unit Vallgossen in Stockholm was constructed by JM. The development began in 1999 and production started in March 2000. In Vallgossen the architectural design and physical environment were accompanied with new smart home functions. The purpose was to offer all residents, regardless of age, desires and needs, a secure and comfortable living environment and a high quality of life.

Figure 5. The Vallgossen project.

The building block comprised 126 flats in total. On the ground floor there were small area-efficient flats while the upper floors had spacious, large terrace flats. The sizes varied from 44 m^2 to 144 m^2. The top floor included a few penthouses with an open floor layout and increased ceiling height. The building had a common laundry room, a guest room, a party room and a sauna. Material and equipment were chosen so as to correspond to a higher than average standard in this type of development.

The architect's aim was to design flats with a flavour of the future. Examples of this design were the frequent use of white colour and clean surfaces. No lintels or architrave's framed the windows. All flats had wooden cupboards in oak or birch and stainless appliances in the kitchen. The rooms were designed to facilitate cleaning, e.g. wall-mounted toilets, frontless bathtubs and folding radiators. The floors consisted of parquet, limestone and clinker.

IT equipment

The IT functions differed between the flats. All 126 flats were equipped with a set of basic functions of so called type #1 flats, while 21 flats had some additional, more advanced functions, type #2 flats. Two particular flats, of type #3, were provided with functions aiming at assisted living and rehabilitation for people suffering from acquired brain injury (stroke), see Sandström and Keijer (2003) and Boman (2008). After a two-year study period the type #3 flats were reconverted to type #2 ones and sold to ordinary customers. For the results from this specific investigation on the rehabilitation flats, the reader is referred to Boman (ibid.).

An important objective, when designing the IT functions in the flats, was to make their physical appearance as invisible as possible. Another objective was to make them user friendly[29]. The demand on the user to control the different IT functions of the flats was designed in order to be moderate. The user was not to be forced to manipulate the functions in order to get on well with her (or his) new habitation. She decided on her own how quickly she wanted to apply the smart home system and to apprehend the available IT functions.

The three main functions in type #1 flats were a 1) *the smart home system*[30], 2) *a laptop computer*, and 3) *a broadband connection*. A more detailed description of the functions of the smart home system is given in appendix 3. The laptop was used by the resident to surf on the Internet and to operate the functions of the smart home system. A cable system integrated computers and telephones at the user's will. An IT-cupboard located in the hall, accommodated the central unit and defined the border between the flat-internal and the external communication systems.

Figure 6. The laptop computer.

In order to increase the security in the building, all doors to the lobby and to other common spaces, e.g. the garage and the laundry room, were equipped with *electronic key locks*. Standard mechanical locks were provided for the front doors of the flats, though. An additional outside lock on the front door, the *away lock*, shut off gas and/or electricity to the stove, disconnected selected electrical outlets, reduced the bathroom ventilation (if the moist detector did not indicate a need for ventilation), and activated the burglar alarm. On return the functions were restored and the lamp in the hall was automatically turned on as a token of courtesy.

[29] The term *user friendly* was used by the construction company JM, however not applied in thesis.
[30] The smart home system was developed by e2-Home, a joint venture company between Ericsson and Electrolux. The reader is referred to appendix 2 for more information about e2-Home and its parent companies.

In the flats of type #2 three other functions were added, i.e. a *built in grid system for loud speakers*, a *security camera at the front door* and a *reception box*. A grid system was installed allowing loudspeakers in the living room, kitchen and bathroom without visible wiring. The security camera at the front door was meant to increase the residents' "feeling of safety" as the resident would be able to see and listen to the person calling from the lobby before opening the front door.

The reception box was placed next to the front door in the lobby and offered space for receiving goods, e.g. groceries and laundry, when not at home. The deliverer got a disposable key code in advance in order to deliver the goods directly to the building. On return, the resident opened the box with his own electronic key. Further description of the installed IT functions is found in paper iv), table 1.

2.2.2 Ringblomman

Ringblomman was developed by Skanska in the district of Södermalm in central Stockholm. The building consists of 59 flats and the first occupancies took place in February 2002. The concept in Ringblomman was to combine design and technology to create a functional and aesthetic living environment.

Figure 7. The Ringblomman project.

The building comprised five to eight floors in each stairwell. The sizes of the flats varied from 46 m^2 to 185 m^2. The top floor included a few penthouses with an open floor layout. The building had some common facilities i.e. a laundry room, a guest room and a sauna.

<u>IT equipment</u>

In Ringblomman all flats were provided with similar IT equipment as in Vallgossen: viz. a smart home system[31], a touch screen on the wall to control it, a computer (to surf on the Internet), a broadband connection, reception boxes, electronic keys and an integrated system for connecting computers and telephones. The central control unit of each flat was located in a wardrobe. A detailed description of the functions of the smart home system and its user interface is found in appendix 3.

Largely, the functions in Ringblomman were the same as in Vallgossen; with a few significant differences. To control the smart home system the residents in Ringblomman had a touch screen on the wall, permanently connected to the smart home system; cf. Vallgossen, where the connection to the system had to be established before use.

[31] Developed by e2-Home, a joint venture company between Ericsson and Electrolux. See appendix 2.

Figure 8. The touch screen.

The resident could control the temperatures in each room separately and set varying temperatures during the day. Similarly, the different outlets could be activated/deactivated at any time according to the resident's choice.

All doors of the residential building, e.g. to the flats, to the lobby, and to common spaces, were equipped with electronic key locks. In addition, the flats were provided with an away lock controlled via the electronic key lock. With the away lock the power to the stove was shut off, the burglar alarm was activated, the outlets in the flat were switched on or off dependent on the pre-chosen scenario. A detailed description of the IT functions in Ringblomman is found in paper iv), table 1.

2.2.3 Smart Living

In the Hagaberg area, some 20 km from downtown Stockholm, JM developed six single-family detached homes. The first one was completed in September 2000 and was used for demonstration. The first families moved in during November/December 2001. The project was given a lot of attention, nationally (Berglund[32], 2000; Erlandson[33], 2000; Westerman[34], 2000), and internationally (Lucchini[35], 2000; Sains, 2000; Soløy[36], 2000; Lang[37], 2001; Williams, 2001).

Figure 9.The Smart Living project.

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[32] In Swedish.
[33] In Swedish.
[34] In Swedish.
[35] In Italian.
[36] In Danish.
[37] In German.

The houses comprised 180 square meter living space with five bedrooms and an otherwise open floor layout. All six houses were displaced 15 degrees to the west in order to capture maximum solar radiation into the large glass surfaces. In the kitchens the stove, the oven and the dishwasher were placed on a comfortable and ergonomically tested working height. The rooms had under-floor heating and cooling. A garage was attached to each house including a carport and storage room and next to the kitchen there was a tiny greenhouse. The houses had 50 percent extra insulation in comparison to other similar buildings to encourage energy conservation.

<u>IT equipment</u>
The smart home system in these houses was explicitly designed to increase quality of life, by making life easier, safer, and more comfortable. Water, heating, ventilation, lighting and access control were integrated and controlled from a display screen in the hall.

Lighting in the hall, bathroom, spa, laundry room, storage room and garage was controlled by motion detectors. The master bedroom had a "good night" switch, by which all the lighting in the house could be controlled. With a single press on this particular switch all lighting in the house could be switch off.

To unlock the front door the residents used an electronic key. The smart home system had two different schemata; the *Home schema* and the *Away schema*. These schemata administered the main water supply, the electricity to the stove, burglar motion detectors, the ventilation and the power sockets. When the residents locked their front door, the Away schema became activated. Then, the electricity to the stove and all power sockets automatically were switched off, the ventilation was reduced to half in order to save energy and the burglar alarm was set on. Two hours later the main water supply was shut off. When the residents returned home, the Home schema was activated. The lighting in the hall automatically lit. The stove and the power sockets could be used again. The ventilation increased and the main water supply was turned on.

The heating arrangement, the geothermal pump and the ventilation system with heat recovery, were integrated into a cost-reducing system and at the same time ensuring a pleasant indoor climate. On hot summer days, the heating system was converted into a cooling system.

There was a reception box to receive deliveries when the residents were out. On top of the garage, there was a weather station. It had two sun sensors and a wind sensor providing daily updates. It also triggered the sun blinds. When it was too windy the sun blinds were automatically pulled up and when the sunlight was strong the blinds were brought down.

An integrated system for television, computer and telephone with the same outlet sockets (RJ45) for all three units was set up; several rooms had pre-installed wiring in the ceiling and walls for 19 loud speakers.

2.3 LITERATURE STUDIES

The research field is vast and literature studies have to be confined to certain areas of particular interest for the present study, of which e.g. consumers' interest in smart home solutions is an obvious one.

It is difficult to find previous investigations similar to those described in this thesis, especially advanced installations in ordinary homes for ordinary people. For some time societal expectations have grown on the possibilities to apply technology as a means for having older people living longer in their own homes and by doing so, postponing the relocation to special housing. Experiences from practical investigations oriented towards this particular problem could be relevant for the present study.

Finally, user benefit and user acceptance is the central theme for the thesis. Consequently, the literature studies are focused on this particular research field – human-computer interaction, HCI – in order to find viable concepts as tools for analysis and interpretation of achieved results.

2.3.1 Consumer interest in Smart Homes

When searching for a new home the chief purpose is to realise certain preferences and, if possible, enhance quality of life (Fransson, Rosenqvist and Turner[38], 2003). These preferences change over time during a household's lifecycle (Forster and McCleery, 1997; Werner[39], 2003). E.g. families with children obviously hold different preferences regarding their dwelling situation when compared to the preferences of retired people.

The location and the floor layout are the two most governing parameters when choosing a new housing according to Swedish investigators (Industrifakta[40], 2000; Werner[41], 2000; Fransson et al., 2003). Smart homes appears to be attractive both to so called early adopters, see section 4.2 and to a broader range of consumers, principally due to their potential to offer safety and security (Pragnell, Spence and Moore, 2000; Werner, 2003). The feeling of being safe is an important quality of a home and its setting (Lind and Bergenstråhle[42], 2002).

The smart home is a relatively new concept and, in case of realisation, mostly built as test projects. Most surveys of smart homes are carried out by letting test persons try different functions and services in laboratories, not in their own homes.

In the beginning of the 1990s several studies investigated the demand for smart homes. The surveys established the fact that there was a demand, especially for security, comfort and energy functions (Atkin and Pothecary, 1994; Abramson, 1995). Later, the Swedish construction company Skanska, found that 18 percent of the respondents in a survey considered homes equipped with different IT functions to be very important (Skanska Nya Hem[43], 1999). The ratio was even higher for people living in medium-sized towns (24 percent). The same survey stated that the development of IT functions in homes was rapidly growing and the interest for advanced technology in homes was increasing.

At the turn of the millennium, a number of studies (Pragnell et al., 2000; Industrifakta[44], 2001; Venkatesh, 2001) investigated if people were interested in living in a smart home. These studies all verified that people were most interested in increased safety and security. However, as residents "upgrade" their homes with more technology their expectations will rise both regarding performance and ease of use (Guza, 2005), and further, they want assistance with maintenance, monitoring and trouble-shooting (Accenture, 2006). Unique service offerings and good customer support were reported to be key factors to improve customer satisfaction of broadband suppliers (Scherf, 2006).

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[38] In Swedish.
[39] In Swedish.
[40] In Swedish.
[41] In Swedish.
[42] In Swedish.
[43] In Swedish.
[44] In Swedish.

Pragnell et al. (2000) made a survey in UK in April 2000 covering over 1000 respondents aged 15 and upwards. Opinions were mixed regarding the respondents interest in living in a smart home. Less than half (45 percent) of the respondents agreed with the statement "I am really interested in having the sort of functions a smart home could offer", while 37 percent disagreed. In terms of future expectations, 40 percent said they could see themselves living in a smart home in ten years time. The authors suggested that the respondents were divided into three groups in terms of their attitude towards smart homes, viz.:

- *The interested* – those interested to live in a smart home: most likely people aged 15-34; family households; those with pay TV and home entertainment systems (i.e. DVDs and video games consoles); those with PCs and/or Internet access; those with higher incomes; those who hold a positive attitude towards new technology.
- *The ambivalent* – those who were neither interested nor uninterested in the idea: well-represented across all population groups, though marginally more likely to be older and with medium/low incomes.
- *The uninterested* – those not interested in living in a smart home: most likely to be aged 55 and over; households without children; households without a PC, pay TV or home entertainment systems; those who hold a negative attitude towards new technology.

2.3.2 Societal demands on smarter homes

Many countries presently face severe problems with an ever increasing ratio of older people in the total population (Miskelly, 2001). Especially, the rising number of people over 80 years of age torments governments and local authorities in charge to provide care for the elderly. In general, resources are lacking to offer care in special sheltered premises. New solutions are necessary allowing old people, also those with some impairment or with an acquired brain injury (including dementia), to stay longer in their own homes before an eventual move to special care.

The interest for assistive technology is increasing. Generally the need for services increases with age (Molin, Pettersson, Jonsson and Keijer, 2007). Different technical services can be a means for traditional living also for disabled persons or persons with other functional disorders – regardless of age (Barlow and Gann, 1998; Gann, Barlow and Venables, 1999). Lanspery, Callahan, Miller, and Hyde (1997) state that older adults and people with disabilities want to remain in their homes even when their conditions worsen and the home cannot support their safety. Many large European projects have focused on independent living in one's own home (Lansley, 2001). In Sweden a three-year project was carried out in order to explore the potential of assistive technology to facilitate daily life of cognitive disabled persons in their own home (Keijer, 2007).

Automated Behavioural Monitoring System, ABMS, is an approach aimed to support people living in their own homes. In the USA, the technology was installed in the homes of elderly and chronically ill individuals (Glascock and Kuznik, 2007). The purpose was to test the system and its usefulness as part of a home health care delivery model.

In Japan, the government initiated an IT-strategy with the goal to develop and implement a working ubiquitous network in society (Murakami, 2004; 2005). The strategy defined the ubiquitous network as an invisible connection "at any place", "at any time" and "with any object". One of the purposes with a ubiquitous network was to provide attentive service solutions at a relatively low cost. Figure 10 illustrates an example of conceivable service solutions when monitoring the health conditions of old parents who live independently and separated from their children.

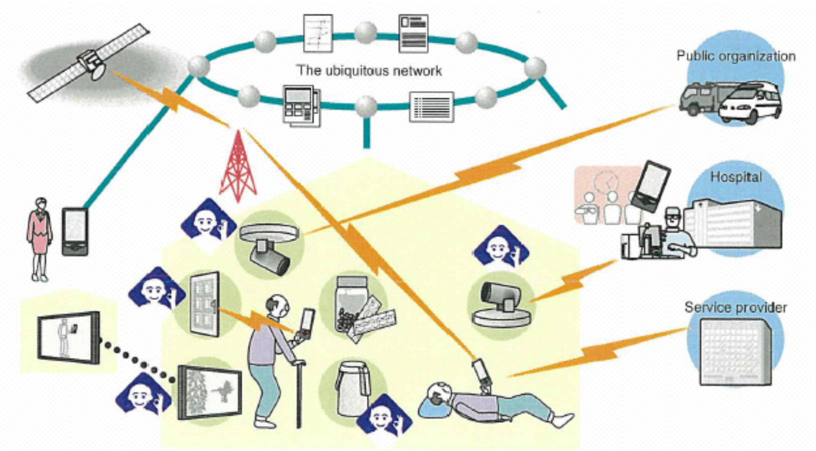

Figure 10. Example of monitoring health conditions of aged parents (Murakami, 2004).

The development, so far, principally was technology-driven, rather forecasting than defining what technological changes will take place in future homes (Dholakia, Mundorf and Dholakia, 1996). Available evaluations of residents' opinions on *installed and used* IT functions in their homes are practically non-existent. There is an intrinsic lack of understanding of what the users, the residents, really want to have in their homes. With this in mind the present work chose this frame of reference as its point of departure.

2.3.3 Human-Computer Interaction

Human-Computer Interaction (HCI) is the study of how people design, implement, and use interactive computer systems, and how computers affect individuals, organisations, and society. During the past twenty years a rich suite of methods, techniques, and theories to understand and address a wide range of issues were developed, mostly concerning the design of usable and useful computer technologies and electronic devices. Early research focused on tasks in which a single user interacts with a desktop computer (Myers, 1998). In the early 1990s HCI research had proceeded through a number of stages, and at that time focus shifted from the dialogue between the human being and the computer to HCI in the work settings (Suchman, 1987; Grudin, 1990). The shift led to new design methodologies, such as User-Centered Design (Norman and Draper, 1986; Norman, 2002), Task-Centered Design (Lewis, Rieman and Bell, 1991) Contextual-Inquiry (Beyer and Holtzblatt, 1998) and more recently Interactive Design (Houde and Hill, 1997; Cooper and Reimann, 2003), of which the latter aims to help designers unpack, not only the users' needs, but the nuances of their everyday work tasks, as well.

Primarily, HCI theories as well as experimental methods studied processes whereby cognitive factors come into play in users' interactions with a specific technology. The goal was to evaluate the ease-of-use and usefulness of an interface design based on objective metrics and descriptions of tasks and context. The Technology Acceptance Model (TAM) demonstrates the importance of both the perceived usefulness and the perceived ease-of-use on user acceptance of information systems (Davis, 1989; Venkatesh, Morris, Davis and Davis, 2003). Classical studies of usefulness were chiefly concerned with improving productivity of work settings (Davis, 1989; Davis, Bagozzi and Warshaw, 1989; Malhotra and Galletta, 1999; Venkatesh and Davis, 2000). In the 1990s there was a need for a broader understanding of the use of computer technologies in real-world situations, see e.g. research on developers and end-users (Nardi, 1993) and technology adoption (Grudin, 1994).

A common misperception is that HCI is limited to usability (Zhang, Carey, Te'eni and Tremaine, 2004). Although usability was a dominant part of the HCI field, many empirical studies on user's acceptance of technology prove that usability is neither the only nor the most important predictor of system acceptance and usage (Davis, 1989; Venkatesh et al., 2003). Recent research in HCI and other related disciplines go beyond usability and explore other factors affecting human interactions with technologies. The user's affective reactions and his holistic experiences with technology are gaining more attention and becoming more important (Webster and Martocchio, 1993; Agarwal and Karahanna, 2000; Zhang, Benbasat, Carey, Davis, Galletta and Strong, 2002).

Misperceptions sometimes come from unclear or conflicting definitions of some key concepts. To facilitate the understanding of the following, three central concepts used in the thesis are further elaborated: i.e. usefulness, usability and accessibility.

2.3.4 Usefulness, Usability and Accessibility

The concept *usefulness* has different meanings in various contexts. Nielsen defined usefulness of a computer system as the issue of whether the system can be used by users to achieve some desired goals (Nielsen, 1993). The concept can be separated in two categories: utility and usability (Grudin, 1992; Nielsen, 1993). Utility is the reply to the question of whether the functionality of the system can do what is needed, i.e. if the functions provided by a computer system support the user's tasks or goals. It is a question of *user benefit.* However, this interpretation seems to be equivalent with the "usefulness" in many technology acceptance studies (Davis, 1989; Venkatesh and Davis, 2000; Venkatesh et al., 2003). Users will not use or interact with a system if it does not provide useful functions. Many technology acceptance studies have found that perceived usefulness (or perceived utility) of a system is the most dominant factor for system acceptance and adoption (ibid.).

The notion of *usability* has shifted over time from focusing only on man as a user to perceiving the product and its use in a context (Löwgren, 1993). Many methods and techniques, like usability and system development methods, take notice on the connection between a product's expected usefulness and the design of the product, often however rather superficially (Ottosson and Berndtsson[45], 2002). Usability is not an objective, observable and intrinsic product quality such as colour or a specific technical function. Instead, usability is a quality that appears at the very moment the product is used. Commercially the concept usability is becoming an important issue (Jordan, 1998). People are increasingly unwilling to tolerate complicated or – frankly expressed – unusable products.

The international standard ISO defines usability as:

"Usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." (ISO 9241:11, 1998).

Further ISO defines *effectiveness*, *efficiency*, *satisfaction* and *context of use* as:

> Effectiveness: "Accuracy and completeness with which users achieve specified goals."
>
> Efficiency: "Resources expended in relation to the accuracy and completeness with which users achieve goals."

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[45] In Swedish.

Satisfaction: "Freedom from discomfort, and positive attitudes towards the use of the product."

Context of use: "Users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used."

Depending on the type of application a certain quality might be more critical than another. For example, if a software is used infrequently, then the quality of "easily remembering the necessary actions for the desired task" will be critical. If the application is time critical then the "efficiency" quality will be critical along with the "error prevention" quality. These definitions are certainly valuable as they make it possible to discuss usability in order to attain an unambiguous understanding of the concept. Thus, the ISO definition on usability involves some interesting aspects, with wider implications for the user than what is commonly discussed.

Nielsen (1993) claims that usability is a quality attribute to assess how easy the user interfaces are to use. He defines usability by five quality components, table 1. Shneiderman (1998) does not define usability but calls it "five measurable human factors central to evaluation of human factors goals". As can be seen from table 1, Shneiderman's "definition" is essentially identical to Nielsen's definition and differs only in terminology.

Table 1. Usability according to ISO 9241:11, Shneiderman and Nielsen.

ISO 9241:11	Shneiderman	Nielsen
Efficiency	Speed of performance	Efficiency
	Time to learn	Learnability
Effectiveness	Retention over time	Memorability
	Rate of errors by users	Errors/Safety
Satisfaction	Subjective satisfaction	Satisfaction

Table 2 shows the usability factors described by Dix (Dix, Abowd, Beale, and Finlay, 1998). This categorisation is rather different from the definitions in table 1. Dix defines three main groups; 1) learnability, 2) flexibility and 3) robustness and suggests that these concepts are on the same level of abstraction. The groups are specified further by factors that influence the group they belong to, e.g. consistency influences learnability positively when a design is consistent within the application and between applications on the same platform. Learnability is subdivided into aspects, chiefly of cognitive nature, thereby getting a better grip on user abilities related to learnability.

Table 2. Usability categorisation by Dix et al. (1998).

Learnability	Flexibility	Robustness
Predictability	Dialog initiative	Observability
Synthesisability	Multi-Threading	Recoverability
Familiarity	Task migratability	Responsiveness
Generalisability	Substitutivity	Task conformance
Consistency	Customisability	

Usefulness is also a part of the ISO definition of usability. Usefulness can be defined as what the user wants to achieve with a product, a software or a system, i.e. the user's goal. Usefulness and usability are easily confused. A product or a service can be demanded by a user and appear useful to him or her at first sight. Still in practice it remains useless. It may depend on the fact that the user does not understand how he or she is supposed to use the function. It can also be out of order or not available when asked for. The function is *not accessible*.

Accessibility is an integral part of usability as access obviously is a condition for at all using a product, a software program or service. Accessibility is complementary to usability in order to attain usefulness. The concept accessibility includes technical aspects such as *response time, set-up time* and *availability*. Availability consists of *up-time*, *mean-time to repair* and *mean-time between failures*. According to IEEE Standard Glossary of Software Engineering Terminology (610.12-1990) these components are defined as (www.ieee.org):

> Availability: "The degree to which a system or component is operational and accessible when required for use".
>
> Response time: "The elapsed time between the end of an inquiry or command to an interactive computer system and the beginning of the system's response".
>
> Set-up time: "The period of time during which a system or component is being prepared for a specific operation".
>
> Up-time: "The period of time during which a system or component is operational and in service".
>
> Mean time to repair (MTTR): "The expected or observed time required to repair a system or component and return it to normal operations".
>
> Mean time between failures (MTBF): "The expected or observed time between consecutive failures in a system or component".

The use of the ISO 9241-11 definition of usability provides a common understanding of the concept. Furthermore, the definition emphasises that usability is objective and measurable. The ISO definition covers a wider range of the aspects that are important to users than most definitions and perceptions of usability do (Göransson, 2004). Often usability is discussed in vague terms such as "user friendly", "easy to learn" or as something that is related to the user interface of an interactive system only. Even though the user interface is important, it is no more than one part of the system. In order to develop a usable system it is important to learn about the potential users, their intentions and goals, their tasks, their context of use, etc. This means that all aspects covered by the ISO definition of usability should be taken into consideration (ibid.).

2.4 RESEARCH METHODS

2.4.1 Frame of reference

The point of gravity in technology research tends to be located either predominantly in the natural sciences or in the social sciences with different methodology. In terms of its methodologies the research work presented in this thesis can be classified as belonging to the broad domain of the social sciences. The objective of the research presented here is to study the relationship between a man made artefact – the smart home – and man himself, see further e.g. Simon (1996) and Dahlbom (2002).

The frame of reference for research within the domain of the social sciences can be qualified by utilising some concepts from the comprehensive treatment of qualitative methods and their scientific-philosophical foundations by Alvesson and Sköldberg[46] (2008). The purpose is not to advance in depth into this matter; rather the purpose is to offer a common platform of scientific understanding in order to be able to proceed directly with the specific research questions put forward in the beginning of the chapter.

According to Alvesson and Sköldberg there is no clear boundary between qualitative and quantitative methods. As their principal starting point is the qualitative method, quantitative methods are more or less supposed to be subsumed under the former. The apparently precise outcome of a quantitative analysis is an illusion and needs interpretation as much as any qualitative analysis. All results need to be discussed thoroughly before any conclusion is drawn. Another point relates to the research process as such. Any researcher should be observant during the course of her research of occurring phenomena, new matters brought into focus and new relevant questions to be asked. To stick firmly to original conceptions without reflection does not make use of the research effort as a whole. (ibid.)

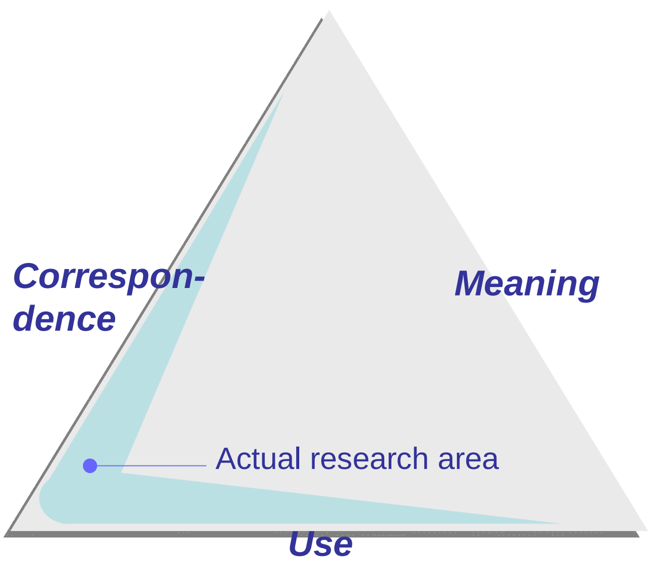

Figure 11. Application of theories based on the tri-lateral truth concept. Definition of an application area of a domain. After Alvesson and Sköldberg (2008). Marked area indicates schematically the theoretical framework for the present research.

A concrete and useful idea to determine the nature of a research undertaking is the *tri-lateral truth concept*[47] described by the authors (ibid.), figure 11. The research work is characterised by three distinct interpretations of truth, each represented by one side of an equilateral triangle, i.e *correspondence*, *use* and *meaning*. "Correspondence" is the intuitive research interpretation of truth: What is found in an investigation represents a significant correspondence to the real world. With "use" is understood another kind of truth: What is sought for is something that is useful in practice. However, according to Alvesson and Sköldeberg (2008) these two truth concepts,

[46] In Swedish.
[47] Translated from Swedish: ”Det trilaterala sanningsbegreppet”.

although distinct, could be merged into one: the *pragmatic realism*. Most technology research, if not referred to natural science, could probably be attributed to this latter suggestion.

"Meaning" is something entirely different: It is about revealing a deeper truth than the one immediately evident. It has nothing to do with usefulness or correspondence to reality (ibid.). As a truth concept "meaning" is not dealt with in this work. In the following *pragmatic realism* seems to be the reasonable choice of methodological framework for the research, as marked in figure 11. That does not exclude some minor comments revealing indications of underlying meanings by some informants at casual occasions.

2.4.2 The case study

Swedish construction companies' interest in evaluating customer satisfaction has increased over the last decade. The rise in interest was caused by the growing call to meet customer needs, demands and desires; the better a company understands its customers' values, the more straightforward it is to sell or let a home. This growing interest for the consumer is not unique for the construction market, rather a late awakening from a regulated domestic sector, since long overdue. The global economy is permeated by the importance of customer satisfaction, a necessity to acknowledge in order to become a successful company (Hayes, 1998). Here are a number of established evaluation methods within housing research, e.g. document studies, walk through evaluation, interviews and questionnaire surveys (see e.g. Preiser, Rabonowitz and White, 1988; Kernohan, Gray and Daish, 1992; de Laval[48], 1994; Ambrose and Paulsson[49], 1996). Merriam (1988) and Patton (1990) suggest that case studies are especially suitable when the purpose is to reach a deeper understanding in a limited number of specific cases, e.g. individual opinions within a defined group.

Four factors are instrumental when assessing if a particular case study methodology is appropriate in a given situation (Smith, 1978), i.e. 1) the type of questions, 2) the degree of control, 3) how the final result will be presented and 4) if a delimited system can be identified. According to Smith, the forth factor is most decisive.

In the present investigation, the case study methodology was applied. The purpose was to gain a deeper understanding of the residents' opinions and attitudes to various IT functions in their own homes. The three studied cases were, as described above, Vallgossen, Ringblomman and Smart Living. Each of these three cases constituted a *delimited system*, and by their apparent similarity, together also a *composite delimited system*. In 2002, at the beginning of the whole study these cases were unique in Sweden with regard to the installed IT functions.

Case studies are suitable to describe individual differences or variations between one case and another (Yin, 1984; Merriam, 1988; Patton, 1990). The three cases were at first analysed separately and later compared with each other in order to identify and utilise perceived differences in order to acquire a deeper understanding of the matter.

Triangulation is a concept particularly used in case study methodology (Merriam, 1988). Merriam defines triangulation as *"using multiple investigators, multiple sources of data, or multiple methods to confirm the emerging findings"*. The multiple methods approach is to maximise the range of information available to the researcher, improve the trustworthiness of the data and provide a basis for triangulation between data sources. Each data source and technique has some particular advantages and some disadvantages. By using a combination of sources and techniques,

[48] ibid
[49] In Danish

inadequacies of one source or technique is supplemented by the advantages of others. The combination of data sources can also provide a mechanism to gain different perspectives on the data. Merriam (1988) emphasises that triangulation is especially useful to secure the validity and reliability of the findings in qualitative assessments.

There is no single specific method defined to gather and analyse information when conducting a case study. Both qualitative and quantitative methods can be applied. Qualitative methods are characterised by the researcher's own interpretation – also called hermeneutical analysis (Patton, 1990; Denzin and Lincoln, 1998). Quantitative methods are characterised by a search for a numerical representation of the research material which can be further analysed and presented, preferably in diagrams and tables (Oppenheim, 1992; Denscombe, 2002). They allow formal statistical methods to be applied and make it possible to accept or reject specific hypotheses. Cf. also Alvesson and Sköldberg (2008) above.

Regarding interviews there is differences between structured, semi-structured and unstructured methodology (Fontana and Frey, 2005). A structured interview requires formalised ordered questions, which must be strictly followed during the interview. At semi-structured interviews there is a possibility to choose questions and their order more freely. The primary goal is to receive answers that cover the desired information. Unstructured interviews rely on the spontaneous generation of questions in a natural flow of an interview (Patton, 1990). Minichiello (1990) defined unstructured interviews as interviews in which neither the question categories nor the answering categories are predetermined[50].

When approaching a new research topic, like user values in smart homes, there is a genuine difficulty to know what questions to ask. In order to decrease the control from the interviewer and let the respondents express their experiences and attitudes more freely the semi-structured interview technique was chosen[51].

Multiple sources of data and of data collection were used. Interviews with residents in Vallgossen, Ringblomman and Smart Living were conducted in order to understand the three cases in depth and in detail.[52] Interviews with key persons at e2-Home and at the construction companies, observations and documents received from the companies, all provided deeper insight into the subject.

2.4.3 Cases and selecting criteria

Selection deals with what cases will be studied, who will be interviewed and what will be observed. The selected cases were fairly obvious: newly built homes with IT functions offering the residents new services. To increase the comparability a criteria was set regarding the similarity of IT functions in the homes. The criterion was fulfilled more or less by itself since the technology development in homes was controlled by available technology on the market at the time of construction.

In interview studies the number of interviews usually should be between 5 and 25 (Kvale[53], 1997). The number depends on available time and resources for a particular study. The law of decreasing yield from each additional input from the same category is applicable also for

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[50] In paper i), iii) and iv) the term "unstructured interview" was generally used instead of the appropriate term "semi-structured interview".
[51] See appendix 5, 6 and 7.
[52] See paper ii), iii) and iv).
[53] In Swedish.

interview studies (Lincoln and Guba, 1985). In other words, to increase the number of interviews above a certain level, usually do not affect the outcome but rather confirm the already anticipated outcome.

It was considered important to understand the respondents' expectations, on the one hand, and their experiences, on the other hand, in connection with the new technology. In Vallgossen the respondents were interviewed before they moved into their new flats. The purpose was to investigate the respondents' (ex ante) expectations about the smart home technology. Later, when they had lived in their new flats for some of months, they were interviewed a second time (ex post). Now the purpose was to uncover if their expectations and attitudes were changed in some way after having used the smart home technology for some time.

The selection in Ringblomman was based on three parameters – flat size, family size and age structure. These parameters were chosen in order to recruit the same category of households in Ringblomman as those in Vallgossen. Data of the respondents in Ringblomman and Vallgossen are given in paper i) and paper iv).

All six households in Smart Living were offered to take part in the study. Paper iii) presents the data on the respondents in Smart Living.

2.4.4 Data collection and realisation of interviews

A schema over the different question areas was developed before the interviews. During the interviews the respondents were given the opportunity to talk freely and the schema was mainly used by the interviewer to check if all questions in the different areas were covered.

Interviews ex ante were conducted in a relaxing environment in the city central while interviews ex post were conducted in the respondents' own home. Thereby an opportunity was given to the residents to show and describe how and why, or why not, they use the IT functions. The respondents were offered an option of the time for the interviews, day-time or evening.

All interviews were tape recorded. In that way it was easier for the interviewer to concentrate on the respondents answers and to ask supplementary questions. A disadvantage with a tape recorder might be the respondent's lack of spontaneity and thereby to subdue vital information (Patton, 1990). No indication in this direction was experienced during the interviews. In addition, notes were taken with the interviews.

2.4.5 Dropouts

To limit the dropout rate is important. It is also important to identify every dropout cause, especially as the selected groups are relatively small.

An analysis of the dropout, its grounds and importance, is given in paper i), iii) and iv). It was concluded that the dropout, overall, was a minor problem for the study.

2.4.6 Analyses – Database construction and coding

After the interviews the answers were analysed. Notes taken during the interviews were copied and complemented with information from the tapes. Thereafter, all information was organised according to the schema used in the interviews. Yin (1984) calls this structuring of material as "the case study database", which he separates from "the case study report".

Yin (ibid.) states that, *"...every case study project should strive to develop a formal, presentable database, so that, in principle, other investigators can review the evidence directly and not be limited to the written reports. In this manner, a case study database markedly increases the reliability of the entire case study."* Case databases should include the data collected and the report generated by the researcher. When a case study report has been established, the analysis can be done from:

- time sequence analysis – e.g. compare expectations with experiences or short term versus long term experiences,
- pattern analysis – e.g. similarities or differences between the cases,
- explanation-building – the goal is to analyse the case study by building an explanation about the case (ibid.).

Here explanations could be phrased, e.g. "the IT functions were a conclusive reason for buying a flat" or "the IT function were uninteresting" or maybe "they were only a bonus when the residents bought the flats".

The work of analysing the interviews was done as soon as the case study report had been established. When analysing interviews it is preferred to translate the respondents' different answers to a unified code or scale (Oppenheim, 1992). The coding of the respondents answers were done by the interviewer. The answers were classified according to a five grade scale, from two plus to two minus. (++,+,0,-,--).

++ - very useful
+ - rather useful
0 - indifferent (neither useful nor not useful)
- - useful to some extent, but principally not useful
-- - very little/not at all useful

2.5 RESULTS

2.5.1 Vallgossen – Expectations 2002

The first interview series in Vallgossen was conducted during January – March 2002. The aim was to gain knowledge of the future households and to find out what their expectations were of their new dwellings before moving in. The number of interviews was eleven. The details are found in paper i).

The determining factors for buying a flat were foremost "the location in the urban area" and "the floor layout". Then preferences like "high standard", "new production", "choice of options" and "good investment" were mentioned as a second reason.

The provided technology, i.e. the smart home functions, was not a conclusive reason for buying a flat. The respondents mentioned that they rather considered the technology as a bonus or as "fun stuff". The households generally pursued a wait-and-see attitude towards the technology. Most of them thought the technology might be interesting in the long term, provided it proved to work.

One household only was genuinely sceptical about the offered IT functions, but did mention that time was required to learn the system. The other respondents were more waiting, felt no cause for alarm and exhibited mainly curiosity. They trusted that any future problem with the systems would be solved in due time: A typical view was: "I will not make it a big issue if it does not work. If it works I guess its fine."

The following functions were considered most useful in advance (the functions are explained in section 2.2.1 above, and in paper i):

- the away lock,
- the alarm system,
- the broadband connection,
- the integrated system for data and telephone,
- the laundry facility booking system, including the "finished laundry" indicator.

Most of the households asked for a *detailed description* of the IT functions. They also wanted to have a document explaining *why* they should use a particular IT function; what they would *gain* if they used this function.

2.5.2 Vallgossen – Experiences 2002

A second series of interviews in Vallgossen was performed in May – June 2002, three month after the first series, and after the residents have occupied their new homes. The aim this time was to gain knowledge of the residents' experiences of using the different IT functions. The interviews were performed with the same households as reported in section 2.5.1 above. The results are also presented in paper i).

Most of the households, according to themselves, unpacked the laptop computer and started at once to get acquainted with the IT functions. The households chose to place the laptop computer in the kitchen or in the study room. Households who chose the kitchen mentioned that this behaviour was due to the specific ScreenFridge[54] concept, which had been presented to them earlier. One household even mentioned that they would have preferred a ScreenFridge. Another household would prefer a flat touch screen on the wall. Another argument was the amount of time the respondents spend in the kitchen. If the screen was close by it would be more natural to use it. Most of the respondents mentioned that they used to switch off the laptop computer when not in use.

The households' opinions of the technology differed. Some explained that it was easy to use the different functions from the very beginning; some others thought it would become easier the more they practiced. One household believed it would be more difficult to use the functions than it turned out to be.

All households verified that the manual for the smart home system was comprehensible and easy to read. Persons working with IT thought the manual was a little bit too "basic". The households had been forced to contact the customer service a few times only, thanks to the detailed manual. One household only experienced severe troubles with the laptop computer. At the time of the interview the household mentioned that the broadband connection had been out of order for 25 days and the connection to the smart home system had been out of order for 17 days.

The following functions were considered most useful (generally the same as previously, only the electronic key was added):

- the away lock,
- the alarm system,
- the electronic key,

[54] See appendix 2.

- the broadband connection,
- the integrated system for data and telephone,
- the booking system, including the "finished laundry" indicator.

Less value was given to the weather forecast and the individual energy measurement. Lowest value was given to the laptop computer, the reception box and the e-notes.

The respondents were asked if they missed any function or service. The following was suggested:

- a function to control the indoor temperature,
- a possibility to receive and read attachments in the e-mail[55],
- a service exchange system between the neighbours, e.g. to hire a baby sitter,
- a device to control the lighting in a simple way, e.g. switch off all lights with one button,
- a possibility to be informed by the smart home system, if mail was received in the mailbox in the stairwell.

2.5.3 Ringblomman – Experiences 2002

It was not possible in terms of time to conduct any interviews before the residents moved in. The first interviews in Ringblomman were conducted in November – December 2002. The aim of the survey was the same as in Vallgossen, which was to gain knowledge of the residents' use of the offered IT-functions. The number of interviews was nine. The results are presented briefly below.

The determining factors to buy a flat in Ringblomman were, as in Vallgossen, "Location in the urban area" and "Floor layout". Then preferences like "New production", "Choice of options" and "Balcony" were mentioned. The offered technology was not a decisive cause for buying a flat in Ringblomman, either. However, a common opinion was the expressed visions, e.g. the energy measurement offering an opportunity to decrease the energy bill, and the heating control allowing a pleasant indoor climate.

All households thought that the terminal had got a convenient place. Most of the households had the opportunity to choose its location. One single household chose to place the terminal standing on the sink top in the kitchen. The others placed the terminal on a wall in or close to the kitchen.

The majority of households, as in Vallgossen, mentioned it was easy to accept the technology. The graphical interface was considered intuitive and easy to understand. Only one household was of an opposite opinion. "I detest that screen, but when I see the things it gives me then I just need to learn. It is not a simple system. I am not stupid but I am not a technician. It is much to learn and you have to sit and read all the time. But, I am not good at the VCR either."

Most of the households did not read the manual. One respondent mentioned that he read the manual occasionally, and would like to have another lesson a year later. "There might be a risk that if the system does not function satisfactorily or if you do not know how to operate it, you ignore it." All households had contacted the customer service. The most common problem, during the first six months in 2002, was how to restart the system. The open floor layout caused difficulties in maintaining different temperatures in particular rooms. Sunshine and influence from the indoor temperature of neighbouring flats affected the temperature of the own flat.

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[55] The deficiency was a consequence of a design criterion called for avoiding virus in the smart home system.

Some respondents revealed they had actually thought the technology would have functioned better than actually was experienced. The consequence became a wait-and-see policy, as in Vallgossen. The residents would simply not use the system until it worked to their satisfaction.

The following functions were considered most useful by the informing residents:

- the electronic keys,
- the weather forecast,
- the energy measurement,
- the broadband connection.

Less value was assigned to the booking system and the heating control. The away lock, the security camera at the front door, the alarm system, e-notes, the terminal and e-mail were rated slightly lower. The calendar, the reception box and the lighting control were least appreciated.

Few suggestions of new functions came up. One of the households admitted that they missed the large amount of extra programs often delivered together with a computer purchase. Functions such as a stopwatch (to be used at cooking) and a calculator were mentioned as preferred options.

2.5.4 Smart Living – Experiences 2002

The first series of interview survey in Smart Living was carried out in September 2003. The aim was to gain knowledge of the residents' experiences of the technology in their new dwelling. It was not possible to conduct any interviews before the residents moved in. All six households in Smart Living were interviewed; in all but one interview both adults of the household participated. The results are further developed in paper iii).

The determining factor for buying a house in Smart Living was the architectural design, e.g. the open floor layout. The technology was important, too. Eight of the eleven respondents were employed by different types of IT companies, or expressed a general interest in IT. They could imagine how to make use of the technology, e.g. the integrated network and the heating system. The expectations were high. However, these expectations turned out to be difficult to fulfil. Technology changes during the construction phase took place and some of the envisaged functions were degraded or omitted, e.g. the remote control (via mobile phone) of the sauna and the shared Internet portal were omitted. This dissatisfaction did not affect the installed functions, however; it was related to some promised but not installed functions.

All six households considered the terminal to be easy to use. Its place in the hall was found logical. When they left the house it was easy to check if all windows and doors were closed and to switch off all lighting in the house.

The informants mentioned that it was easy to adapt to the technology. The following functions were considered most useful by the residents:

- the away lock,
- the passage system,
- the lighting control,
- the integrated system for television, data and telephone.

All six households rated the broadband connection and the reception box lowest. The broadband connection displayed continual interruptions. Also the broadband customer support was considered inferior. No household had tried to shop groceries on the Internet and they saw, therefore, no value in the reception box.

The technology had strongly contributed to a closer friendship between the families in these houses. "It is an incredible interest in sharing experiences if someone finds a better setting …". The interviewer got the feeling the informants cared more about each other than about the other neighbours. It was almost as if there were two groups in the area: "The smart houses and the stupid houses".

2.5.5 Summary of the results of the first phase

The study was conducted by interviewing 26 households at one or two occasions. In all 37 interviews were completed, thereof 11 interviews before occupancy and 26 interviews rather soon after occupancy. The results showed that the foremost factors for buying a flat or a house were "the location in the urban area", "the floor layout" and "it is a brand new production". The smart home functions were not found to be a conclusive reason for buying the flats and houses; the households considered them rather to be a bonus at the moment of purchase; the price tag was not higher for flats with the specific smart home technology than for identical ones without the technology. Worth mentioning is that a certain number of the residents who actually bought these flats or houses were IT professionals or were skilled IT users. It is reasonable to assume that these buyers were interested in modern IT above the average purchaser. It can also be assumed that these persons perceived a value, or as it was mentioned "fun", to have a home with technology that stands out from homes in general.

Albeit the offered functions were not a conclusive reason for a home purchase, they still had a value. Functions increasing safety and security (e.g. alarms), saving time (e.g. booking of common facilities) and increasing comfort (e.g. sunshade control) were most appreciated. On the other hand, the possibility of energy conservation was less appreciated. Likewise, the reception boxes in Smart Living were regarded superfluous. Detailed results from the first phase of the investigation is found in paper i) and iii).

2.6 CONCLUSIONS AND IMPLICATIONS FOR THE SECOND PHASE

2.6.1 Comments on used interview method

Using semi-structured interviews for the first phase of the investigation was found to be a convenient choice. The alternatives were precise structured interviews or questionnaires. With the semi-structured interview the respondent seemed to be willing to answer spontaneously and more freely and probably conveyed more information to the interviewer during the available time in comparison to the formal structured interviews. As an unexploited research area, it became a sensitive task to decide what to ask and how to ask. The semi-structured interview methodology turned out to be appropriate for the task.

The interviews gave a thorough insight into the problems new residents encounter and how they respond to not fully developed smart home systems in their new homes. Based on these findings it was possible to proceed and develop some generalised model for the further investigation.

2.6.2 An elaborated user model

The interviews showed that the development of IT functions in homes has to be based on the users' genuine needs and to be designed with focus on usability and accessibility. Any particular function must be easy to learn and easy to remember, in short it should be designed for intuitive use. The functions must also have high and stable accessibility in technical terms from the very start. If it does not function as assumed, the user tends to exercise a wait-and-see behaviour, which might lead to a situation where he or she will be reluctant to try the function again, or totally refrain from using it.

The user should get appropriate information explaining the usefulness of each specific IT function. A person who has not tried a function has to be made aware of what he or she can expect from it.

Paper iv) presents a user model with the concepts *usefulness*, *usability* and *accessibility*, based on the results in the first investigation phase, see section 1.4. The user model has its origin from the ISO definition of usability, which covers not only the user interface as such but also other usability aspects. The model became an important tool when analysing the respondents' answers in phase 1 of the study. Likewise the model was useful for the design of the interviews and survey questions in phase 2, as it offers a richer variety of entries than other conceivable models that could have been considered for the study.

Usability can be perceived as something that reveals and comes true when a product, a function or a service is applied and used.

The concept usefulness determines if a product or a service supports the user in fulfilling a task, satisfying a need or solving a problem. There is a problem with the two words usefulness and usability. A product or a service can be demanded by a user and appears to be useful to her. Still it remains useless in practice. It may depend on the fact that the user does not understand how he or she is supposed to use the function. It can also be out of order or not available when asked for; the service or function is not accessible.

Accessibility is supplementary to usefulness in order to attain usability. These concepts are explored further in the second phase of the investigation where the long term use of the installed smart home functions will be evaluated. An additional concept will be introduced, the notion of *trust*.

3 SECOND PHASE – THE LONG-TERM VIEW

The present chapter begins with a re-examination of the research questions of the second phase and associated delimitations. The study objects, applied theories and used methods are described. Both interviews and questionnaires are used. The latter allow for statistical analysis identifying significant differences regarding residents' opinions about almost similar smart homes solutions. Trust as a concept for digital consumer artefacts is introduced. The chapter concludes with a presentation and discussion of the results.

3.1 EXPERIENCE OF POST-OCCUPANCY EVERY DAY USE

3.1.1 Modification of the research questions

The conclusion from the first phase of the investigation, detailed in the previous chapter, gave evidence to the fact that most of the interviewed residents were satisfied – in some cases very satisfied – with their choice of new homes. However, the residents' opinions of their smart home systems differed. Some of the stipulated IT functions did not work satisfactorily from the very beginning, but this did not change the overall complacency. Most residents expected to have them remedied shortly. However, obviously, it was too early to draw definite conclusions about the real user value of the installed functions. The questions posed from the beginning remained unanswered, i.e.: "Do residents find specific user values with smart home functions?" and "What demands do residents have on smart home functions regarding design and functionality?". In order to capture more precise answers to these two questions, it was considered effective to proceed with further investigations about the real use and the long-term attitudes to the installed IT devices and functions.

So, a second round of <u>interviews</u> was conducted in 2005. The purpose was to focus on the residents' long-term use of the installed IT equipment. The functionalities of the technology over time, in other words, the sustainability, was considered to be a key question for the viability of smart home solutions in general. Maintenance and the possibility of upgrading the technology were important issues to address after some period of use, too.

After the interviews were completed <u>questionnaires</u> were sent to all households in both Vallgossen and Ringblomman. In addition, the same questionnaire, somewhat modified though, was distributed to the households of another residential block, Fatbursstranden. The objective of the questionnaire was on the one hand to verify the results from the interviews and on the other hand to compare the answers from residents living in smart homes with those not doing so. Fatbursstranden is described in section 3.2.2 below.

3.1.2 Delimitations

The delimitations of the investigation for the second phase are largely the same as for the first phase, see section 2.1.2. The residents' experiences are still in focus but now from a long-term perspective.

3.2 AN ADDITIONAL STUDY CASE

3.2.1 Previous cases revisited

The previous cases, i.e. Vallgossen, Ringblomman and Smart Living, were also the objects for the continued investigations. The principal objective was to interview the same households a second time with the purpose to examine if their attitudes to the various smart home functions had changed with use and with time.

A fourth case, Fatbursstranden, with neither installed nor planned IT functions served as a complementary reference object. A study (Sandström and Keijer[56], 2006) commissioned by the Stockholm County Police Authority, aimed to investigate the possibility of increasing the residents feeling of safety if some IT functions were installed in their homes. This study offered an opportunity to ask respondents in Fatbursstranden if they would like to have other smart home functions, as well.

3.2.2 Fatbursstranden

Fatbursstranden was comparable to Vallgossen and Ringblomman, regarding location, duration of inhabitation, year of construction and the size and quality of the flats. The only principal difference between Vallgossen and Ringblomman on the one hand and Fatbursstranden on the other hand was the lacking smart home technology of the latter.

Fatbursstranden was built in the district of Södermalm in Stockholm in 1991 and at the time commissioned by the municipal housing company Familjebostäder. The building comprised 180 flats in total. The sizes varied from 53 to 159 m^2. The building had a common laundry room in every stairwell and a party room. Initially the flats were rented out. In 2002, the building changed owner; it was transformed into a housing association, formed by the residents.

One of the association's main targets was to diminish the number of burglaries and troublesome individuals of the neighbourhood in order to increase the residents feeling of comfort and safety in the homes. In fact, in the end of the 1990s, the area around Fatbursstranden was bothersome, indeed. The number of burglaries in homes and cars was more frequent than some five years earlier. The measures taken were effective. Forty burglaries were documented during the period 2002/2003; in 2004 only one was reported.

The favourable development was justified by several taken measures. The association initiated a "neighbourhood watchman" in co-operation with the local Police authority. Further, all flats got a fire alarm. The locks in the building were replaced with a newer and safer code lock system, whose codes were changed frequently. To use the electronic keys during nights was compulsory. Each stairwell used a unique code to bring the elevator down to the basement. The laundry rooms and gates got a specific break in protection. Other external doors were equipped with bolted safeguards. Through these measures the residents were confined to their own stairwell only and to a single common entrance. Many residents changed the lock in their front doors in order to have the new stairwell key fit for their own door, too.

3.3 ANOTHER RESEARCH THEME

3.3.1 Trust

As earlier mentioned in section 2.6.2, the concept of trust was to be further explored in the second phase. Traditionally, trust in digital environments focused on security and development of more foolproof systems. Marsh and Dibben (2003), though, argue that when studying the impact of trust in the digital environment the first requirements is a detailed understanding of trust as a general social phenomenon.

[56] In Swedish.

A wide set of definitions of trust have been proposed in the literature, and attempts to uncover the concept have been made in disciplines ranging from philosophy (Baier, 1986; Hosmer, 1995), sociology (Barber, 1983; Gambetta, 1990) and psychology (Deutsch, 1962) to marketing (Moorman, Deshpande and Zaltman, 1993; Kumar, 1996) and management (Driscoll, 1978; Sako, 1998).

Chopra and Wallace (2003) suggest that an integrated definition of trust recognises the union of three elements; a trustee to whom trust is directed, confidence that the trust will be upheld, and a willingness to act on that confidence, as follows: *Trust is the willingness to rely on a specific other, based on confidence that one's trust will lead to positive outcomes.*

In order for trust to be relevant in a particular situation, two preconditions must be present. The first precondition is the dependence of the trustor on the trustee (Rousseau, Sitkin, Burt and Camerer, 1998). Trust can only arise when there is a state of dependence between the trustor and trustee, and when acting on this dependence entails taking a risk, i.e., the trustor possesses uncertainty about the outcomes and vulnerability to a potential loss if the outcomes are undesirable.

The second precondition, the concept of risk, contains both uncertainty and vulnerability. Several authors have emphasized the importance of uncertainty as a necessary condition of trust (Gambetta, 1990; Doney and Cannon, 1997; Hardin, 2001), while others assert that the very function of trust is to decrease one's uncertainty (Heimer, 2001). The question of trust becomes relevant only if the trustor suffers from a loss and the trust is betrayed (Doney and Cannon, 1997).

Chopra and Wallace (2003) identified four domains in the context of electronic environments where the question of trust is relevant, of which two domains are related to smart homes:

- Information: Can we trust the information we obtain from the smart home system?

- Information systems: Are the computing systems upon which we rely trustworthy?

Trust in information is directed toward a technological artefact, in this case a specific item of information. The trustee in this relation is a specific electronic document, e.g. the graphical user interface of the smart home system. The confidence exists because the user expects the information to be reliable and valid. Moreover, the user enters into the relation willingly, since she is free to accept or discard the information.

Both preconditions for trust, dependence and risk, are present in electronic information. A person may search for information to satisfy a need. Risk arises because she is consciously aware that the information is of uncertain quality and that relying on poor information renders her vulnerable to errors (Marchand, 1990).

Trust in information systems is directed to the specific system with which one interacts directly. The trustee is the smart home system, i.e. hardware and/or software, and trust entails an expectation of proper functioning. The willingness to engage in trust arises because a person is (often) free to select an entirely different method to perform an activity.

Dependence on an information system arises when a person needs to transmit information (communication) or perform operations on data (computation). Risk is present because there is the potential of a system failure, in which case the user may lose valuable information.

3.4 METHODS

Both *interviews* and *questionnaires* were used to examine the residents' attitudes in the second phase. The interviews were carried out in the same way as in the first phase, i.e. as semi-structured interviews, see section 2.4.2 above.

The design principles for questionnaires are well documented (e.g. Oppenheim, 1992; Denscombe, 2002). A questionnaire is a list of questions used to find out what an informant thinks or feels about an issue, product or service. The answers are written down, in absence of the researcher, as a self-administered, group-administered or postal questionnaire.

Questionnaires can provide *quantitative data* using closed (or fixed-response) questions, where the respondent is presented with a number of alternative responses to a question and asked to mark the one that she regards as most appropriate (Oppenheim, 1992). *Qualitative data* can be gathered using open (or free-response) questions to which respondents are asked to reply in their own words (ibid.).

The method using closed questions is criticised for forcing people to choose their answers from the provided alternatives rather than answering in their own words (Converse and Presser, 1986). However, closed questions are more specific than open ones and communicate the same frame of reference to all informants. Well designed response categories can more accurately detect differences among the informants. One argument against closed questions is that they may fail to provide an appropriate set of responses that are meaningful in substance or wording to respondents. However, the questionnaire design should begin with open questions in a pilot or pre-test work, in principle interviews (ibid.). These pre-test results can then be used to create appropriate sets of predefined responses for closed questions. Using open follow-up questions as probes of key closed questions can combine the advantages of both forms (ibid.).

3.4.1 Interviews 2005

The aim with the updated investigation in 2005 was to interview the same households for a second time in Vallgossen, Ringblomman and Smart Living. The main objective was to investigate if and how the residents' attitudes towards the smart home systems changed between 2002 and 2005 along with the use of it. Not surprisingly, some of residents had moved. Six new respondents, therefore, were selected to replace them. In all, 18 interviews were carried out.

Data on the respondents in Vallgossen, Ringblomman and Smart Living are presented in paper iii) and iv). The interviews were designed in the same way as in 2002, i.e. the respondents were able to talk freely. All interviews were tape recorded and notes were taken.

The same technique for coding and analysing the interviews were used as in the first phase, see section 2.4.6. The classification according to the five grade scale made it possible to identify differences and find patterns between the first and the second interview turn in Vallgossen, Ringblomman and Smart Living, see paper iii) and iv).

3.4.2 Questionnaires 2005

Questionnaires were sent to all households in Vallgossen, Ringblomman and Fatbursstranden, in total 365 households; of which 185 dwellings were equipped with IT functions. The results from the new interviews formed the background for the questions in the questionnaires.

The purpose was partly to find out what IT functions the residents used (or would like to use), and partly to see if some IT functions increased (or would increase) the residents safety in their home, building or neighbourhood. These latter questions covered a specific area of interest, some chosen in co-operation with the Stockholm County Police Authority.

The questionnaires and postage-paid reply envelopes were sent by post, see appendix 8. Two weeks later the respondents received a reminder to reply.

A common criticism of postal questionnaires is that they often get a low response rate. The response rate is the single most important indicator as to how much confidence can be placed in the results of a questionnaire. A low response rate can be devastating to the reliability of the study (Oppenheim, 1992).

The required response rate to ensure trustworthiness of the results depends on the degree to which the respondents are representative of the sample. Baker (1999) suggests that a response rate of 70 percent is adequate for a carefully selected sample, although this could still be unrepresentative if the 30 percent who do not respond represent a particular sub-sample within the population. Cohen, Manion and Morrison (2000) suggest that a researcher should be satisfied with a response rate of 50 percent. The response rate in Vallgossen, Ringblomman and Fatbursstranden is presented in table 3.

Table 3. Selection and response rate.

	Vallgossen	**Ringblomman**	**Fatbursstranden**
selection	126	59	180
number of answers	79	40	120
response rate	63 %	68 %	67 %

The dropout, which was about one third could be categorised into three types:

1. Respondents who choose not to answer the questionnaire at all, i.e. the difference between *Selection* and *Number of answers* in table 3.
2. Respondents who choose to answer specific questions with "no opinion". These respondents were disregarded in the mean estimation of the specific questions.
3. Respondents who choose not to answer specific questions. These respondents were also disregarded in the mean estimation in these specific questions.

The answering rate was acceptable in view of the discussion just above, and was also almost the same for the three cases. It is likely that additional answers would not have affected the results significantly. Therefore, it was assumed there was no reason for any deeper discussion of the dropout regarding type 1. Regarding the "no answer", "no opinion" responses, type 2 and 3, were generally too few for the questions to impose any bias of the result.

The distribution of household sizes, number of children and age among the respondents is presented in table 4, table 5 and table 6.

Table 4. Household sizes and types.

	Vallgossen	**Ringblomman**	**Fatbursstranden**
single	38 %	18 %	35 %
single with children	-	5 %	8 %
couple without children	35 %	42 %	22 %
couple with children	27 %	35 %	35 %

Table 5. The distribution of the number of children of the households.

	Vallgossen	**Ringblomman**	**Fatbursstranden**
0 child	74 %	60 %	58 %
1 child	16 %	25 %	10 %
2 children	9 %	10 %	23 %
3 children	1 %	5 %	6 %
4 children	-	-	3 %

Table 6. Age distribution of the respondents.

	Vallgossen	**Ringblomman**	**Fatbursstranden**
15 - 24 years old	4 %	3 %	3 %
25 - 34 years old	23 %	13 %	11 %
35 - 44 years old	20 %	25 %	27 %
45 - 54 years old	22 %	25 %	27 %
55 - 64 years old	16 %	28 %	16 %
> 64 years old	15 %	6 %	16 %

The analysis of the questionnaires used the statistics software package SPSS 13.0. Questions of interest for the thesis constitute ordinal scales. The results were analysed with the Mann-Whitney test, a nonparametric test (Siegel and Castellan, 1988). The test is a rank sum test and compares two unpaired groups by ranking all the values from low to high. The mean ranks of the two groups are compared. With a given level of significance the test yields an answer to the question if the two groups differ or not. The results are presented in section 3.5.4.

3.5 RESULTS

3.5.1 Vallgossen – Experiences 2005 from interviews

The third interview round in Vallgossen was conducted in February 2005. The aim was to gain knowledge of the residents' long term use and experiences of the IT functions. The results are presented in paper iv).

The following three functions were mentioned as most useful:

- the away lock,
- the electronic keys,
- the booking system.

No interest was shown for any other available function of the smart home system, such as the calendar, e-mail and e-notes.

All respondents in Vallgossen stated that they had had no problem with accessing the smart home system. At the beginning some problems occurred, which became less pronounced later on. The respondents revealed that they probably would have used more of the available functions if the set-up time was shorter. One particular household pointed to the disadvantage of using a laptop computer to cancel a false alarm, as it takes several minutes only to start the computer. A fixed connection to the smart home system would be a much better solution, according to this respondent.

3.5.2 Ringblomman – Experiences 2005 from interviews

The second interview round in Ringblomman was conducted during January – February 2005. The aim was to gain knowledge of the residents' long term use and experiences of the IT functions. The results are also presented in paper iv).

The following functions were mentioned as most useful:

- the booking system,
- the weather forecast,
- the broadband connection.

Opinions regarding other functions differ. Some appreciated the alarm system and the away lock, while others did not. One respondent looked at the energy measurement every day; other households did not pay any attention to this particular function.

The respondents did not use the calendar, e-notes or e-mail due to difficulties in using the touch screen to write. Most respondents used the smart home system every day to look at the indoor temperature, the weather forecast and the clock.

The use of the terminal and the smart home system had diminished over time, mostly due to its low reliability. For example, the individual energy measurement was often faulty, as was the weather forecast. The respondents did not trust the displayed information and therefore they did not use it. The reason why they used the weather forecast was more out of curiosity, e.g. to compare the TV forecast with the one predicted by the smart home system.

Opinions related to the electronic keys also differed. Most respondents appreciated the electronic keys for the lobby and for common spaces, however, not for the front door. They felt that the technology might fail. It could turn out to be really crucial if they were not able to enter their homes at all on return.

3.5.3 Smart Living – Experiences 2005 from interviews

The second interview round in Smart Living was conducted in February 2005, about three years after the first one. The aim was to gain knowledge of the residents' long term use and experiences of the IT functions. These results are also presented in paper iii).

The technical solutions were appreciated and gave an added value to their living. But, what functions the residents used depended on how well their individual needs were satisfied.

The following functions were mentioned as most useful

- the away lock,
- the lighting control,
- the access control system,
- the integrated system for television, telephone and computer.

Slightly less useful were the automatic sun blinds. They lacked a button that would shut off the sun blinds' automatic functions. One household noted that the sun blinds had two purposes, viz. first to block the sun on the terrace, then second, to block the sun in order to create a pleasant indoor climate. However, the sun blinds were only programmed to support the second purpose. If the residents sat on the terrace when it was windy they could not screen off the sun. Furthermore, the weather station which registered the wind speed was placed on the other side of the house and was not considering that the terrace and the sun blinds were on the lee side when it was windy.

The electronic keys and the heating/cooling system had decreased use, due to unreliable technology. The electronic keys did not function satisfactorily. Sometimes the residents must activate the key codes several times before the system responded accordingly.

The reception box was regarded least useful. No one shopped on the Internet. Some households, though, used the box for returning things to neighbours and friends when away from home.

The households felt uncertain regarding the future and they did not know from whom they could get help regarding the EIB technology (EIB, see appendix 4). "When the construction company's warranty period expires – what do we do then?"

3.5.4 Questionnaire survey – Results compiled

The questionnaire survey was done for the Vallgossen, Ringblomman and Fatbursstranden sites. The results from some of the questions have been published in a report[57] commissioned by the Stockholm County Police Authority. Other questions and answers are included as considered relevant for the present work, namely:

- the residents actual use of functions in the smart home system,
- what functions the residents would ask for if it was not available in their next home,
- the residents opinions regarding accessibility and ease of use,
- if some functions increase (or would increase) their feeling of safety,
- if some functions allow (or would allow) the residents to use their time more efficiently,
- if some functions results (or would result) in decreased living costs.

[57] See Sandström and Keijer (2006).

The results from the first three questions will be presented briefly in this section. These questions were not asked in Fatbursstranden. A deeper discussion of the results is presented in paper v).

Actual use of functions in the smart home system
The broadband connection was the most frequently used function. Three out of four households, 75 percent, in Ringblomman and 70 percent in Vallgossen used it everyday. The second most used function in Vallgossen was the away lock. A portion of 56 percent used it everyday, compared to only 25 percent in Ringblomman. The second most used function in Ringblomman was the weather forecast, as 48 percent used it everyday, compared to Vallgossen's five (5) percent only.

The usage of the indoor thermometer and the clock showed similar differences. 43 percent used the clock and 20 percent used the indoor thermometer everyday in Ringblomman. In Vallgossen these numbers were six (6) percent and five (5) percent respectively.

Functions the respondents would miss
The broadband connection would be most asked for if not available in their future home. Not less than 77 percent of the respondents in Vallgossen and Ringblomman would ask for the function "very much". Further, 53 percent in Vallgossen would ask for the away lock very much, compared to only 33 percent in Ringblomman.

The weather forecast, the clock and the indoor thermometer would be asked for much more in Ringblomman than in Vallgossen. One fifth, i.e. 20 percent, in Ringblomman would ask for the weather forecast and the indoor thermometer very much and nearly 25 percent rather much. In Vallgossen more than half (55 percent) would not ask for these functions at all.

Opinions about learnability, accessibility and support
About one third (34 percent) in Vallgossen stated that the smart home system was very easy to learn; one tenth, only, in Ringblomman declared the same. Most of the respondents (50 percent) in Ringblomman mentioned the system was rather easy to learn. The corresponding number in Vallgossen was 44 percent. In Vallgossen one in three claimed it was very easy to remember how to use the smart home system, while only seven (7) percent in Ringblomman agreed to that.

It seemed more important to have fast access to the broadband than to the smart home system. Four out of five (80 percent) in Ringblomman claimed it was very important to have fast access to the broadband, compared to 63 percent in Vallgossen. More than half of the respondents (53 percent) in Ringblomman mentioned it was very important having fast access to the smart home system. The corresponding number in Vallgossen was 28 percent. However, no significant difference between the sites was found.

The importance of external support was rated higher for the broadband than for the smart home system. 83 percent in Ringblomman claimed that it was very important with fast support of the broadband and only 48 percent mentioned the same regarding the smart home system. The corresponding numbers in Vallgossen were 65 percent (broadband) and 37 percent (smart home system). No significant difference between the sites could be shown.

Opinions of functions increasing safety
The residents were asked to specify to what degree some functions influenced (or would influence) their feeling of safety in their living, see table 7 for the specific questions. To answer "no opinion" was possible, as well. The scale was as follows:

#1 - very little/not at all
#2 - somewhat
#3 - rather much
#4 - very much
#5 - no opinion

The Mann-Whitney test was used to test for significant differences between the sites. If the *sig* value, for significance, is less than 0,05 (5 percent), the "null hypothesis" is supposed to be rejected, which means that there should be a significant difference between the two groups. In other words, one group ranks the current function significantly higher than the other group. The results presented in table 7 reveal significant differences (*sig* < 0,05) in opinion between Vallgossen and Ringblomman regarding all safety functions, despite the same smart home system were installed at both sites. Generally, the safety functions were valued higher in Vallgossen. The higher a median in table 7, the more a specific function is appreciated regarding the residents' feeling of safety.

Table 7. Median, mean ranks and rate of significance of the respondents feeling of safety regarding smart home functions. Sig. <0,05are underlined to highlight significant differences. (Mann-Whitney test).

Question: *Specify to what degree the following functions influence (or would influence) your feeling of safety in your living?*	**Group**	**Median (#)**	**Mean rank**	**Sig.**	**Mean rank**	**Sig.**	**Mean rank**	**Sig.**
Function 1	Vallgossen	4	61,74	**0,050**			96,55	
Fire alarm activated by smoke indication.	Ringblomman	4	50,72		68,29	0,879		**0,017**
	Fatbursstranden	4			69,30		80,48	
Function 2	Vallgossen	3	59,88	**0,001**			84,60	
The alarm signal will be sent as a text message (SMS) to optional mobile phone or to optional e-mail address.	Ringblomman	2	40,36		52,49	0,055		**0,047**
	Fatbursstranden	3			65,42		70,92	
Function 3	Vallgossen	4	62,24	**0,000**			100,95	
Burglar alarm which is activated by a motion detector in the hall.	Ringblomman	2	39,03		63,32	0,784		**0,000**
	Fatbursstranden	2			61,45		62,66	
Function 4	Vallgossen	3	61,11	**0,000**			94,26	
The alarm signal will be sent as a text message (SMS) to optional mobile phone or to optional e-mail address.	Ringblomman	2	36,77		56,29	0,327		**0,000**
	Fatbursstranden	2			62,92		65,67	
Function 5	Vallgossen	3	59,98	**0,030**			92,48	
Leakage alarm under the sink that shuts off incoming water when indicating any leakage.	Ringblomman	3	46,66		66,20	0,100		**0,000**
	Fatbursstranden	2			55,67		62,88	
Function 6	Vallgossen	3	56,99	**0,006**			84,78	
The alarm signal will be sent as a text message (SMS) to optional mobile phone or to optional e- mail address.	Ringblomman	2	40,53		56,82	0,585		**0,000**
	Fatbursstranden	2			53,43		59,30	
Function 7	Vallgossen	3	62,09	**0,033**			97,01	
Electronic keys at the lobby and common spaces, e.g. the common laundry room and the garage.	Ringblomman	3	49,01		68,22	0,364		**0,000**
	Fatbursstranden	2			62,06		67,39	
Function 8	Vallgossen	2	44,22	**0,012**			70,30	
Electronic keys in the front door to your flat.	Ringblomman	3	58,53		73,03	**0,002**		0,832
	Fatbursstranden	2			53,41		68,91	
Function 9	Vallgossen	4	63,81	**0,002**			107,65	
The burglar alarm is set on.	Ringblomman	3	45,74		68,66	0,674		**0,000**
	Fatbursstranden	3			65,66		70,05	
Function 10	Vallgossen	4	65,45	**0,000**			110,56	
Shuts off electricity to the stove.	Ringblomman	3	40,28		66,31	0,896		**0,000**
	Fatbursstranden	3			67,26		69,86	
Function 11	Vallgossen	4	63,78	**0,001**			110,24	
Shuts off incoming water after two hours.	Ringblomman	3	43,89		70,63	0,318		**0,000**
	Fatbursstranden	2,5			63,54		66,80	

The fire alarm (function 1) was ranked highest of all functions for the three sites (median #4). 68 percent in Vallgossen, 60 percent in Fatbursstranden and 50 percent in Ringblomman claimed the function increased their feeling of safety very much. Almost half of the respondents in Vallgossen (49 percent) claimed the burglar alarm (function 3) increased their feeling of safety very much. The corresponding share in Ringblomman was 23 percent and 16 percent in Fatbursstranden.

Almost half (44 percent) of the respondents in Vallgossen mentioned that electronic keys (function 7) affected their feeling of safety very much. One out of three (35 percent) mentioned the same in Ringblomman and less than one of four only (22 percent) in Fatbursstranden.

Ringblomman had also electronic keys to the flats' front doors (function 8). Over a third (35 percent) answered that it affected their feeling of safety very much. 32 percent in Vallgossen and 35 percent in Fatbursstranden claimed the function would increase their feeling of safety very little or not at all. There was no significant difference in opinion between Vallgossen and Fatbursstranden (sig = 0,832 > 0,05).

Opinions of functions supposed to save time

The residents were asked to specify to what degree some functions allowed (or would allow) them to use their time more efficiently. The specific questions are presented in table 8. The respondents were asked to estimate their use on the four-level scale described above.

The possibility to save time with different functions was generally regarded as low, see table 8. The booking system (function 12), showed a significant difference between Vallgossen / Ringblomman and Fatbursstranden. In Ringblomman, one out of four (27 percent) claimed the booking system allowed them to use their time more efficiently very much, 21 percent in Vallgossen chose the same option. Only 16 percent in Fatbursstranden answered "very much".

The laundry indicative status (function 13) was the only function in this category that showed a significant difference between Vallgossen and Ringblomman (sig=0,023). It was most appreciated in Ringblomman. 27 percent answered "very much", compared to only 5 percent in Vallgossen.

Table 8. Median, mean ranks and rate of significance of reported possibility to save time with smart home functions. Sig. <0,05are underlined to highlight significant differences. (Mann-Whitney test).

Question: *Specify to what degree following functions allows (or would allow) you to use your time more efficiently?*	**Group**	**Median (#)**	**Mean Rank**	**Sig.**	**Mean Rank**	**Sig.**	**Mean Rank**	**Sig.**
Function 12 *The booking system that makes it possible for you - via the smart home system - to book the laundry room, the sauna and/or the guestroom.*	Vallgossen	3	60,14	0,770			106,99	
	Ringblomman	3	58,25		87,61	**0,015**		**0,002**
	Fatbursstranden	2			68,91		82,80	
Function 13 *A notification in the smart home system telling you that the washing machines in the common laundry room are done.*	Vallgossen	2	54,52	**0,023**			91,69	
	Ringblomman	3	69,21		87,85	**0,013**		0,767
	Fatbursstranden	2			68,82		93,96	
Function 14 *Mutual calendar in the smart home system for all family members.*	Vallgossen	1	59,87	0,667			95,09	
	Ringblomman	1	57,33		73,54	0,931		0,546
	Fatbursstranden	2			74,17		90,64	
Function 15 *A chosen point of time before a booked appointment in the calendar a text message can be sent as an SMS to your mobile phone or as and e-note in the smart home system.*	Vallgossen	2	59,39	0,855			100,88	
	Ringblomman	2,5	58,25		81,85	0,119		**0,040**
	Fatbursstranden	2			70,35		85,55	
Function 16 *E-notes (electronic post it-notes) in the smart home system to remind yourself or others in the household.*	Vallgossen	2	61,44	0,143			98,21	
	Ringblomman	1	52,71		69,50	0,454		0,185
	Fatbursstranden	2			74,96		88,39	

The last three functions (function 14, 15 and 16) had a large dropout. About a third of the respondents in all three cases chose to answer "no opinion". Hence, the result should be interpreted with cautiousness.

More than half of the respondents in Vallgossen (55 percent) and Ringblomman (53 percent) mentioned function 14 did "not at all" affect their use of time in a more efficient direction. The corresponding share for function 16 was 50 percent in Vallgossen and as much as 62 percent in Ringblomman.

Opinions of functions decreasing living costs

The residents in Vallgossen and Fatbursstranden were asked, on a four-level scale, to specify to what degree some functions resulted in (or would result in) decreased living cost. Table 9 presents the specific questions. To answer "no opinion" was possible, as well. These questions were not asked in Ringblomman due to repeated failures in the energy measurement function. The same four-level scale as before was applied.

The respondents in Vallgossen had only access to three of the functions presented in table 9; function 17, 18 and 19. The other two functions were asked from a hypothetical point of view, as regards all questions asked in Fatbursstranden. A low median in table 9 shows that the function does not decrease the respondents living costs to any significant extent.

Table 9. Median, mean ranks and rate of significance of smart home functions affecting living costs. Sig. <0,05are underlined to highlight significant differences. (Mann-Whitney test).

Question: *Specify to what degree following functions have resulted (or would result) in decreased living cost in your household?*	**Group**	**Median (#)**	**Mean Rank**	**Sig.**
Function 17 *Individual measurement of electricity.*	Vallgossen Fatbursstranden	2 3	80,20 104,42	<u>**0,002**</u>
Function 18 *Individual measurement of hot and cold water.*	Vallgossen Fatbursstranden	2 3	83,78 101,78	<u>**0,023**</u>
Function 19 *Graphical presentation of energy consumption in the smart home system.*	Vallgossen Fatbursstranden	2 3	80,63 103,15	<u>**0,004**</u>
Function 20 *A possibility to individually set the temperature in every room.*	Vallgossen Fatbursstranden	3 3	84,77 102,04	<u>**0,027**</u>
Function 21 *A possibility via the smart home system to decide which lamps should be on or off at a given point of time.*	Vallgossen Fatbursstranden	2 2	90,69 97,96	0,350

The general opinions in Vallgossen were that these functions had no (or would not have any) effect on their living cost at all. Four out of ten respondents in Vallgossen mentioned function 19 had no effect on the cost while almost one third (29 percent) answered it decreased their living cost somewhat. The respondents' expectations in Fatbursstranden were higher than Vallgossen's experiences. Nearly one third (28 percent) in Fatbursstranden thought individual measurement of electricity (function 17) would affect their cost "very much", only 13 percent answered the same option in Vallgossen. One out of four (24 percent) in Fatbursstranden chose "very much" regarding the individual measurement of water (function 18), compared to only 8 percent in Vallgossen.

3.6 CONCLUSIONS FROM USER EXPERIENCES

3.6.1 Comments on the applied methods

The methods used in the second phase during 2005 were both semi-structured interviews and questionnaires. The multiple method approach was used in order to maximise the range of information. Each survey technique had particular advantages and disadvantages. By using a combination of different techniques, inadequacies of one of them is supplemented by the possible advantages of the other. The combination of data sources adds different perspectives to the available (triangulation). The results from the questionnaires were used to back up results from the interviews, and the interviews were used to explain some of the results from the questionnaires.

3.6.2 Major findings

The smart home systems of Vallgossen and Ringblomman were developed by the same company and the offered functions were much the same at the two sites. However, the residents' opinions regarding the functions differed. In Vallgossen the most useful functions were those which could be used without accessing the smart home system all the time, such as the broadband connection, the away lock, the electronic keys and the booking system. In Ringblomman the weather forecast, the booking system and the broadband connection were most useful. The differences may seem to be trivial, but offer interesting conclusions.

The screen solution, i.e. the laptop computer and the touch screen, were very important and decided to a great extent how frequently the residents used the smart home system. At Vallgossen, there was only one socket per flat to connect to the smart home system; the other sockets were to connect to the Internet. The laptop computer must be restarted when switching between the Internet and the smart home system. If one had to move physically and also to restart the laptop computer in order to be able to connect to the smart home system, one might very well abstain from using it. At Ringblomman, on the other hand, one did not need to login to the smart home system. The touch screen was always on and connected.

In Vallgossen most of the respondents had their laptop computer shut off or logged on to the Internet. No function in the smart home system required a daily visit by the respondents. This means that the respondents must have a need to visit the smart home system. In Ringblomman many respondents visited the smart home system every day, for functions such as the weather forecast and the clock.

The opinions on what kind of functions the respondents would ask for if not available in their future home differed between the sites, as well. The respondents in Vallgossen would ask for the alarm functions (burglar, fire and leakage alarms) more than those in Ringblomman. On the other hand, the respondents in Ringblomman would ask for the weather forecast, the clock and the indoor temperature more than the respondents in Vallgossen. The results correspond well with the residents' actual use of these functions in Vallgossen and Ringblomman, respectively, according to the previous analysis.

In Smart Living there were three functions in the smart home system that was ranked higher than the others; the access control system, the away lock and the lighting control. The integrated system for television, telephone and computer was also considered to be very useful.

The evaluation of the smart home system gave evidence that the concept of trust was important to consider. As mentioned in section 3.3.1, trust can be attributed to two different circumstances, i.e. trust related to the technology as such (expectation of proper functioning of hardware and software) and trust related to the information presented in the graphical user interface (expectation of the information to be reliable and valid). The results showed that residents' lack of trust affected their use of some functions negatively, e.g. the away lock and the energy monitoring.[58]

[58] See also paper v) for a deeper discussion regarding the concept of trust.

3.6.3 Technology reliability and quality of service

IT and telecommunication have always been areas where seconds and minutes of downtime can negatively impact the market value of its business. It is crucial that the physical infrastructure that supports the networking environment is reliable. In the International Telecommunications Union (ITU-T, 1994) recommendations E.800 reliability is defined as *"the ability of an item to perform a required function under given conditions for a given time interval"*. A commonly used method of quantifying reliability is MTBF (Mean Time Between Failures) which affects the concept "availability" in the evaluation model presented in paper iv) and above in figure 4.

The concept "Quality of Service" (QoS) can be defined in different ways and is becoming more and more prevalent in today's increasingly connected society. In the context of telecommunications the term is used as a way to assess if a service satisfies or does not satisfy user's expectations. The ITU-T recommendation E.800 defines QoS as *"the total effect of service performance that determines the degree of satisfaction of the user of the service"*. Both reliability and availability are components of the long term view of QoS.

The results from the second phase show that it is important for a smart home system to be available when asked for. If not, there is an obvious risk that residents loose interest in the offered functions. The importance of the availability to the smart home system and to the broadband was unanimous between Vallgossen and Ringblomman. Available and fast support was considered of utmost importance if a particular service failed.

3.6.4 New questions

From the beginning, the scope of the present research was to encompass both an early investigation on residents' valuation of their perceived desires of smart home functions of their new homes and their factual appreciation of such functions after having got acquainted with them shortly after having taken them into use. This was the first phase of the study which is described above in chapter 2. It was also asked to what extent these early findings of the users' perceived values of the smart homes were maintained over time, and what other experiences concerning the users' attitudes towards the new artifact could be asserted. This challenge was fulfilled in the second phase of the work and is elaborated in this chapter. In all, the original questions are answered, and the investigations could have stopped after some concluding summing up.

However, other phenomena were revealed during the course of the study, not pertaining to the specific functions and their benefit to the user, but nonetheless strongly affecting the perceived user values. As *user values* of smart homes is the main theme of this work, the work was felt to be unaccomplished without a deeper analysis of how the studied cases, Vallgossen, Ringblomman and Smart Living developed during the investigation period 2001-2005.

The chief event during the five years period was that the responsible actor[59] of the smart home technology in Vallgossen and Ringblomman, the principal technical developer e2-Home shut down its business. As compensation, the residents in Vallgossen were offered three non-integrated functions in their homes and, in addition, a traditional Internet connection. The functions were a booking system of common facilities, electronic keys and energy monitoring. The residents in Ringblomman were economically compensated. For Smart Living the conditions were different. Here the e2-Home was not engaged, which offers another interesting comparison between the different cases. Instead of single smart home functions, organisational issues will

[59] *Actor*, see appendix 1.

come into the foreground. Thus, a third phase of the study is called for, however not without a dramatic change of view.

Thus, the next chapter will be devoted to new matters within the same general framework of study objects. However, these new phenomena were not foreseen from the beginning of the research and no measures for investigating them were prepared in advance. They revealed themselves during the course of the study. In a way, the third phase should be seen both as a continuation of the foregoing and as a restart with new urgent questions. The scope is widened and the research methods are appropriately adjusted in comparison to the ones of the previous two research phases.

4 THIRD PHASE – SMART HOME SYSTEMS AND LONG-TERM VIABILITY

This chapter presents a radical change of the perspective on the studied matter. The previous chapters focused on end user opinions regarding smart home technology. During the course of the study new insights into the matter were made. New circumstances were revealed above all regarding the organisation of smart home technology provision and the long-term viability of smart home systems influencing the perceived value of it. Some models are introduced in order to be able to reason about the eventual outcome of the smart home undertaking as a whole. A complementary discussion on the applied research methods is effectuated. The models are applied to the studied cases. Finally, the governing question for the research – the user value of smart homes – is brought back in a tentative discourse about the necessity of a structure that is able to manage also smart home technology within the traditional construction organisation.

4.1 CHANGE OF VIEW

The two first phases of this study aimed to examine the residents' opinions about smart home systems, their functioning and appropriateness, regarding expectations before occupancy and after use, short-term and long-term. During the second phase, which took place after a sufficient period of residential use, it became obvious that long-term satisfaction with the systems largely depended on robustness of the systems and available maintenance in addition to the perceived benefits of the smart home functions. Maintenance and access to easy, swift and cheap upgrading of the functionalities seem to be important attributes, and increasingly so, for the long term viability of smart home technology in the domestic environment. Like installations of other kinds in today's homes and residential buildings, e.g. heating, ventilation, lifts, also smart home functions must work as faultless as possible and be able to maintain, repair and improve during the entire life cycle of the buildings.

In chapter 2, and in paper iv) the concepts *usefulness*, *usability* and *accessibility* were elaborated. The results from the interviews with the residents indicate that these concepts and their derivatives, see figure 4 in section 1.3 above, have to be ensured over time. Inevitably, the construction process of the home building, including the formation of functioning smart home systems, will then be brought into forefront. One has to observe, however, that the technology of smart home systems differs in character from ordinary building practice. The ordinary routines to handle installations in the construction process will not suffice. The variety and versatility of the systems in combination with the individual resident's varying demands and interests pose new challenges on the construction industry. The residents' lack of acquaintance and understanding of digital systems and interfaces adds to these challenges. In addition, "the development of the technology, the necessary organisation and the market are mutually intertwined in a not yet matured industry", a citation from Keijer and Nilsson (1996). The comment is still relevant.

The third phase of the present study therefore will focus on the *long-term viability* of smart home system. The objective is to offer a founded explanation of the final outcomes of the three undertakings studied in this thesis. Paper ii) presents the following three questions, viz. "how is a viable organisational and business model designed in order to create prevailing added value for the residents?", "what are the tasks and what are the actors' roles when included in the model?" and "what are the requirements on the actors in order to fulfil these roles?". These questions form the starting point for the third phase.

Four issues seem to be of particular interest in this connection and will be brought to the fore in the following, viz. 1) the process of adoption of new technology, 2) the competence bloc theory according to Eliasson and Eliasson (1996), 3) a role/actor model for the IT-based service delivery to the homes according to Keijer and Nilsson (1996), and 4) the housing construction process and its intrinsic prerequisites.

These generic tools are eventually applied to the study objects. Occurring divergences and incompleteness are identified and utilised for various plausible explanations of the outcomes of the investigated undertakings in Vallgossen, Ringblomman and Smart Living. In the end an attempt is brought about to carry back the analysis in this part of the study to the original user-oriented concepts, i.e. usefulness, usability and accessibility.

4.2 TECHNOLOGY PUSH – FROM VISIONARIES TO EARLY MAJORITY

Research on the adoption, acceptance, and use of new and emerging technology goes back to the early 1960s with the work by Everett Rogers on diffusion of innovations (Rogers, 1983). Regarding IT, three major features characterise the adoption of this technology in comparison to previous innovations: 1) critical mass, 2) regularity and frequency of use, and 3) the capacity of adaptation and modification by individual adopters (ibid.).

Innovation is a process characterised by interactions between enterprises, customers and society. Innovations originate either via "technology-push", i.e. technological development is behind the innovation (Schumpeter, 1984), or via "demand-pull", which means that innovations are driven by needs or desires identified in the market (Schmookler, 1966). A particular case of demand-pull is so called pre-competitive procurement, where a number of actors, not seldom by direct government engagement, form a strong first-buyer group, see e.g. Westling (1996).

When a technological innovation is introduced on the market its adoption develops gradually (Rogers, 1983), and is often modelled as a bell-shaped curve. The adopters on the market are categorised in five distinct groups, viz. 'innovators' (2,5 percent), 'early adopters' (13,5 percent), 'early majority' (34 percent), 'late majority' (34 percent) and 'laggards' (16 percent) (ibid.), see also figure 12. For a technological innovation to take off, the first two groups are most important in the first phase, however, the third group (the early majority) is crucial for the economic success and the long term viability of the innovation.

The innovator represents the igniting spark in the market. The early adopter wants to try new ideas, too, however, rather in a more guarded way. The role of the early adopter, from the market perspective, is to decrease uncertainty about the innovation by adopting it and conveying it to a subjective evaluation. The early majority is cautious as a group, but identifies and accepts new products or services on the market more openly than the average consumer. When it comes to the rate of adoption – not less important in order to win market success – it depends on a variety of factors, i.a. (ibid.):

- perceived benefit compared to alternative products,
- communicability of the benefits of the product,
- price and ongoing costs,
- ease of use,
- promotional effort,
- distribution intensity,
- perceived risk,
- compatibility with existing standards and values,
- divisibility (the extent to which a product can be tested on a limited basis).

Geoffrey Moore (1991) bases a similar theory on diffusion of innovations on that of Roger, adding the observation that there is a distinct chasm between early adopters and early majority. Moore's key point is that these two groups adopt new technology for entirely different reasons. The early adopter pursues a "radical change" while the early majority looks for a "productivity improvement". The latter group wants a complete functioning product; while the constituents of the former group are satisfied in principle with the core product and consider themselves having the technical skill and economical resources to make the product work.

The challenge with the development of a new high-tech market lies in making the transition from an early market dominated by a few visionary customers (early adopters) to a mainstream market dominated by a large block of customers, essentially an early majority (ibid.).

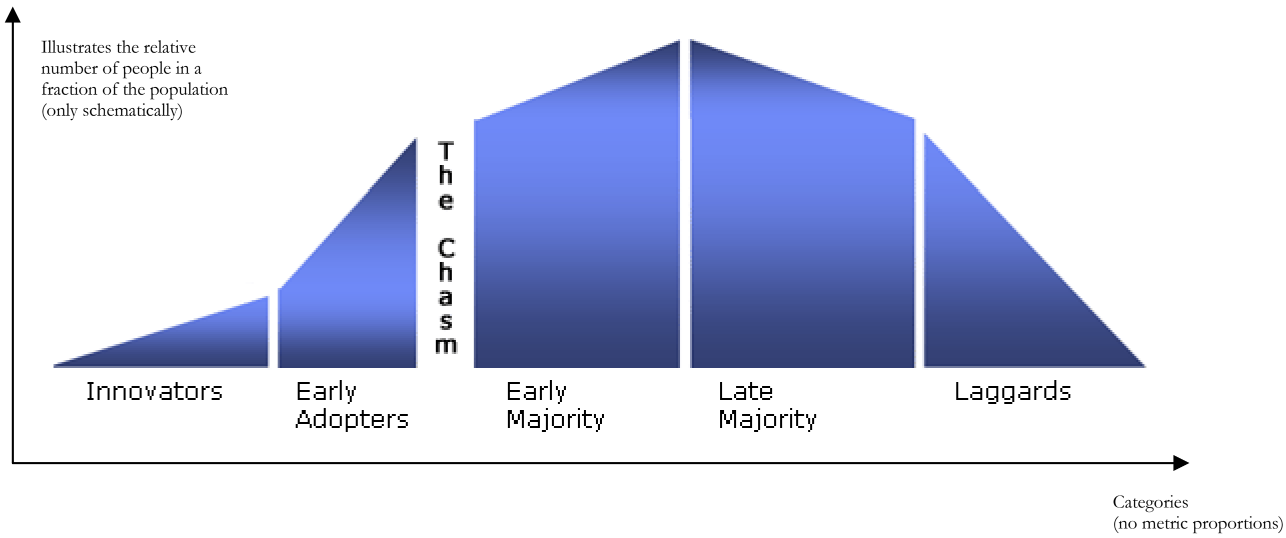

Figure 12. Innovation-adopting categories (Rogers, 1983) with the chasm as defined by Moore (1991).

It is difficult to draw any conclusion regarding the group to which the residents in Vallgossen, Ringblomman and Smart Living is supposed to belong. However, it is likely that the smart home systems, consciously or unconsciously, affected their choice of dwelling. Many respondents had occupations within the IT sector, see table 2 in paper iii) and table 1 in paper iv). There is reason to assume that these respondents were interested in having smart home technology, or as some of them mentioned "fun", in their new dwellings. At the beginning of the 21st century, there were not many dwellings equipped with this kind of technology. However, it is a question not analysed in depth.

The governing ideas of e2-Home's business concept were developed within Ericsson Denmark in the end of the 1990s.[60] The principal purpose was to meet the challenges facing the telecom industry owing to the commercial breakthrough of the Internet in the mid 1990s (Madsen and Ulhøi, 2002). In order to understand the market, focus-group interviews were established to get a first-hand understanding of the end users as human beings. Each group consisted of five to ten people of the same age and sex. Half a day was spent discussing communication and information technology, the other half on discussing quality of life – happiness, dreams, expectations, concerns, agonies, etc. The purpose of the latter was to discover unarticulated needs with regard

[60] The short history of e2-Home and its business concept is presented in appendix 2.

to available means of communication, from which requirements of the new technologies could be derived.

The results showed that early adopters were characterised by what was defined as male values (Madsen and Ulhøj used the term "masculine values"). The mass market, on the contrary, was characterised by female values, see appendix 2. The mass market, representing 90% of the market, displays no interest in technology as such and focuses on use and benefit only. It exhibits no tolerance towards complexity and errors; quality is a prerequisite in all respects (ibid.). The development of e2-Home system was essentially based on the knowledge generated by these focus groups.

It is not possible to make a definite conclusion about the e2-Home venture or if the chosen approach really had the potential to succeed in developing a smart home system for the mass market. The undertaking was discontinued too early. Nevertheless, there is no doubt that e2-Home was truly user-oriented and the technology was seen only as a vehicle to achieve real user benefit. In connection with the general market down-turn in the beginning of year 2000[61] (the burst of the dot.com bubble), e2-Home was reconstructed and shut down completely after a couple of years.

The burst of the dot.com bubble 2000-2002 influenced many ventures at the time. If e2-Home was one of these is conceivable but still an open question. The *competence bloc theory* (the CB theory) may shed some additional light on the necessary market components to be present for a prosperous business development of the kind e2-Home represents. This theory and its bearing on the venture studied here will be the object for treatment in next section.

4.2.1 An incomplete innovation

It is well known that economic growth principally arises as a consequence of either 1) increased use of production factors, such as labour and capital, or 2) increased productivity. A combination of the two is common (Solow, 1956). History has shown that increased productivity is the main driver of economic growth. Higher levels of productivity are generally results from the creation and use of new knowledge – the technology factor (Hayek, 1945; Romer, 1990; Edquist[62], 2009).

According to the competence bloc theory (Eliasson and Eliasson, 1996), the creation and application of new knowledge with the potential to increase the productivity of companies (and wider, to contribute to the growth of nations) is a complex process. The role of the CB theory is to explain the competitive selection processes generating growth. When efficiently organised, the CB organisation minimises the incidence of errors of two types, viz. 1) keeping losers going on for too long and 2) loosing the winners (Eliasson, 1997). The theory is an analytical vehicle with the purpose to explain the development of an (new) industrial organisation driven by the complex interaction of competent actors.

The actors of the CB carry out critical economic functions, i.e. to identify, select, expand and exploit business opportunities. It is based on a micro-economic perspective and understands economic growth as an innovative project selection process and stresses competence, institutional conditions, entrepreneurship, and the dynamics of economies.

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[61] The dot.com bubble is described in section 4.2.2.

[62] In Swedish.

In principle, a competence bloc consists of actors taking six specific roles (Eliasson and Eliasson, 1996):

- *the competent and active customer*, for example a major industry, a governmental or public organisation, or a well defined and well organised socio-cultural group of customers, demanding high-technology products,
- *the innovator* who integrates old and emerging technologies in new ways and finds new solutions,
- *the entrepreneur* who identifies profitable innovations and who has the ability to implement the new solutions on the market,
- *the venture capitalist* who recognises and finances the entrepreneur in an early phase of the innovation,
- *exit markets* facilitating ownership change and thereby transfer investment capital from losers to winners,
- *the industrialist* who has knowledge and access to resources in order to take successful innovations to production on an industrial scale.

The innovation and selection process in the competence bloc is organised as follows (ibid.):

First, the product chosen or created in the process never exceeds what the customer demands, is capable to appreciate, and willing to pay for. The long-term direction of technical change is always set by the customer, also when the innovator, entrepreneur or industrialist takes the initiative.

Second, basic technology may be available internationally, but the capacity to receive it and make a business of it requires local competence.

Third, the task of the entrepreneur is to identify commercial winners among the suppliers of innovations and to bring his/her choice of technology commercially viable. The entrepreneur rarely has resources of his own to move the project forward.

Fourth, the entrepreneur needs funding from a competent venture capitalist, i.e. a provider of risk capital, capable of understanding innovators of radically new technology and able to identify business needs and provide a context. In fact, the money is least important. What matters is the competence to understand and identify winners and, hence, provide reasonably priced equity funding (ibid.).

Fifth, the venture capitalist and his escape (exit) market are the most important incentives supporting actors. With no understanding of venture capitalists the price of new capital will be prohibitively high or not available, and winners will be filtered away. With badly functioning exit markets the incentives for venture capitalists will be small and, hence, also for the entrepreneurs and the innovators.

The main purpose of the competence bloc is to identify winners, to find external financing and to move on to the industrial scale of production and distribution (Eliasson and Keijer[63], 1998). All roles of the competence bloc are crucial and must be filled. If the competence bloc is not appropriately complete there is an obvious risk that probable winners will get lost.

[63] In Swedish.

In addition, the competence bloc theory can help to identify missing parts in the market and explain the negative market development. In paper iii) the Smart Living project was analysed employing the competence bloc theory. Here, the focus will be directed at the actors in Vallgossen and Ringblomman.

The first role, *the competent and active customer*, is represented by the marketing and sales division within the construction companies (JM and Skanska). These divisions are consumer oriented and conduct market research regularly. They can be seen as representatives of the future group of end-customers[64].

The second role, *the innovator*, is held by the technology company that developed the smart home system in Vallgossen and Ringblomman (e2-Home). The company created the system with new winning combinations of old and new technologies and this constitutes the typical innovator of a competence bloc.

The third role, *the entrepreneur*, is also presumed to be held by the construction companies; however, now by their production divisions. These divisions develop the buildings, procure all site work and deliveries and monitor the construction work. The entrepreneur has the knowledge to use new or existing products and processes for the production of homes.

Table 10. Roles and actors in Vallgossen and Ringblomman.

Roles according to the competence bloc theory	**Actors in the projects**
Competent customer	*Marketing and sales division within the construction companies*
Innovator	*e2-Home – developed the smart home system in Vallgossen and Ringblomman*
Entrepreneur	*Production divisions within the construction companies*
Venture capitalist	*n.a.*
Exit markets	*n.a.*
Industrialist	*n.a.*

One of the construction companies indicated a need for a new actor on the market; a system integrator with the purpose to offer other construction and real estate companies an overall solution with business development, project management, procurement and quality audit. This company also spent considerable time to discuss the possibility to acquire a share of the company providing this technology. However, both the prospect for the new system integrator and the acquisition of shares were withdrawn, most likely as a consequence of the marked fall in the stock market from 2000 and on, which hurt the IT sector in particular, see section 4.2.2. The prospect was never presented to any *venture capitalists* or a corresponding function and, as a consequence, the discussion of the potential availability of an *exit market* or a possible *industrialist* to complete the competence bloc was void. Obviously, severe obstacles were identified for a prosperous take off of the e2-Home invention.

[64] The housing industry is affected by the particular problem that consumer's preferences are often manifested considerable time after the planning phase. Implicitly or explicitly the building client or the builder itself replaces the ultimate consumer's role.

4.2.2 *The dot.com bubble*

The term *Information superhighway* was coined in the early 1990's by Al Gore, describing the expansion of Internet beyond its then-current state. With the rapid growth of Internet many new companies popped up. Intel produced its first Pentium processor and Microsoft introduced Windows 95. Several programs for viewing content on the Internet were developed, e.g. Internet Explorer and Netscape Navigator. E-commerce started. A multitude of companies like Amazon, Yahoo and AOL grew rapidly by exploiting the increasing momentum of the Internet, in its turn spurring Internet further on into the commercial and governmental sectors.

The Internet became a playground for businesses aiming to reach a worldwide market with limited overhead cost. The possibility to sell goods and handle advertising, sales and customer relations led to the realisation of new business models and a substantial increase of revenue. The Internet wave covered roughly 1995-2001 (with a peak in March 2000) during which stock markets in Western nations saw their value increase rapidly from the new Internet sector and related fields. When the dot.com bubble eventually burst, the result became a moderate, though long-lasting recession, predominantly in the Western economies.

e2-Home, the company that developed the smart home system in Vallgossen and Ringblomman, was established in October 1999[65]. At first, e2-Home experienced a rapid growth. Several development projects and a large field trial in Denmark were initiated. In the end of year 2000 the effects of the dot.com bubble troubles started to affect e2-Home, too. During the following years, e2-Home gradually wound up its activity. It was completely terminated in 2005.

4.2.3 *Some further theoretical notions*

This may be the place for a brief discourse on the methodological question pertaining to the discussion just above. The smart homes undertaking of the present scale, at a certain place, at a certain period of time and with a certain set of actors, cannot be considered to be unaffected by the prevailing societal conditions at the time, neither technologically nor economically.

Going back to the two first phases of the study presented in chapter 2 and 3, it is quite clear that the treatment is based of a combination of two generally acknowledged methods of analysis, *induction* and *deduction* (Lundequist, 1995; Alvesson and Sköldberg, 2008)[66]. Induction develops facts from the particular to the general. The method does not ensure truth, but "it offers a possibility to reach conclusion of unobserved things on the basis of what have been observed". Induction requires some hypothesis, at least implicitly. Deduction, on the other hand, is a method offering a possibility to define a statement as valid or not valid (Alvesson and Sköldberg, 2008). However, it requires that the presumed preconditions are valid in the first place. Roughly, it is possible to state that the reported interviews in chapter 2 and 3 leading to a more precise understanding of the study object were based on inductive reasoning. This understanding contributed to the phrasing of the questions of the survey. The statistical analysis in chapter 3 of the results from the survey was clearly deductive.

In a more open situation where the observable set of facts are more complex and influence each other, induction, the only alternative, is hardly applicable in order to arrive to more general conclusions. The spectrum of possibilities is too wide. A third alternative, however generally with a lower degree of validity, is the abductive validation. "This can be called reasoning through successive approximation. Under this principle, an explanation is valid if it is the best possible

[65] A more detailed description of e2-Home is presented in appendix 2.
[66] In Swedish, for English, see for example Wikipedia "induction" and "deduction", respectively.

explanation of a set of known data". *Abductive reasoning* starts from a set of accepted facts and infers their most likely, or best, explanation (Alvesson and Sköldberg, 2008)[67]. Abduction is used as a method to generate – not to verify – hypotheses (ibid.).

Above in this chapter, some phenomena were described that might have significant influence of the development of Smart Homes in Sweden, in particular the projects studied in this work; The discussion concerned the presence of the dot.com bubble that slowed e2-Home's activity, the inherent difficulties with the chasm when introducing new technology on a larger scale, and the incomplete competence block affecting the innovation to take off. These are real facts pertaining to the studied cases. However, further explanations of the perceived failure or relative success will be pursued, in line with the principle of abductive reasoning. The housing construction process in Vallgossen and Smart Living, respectively, utilise some dissimilar characteristics regarding the organisation of the smart home technology development. These dissimilarities in organisation of the provision of technology will be utilised in the following in order to gain further indications of the reasons for the different outcomes of the mentioned ventures, both developed by the same construction company. Before that however, a model for long term delivery of IT based services to the home will be introduced. It will be used as an explanatory tool for the concluding analysis.

4.3 ORGANISATION OF TECHNOLOGY

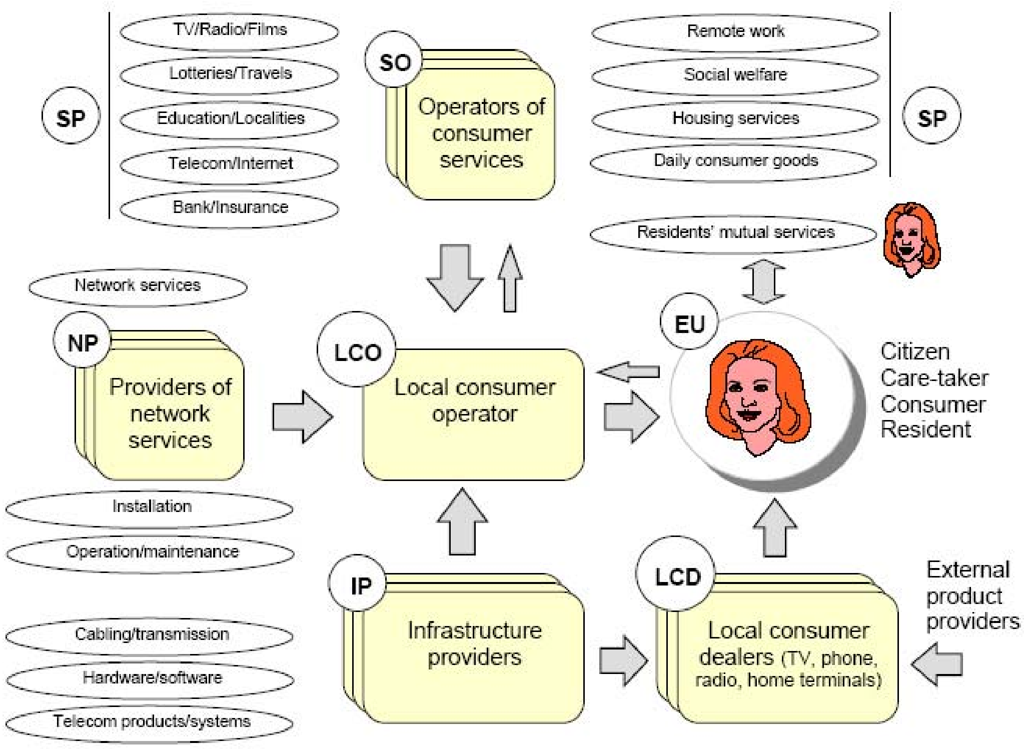
4.3.1 A performance model for IT-based home services market

Keijer and Nilsson (1996) elaborated the emerging market of home services based on information technology and telecommunication. The subject was based on a general discussion on a role-actor model for service delivery and the value added chain. It was argued that the new technology had the potential to offer the end consumer in his or her home strength enough to demand and acquire the desired service, instead of relying on offerings provided by traditional service providers, typically telecom operators. The principal question posed by the authors was: "why and how should a new demand chain be established from the end consumer living in her home to the particular service provider?"

The concept *service provider* was then understood not only as the telecom operator but as all kinds of enterprises offering services of any kind towards individuals living in their own homes. This includes such different providers as grocery stores, chemist's shop, travel agencies, local carers, municipality services, congregations and associations of different kinds, banking services, etc. Internet as well as telecom operators are included, provided these entities do not establish a monopoly and a working control of the service supply chain. The end user should be able to acquire the service he or she asks for, in principle at any time a need arises. The resulting business structure of cable networks for television was pointed out as a cautionary example. A complete monopoly, often based on long contractual periods, locked in many housing companies and their tenants in service packets defined by the television service providers. This was a situation to be avoided with the new digital networks.

With this background in mind Keijer and Nilsson developed and described in their above-cited article, a business model for implementation of consumer services. Their expressed purpose was to put the consumer/resident in her home and her desires in the centre. The model defines several independent business roles and actors, related to each other, in order to fulfil the services. Between the actors taking these roles there are a flow of services and products, payment and information.

[67] For English, see Wikipedia "abduction".



EU	*The end user*, the objective for the services provided. In this context the consumer is the resident in her home asking for a particular service,
IP	*The physical infrastructure provider*. Provides the basic communication system and necessary software, aiding the *LCO* to run his business successfully.
LCD	*The local consumer equipment dealer*. Provides easy access for the consumer to purchase and repair of personal hardware and software, see discussion above.
LCO	*The consumer operator*. The role that contracts services on behalf of the consumer. Monitors rules for agreements and transactions induced by an agreement.
NP	*The network operator*. Defines the access rules for the transactions on the telecom network and upholds quality of service, QoS. In principle, the network operator itself should not engage in service provision. In such a case the free access to the business structure could be jeopardised, as the network operator could favour its own services to those of its competitors, and the "open" character of the system deteriorates.
SO	*The services operator*. The services operators engage different service providers and organise the providers in viable services clusters. The services operator can itself be a service provider, concurrently competing with other ser-vices operators, by offering the consumer service packages through the *LCO*.
SP	*The service providers*. Entities offering different services to the home, including Internet and entertainment media.

Figure 13. The Business structure model as developed by Keijer and Nilsson (1996).

The model was an early attempt to define a structure putting the consumer's individual interest in focus – not the service providers, who generally see their possible supply to a broad and uniform customer base as their primary business target.

The resulting model is depicted in figure 13. The consumer is interested in a variety of services, for a good and developing living. However, she or he cannot handle all offered services and know how to choose between an increasing numbers of options. A particular new agent/role, first named the *access operator,* later more adequately, the *local consumer operator* (LCO) was introduced, who, on behalf of the end users, negotiates with different service and product providers in order to fulfil the end users' needs.

Another actor, of specific interest for this thesis, is the *local dealer/technician* (LCD). The very fast market development of the television market some fifty years ago had not been possible without the local dealers around the corner. This man (always a man at that time) could provide advice, equipment, installation and repair services, necessary for ignorant telly watchers. In the model, figure 13, this role is included in the lower right corner. It is assumed that the same role (although not necessarily just around the corner) will be necessary for a viable business structure, also for the new digital service deliveries. This particular agent will play a significant role for the final analyses in the following.

The different roles of the model are explained in detail in figure 13. It is important to make a clear distinction between *roles* on the one hand, which are parts of the model and *actors,* on the other hand, which are the real agents that adopt and fulfil these roles.

An obvious requirement for a viable business based on the model, actors willing to fulfil these different roles have to enter the scene, and necessary agreements between these actors have to be established. These agreements must be based on commercial considerations. Otherwise the structure will dismantle successively, and services to the customer will be fulfilled in ways not primarily in the consumer's interest.

The theoretical model, presented in figure 13, formed a starting point for the first attempt to establish network services to tenants of the housing company Svenska Bostäder, in Stockholm, in their Vällingby branch, see Hunhammar (1998). The principal model has persisted over the years. However, it has been found, so far, that the LCO has difficulties to establish a long-term viable business role. Its contribution in the value chain is too modest, at least until now, to offer a viable business opportunity. The Internet operator has more or less replaced the LCO as the key consumer operator. In Vällingby, however, a number of Internet providers compete, and by that, preserving the original idea of keeping the end users' interest in focus.

The model and its components will be used extensively in section 4.4, in order to explain some of the shortcomings of the long-term viability of the studied smart home undertakings. The next issue to be treated is the current housing construction process, in order to be able to examine its possibility to contain also essential parts of a service delivery model of the kind just considered.

4.3.2 The housing construction process – The governing agenda

During the period 1940s-1980s, the Swedish housing policy developed as part of a general welfare policy. The goal was to ensure that everybody, also low-income households, could find comfortable and affordable dwellings. Decent housing became a social right. Within this framework, an important tool for Swedish housing policy was the municipally owned public housing companies. Housing construction was underpinned by big governmental subsidies. A radical change took place in the beginning of the 1990s. Albeit not abandoning the social rhetoric, the housing policy became markedly market oriented. Strong economic development, in general combined with low interest rates and increasing salaries, boosted the housing market despite discontinued subsidies during the 1990s (Werner, 2003). Within this framework, private construction companies prospered, focusing on production of residential units for housing associations, like Vallgossen and Ringblomman.

The business model for the private housing construction companies that developed Vallgossen and Smart Living is the *project development*[68] model. If houses could be developed with high quality, at low cost and in short time an opportunity for ample profit arises. The process starts usually with the acquisition of land. Next follows a planning phase that engages architects and other consultants. Figure 14 shows a schema depicting the most typical actors during the planning and construction phase and their relative positions in the construction process according to the model.

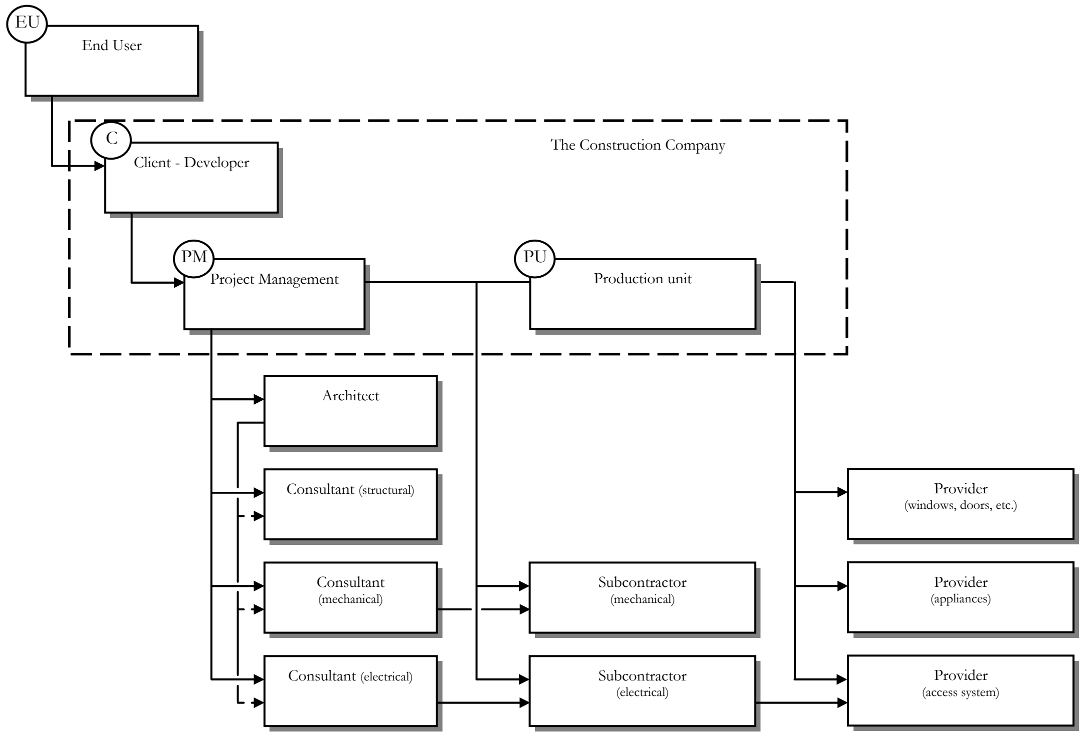


Figure 14. Organisation schema during an ordinary planning and construction phase.

According to figure 14, the activity of the housing construction company, marked by the dashed line, fulfils three key tasks. The first task is that of the Client-Developer, C, which is fulfilled by the company's marketing and sales division.

The idea is to identify relevant components of a possible competence bloc for the development of a viable smart home business structure. Accordingly, the Client-Developer[69] is most appropriate assigned to the "the competent and active customer" role in the competence bloc structure, see section 4.2.1.

The second task, Project Management, PM, includes usually both the project management and the planning management in one single entity. The PM monitors the over all planning of the project as a whole, while the specific planning manager's responsibility is confined to the planning phase. The PM puts together necessary competences for the planning phase, and, by that essentially fulfils "the entrepreneur's" role of the competence bloc.

[68] *Project development*, see appendix 1.
[69] See footnote 64.

As a third task, the Production Unit, PU, procures subcontractors and deliveries and monitors the construction work at the site. This is the traditional entrepreneurial role of a construction company, and it is linked, but subordinated, to the PM.

Figure 14 outlines the habitual working procedures of any construction company that has to identify its customers, to plan and produce attractive dwellings and eventually to sell them on a competitive market. In the next section the picture is developed by deploying the planning and delivery of smart homes functions into the general schema.

4.3.3 The construction process with smart home functions

Figure 15 illustrates the organisation chart for the Vallgossen project where two new roles/actors, are introduced into the planning and construction process, viz. the Consultant (smart homes), CSH, and the Subcontractor (smart homes), SSH. For the sake of clarity, from here, in this chapter, Vallgossen serves as the single reference case. The small differences between Ringblomman and Vallgossen are insignificant in this connection.

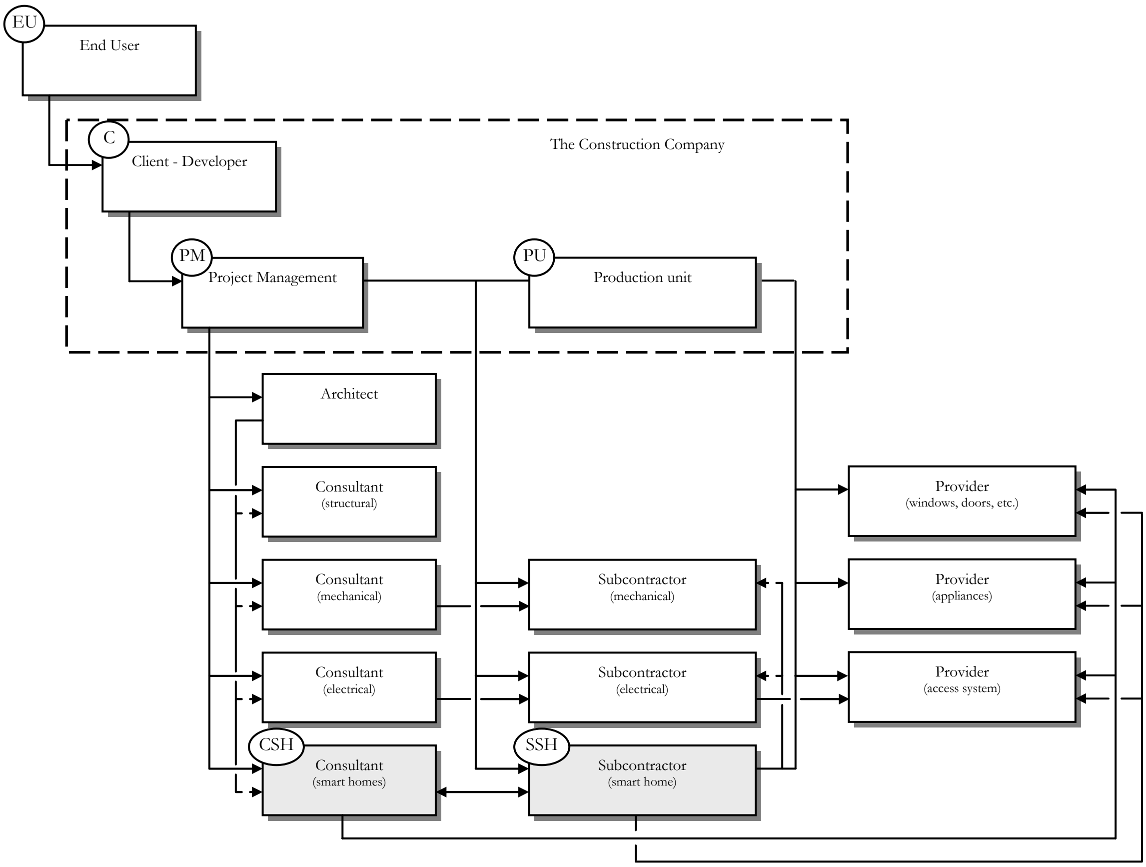


Figure 15. Organisation schema during the planning and construction phase in Vallgossen. Note in particular the two additional roles, the CSH and the SSH.

The Consultant (smart homes) principal function was to act as a liaison between the Consultant (electrical), CE, and the Subcontractor (smart homes). The latter had no experiences from the construction industry and was far from familiar with its working culture. It consisted of people from the telecom and appliance sector, predominantly from research and business development.

The effect of including the new actor, SSH – in fact fulfilling a key role – was that traditional boundaries of the planning and construction phase were disarranged. SSH represented a serious and huge undertaking (e2-Home) and was committed to bring the venture to success. Representatives from the SSH were present during the whole planning and construction phase and continuously put requirements on other consultants, subcontractors and providers.

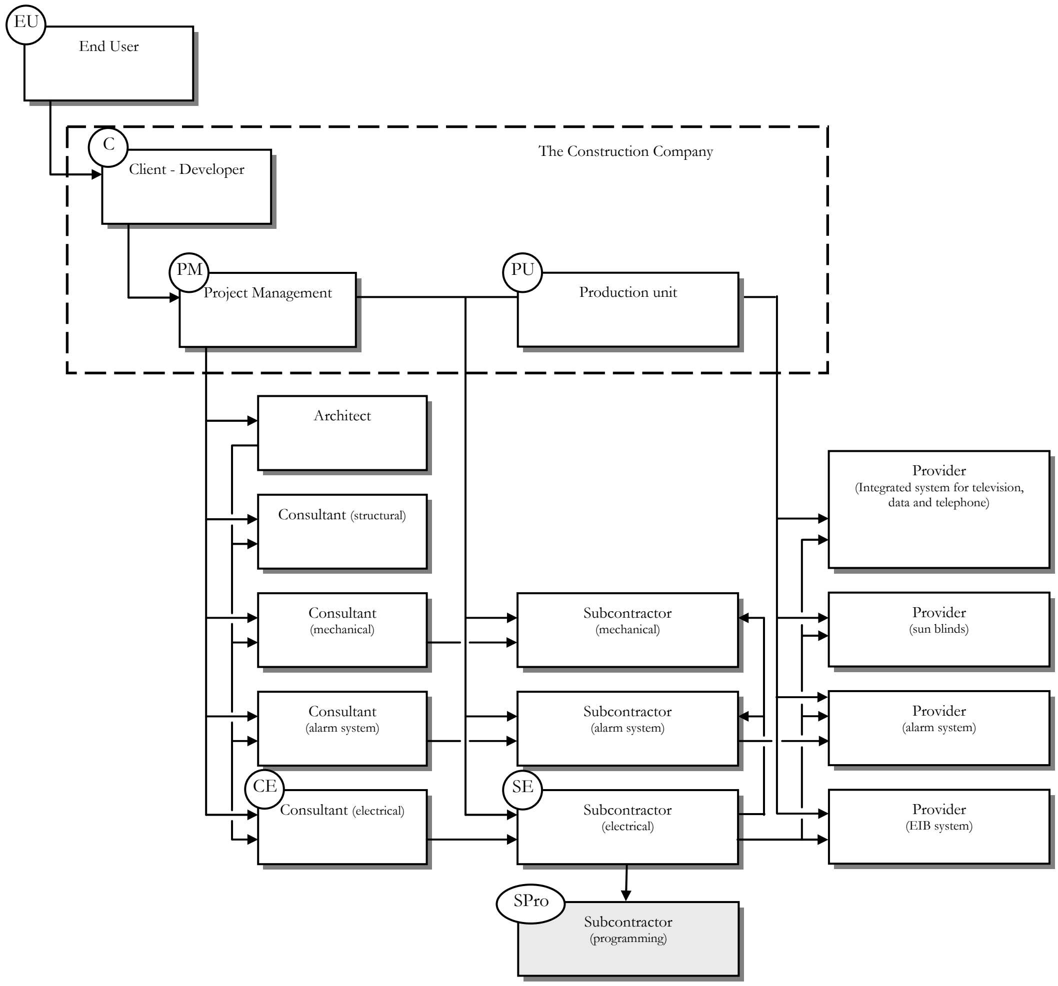


Figure 16. Organisation schema during the planning and construction phase in Smart Living.

The organisation schema in the Smart Living project was different, figure 16. In this case the Client-Developer decided what functions to offer the end users and the Consultant (electrical), CE, suggested the use of the EIB system. The responsibilities for the smart home system was assigned to the Subcontractor (electrical), SE, which in turn engaged a Subcontractor (programming), SPro, for the installation and start-up of the EIB system. The smart home system was based on available technology, which was not the case in Vallgossen where the e2-Home development was installed. So, a specific Subcontractor (smart homes) was not required in Smart Living. The installation was accomplished fully by the Subcontractor (electrical). For Vallgossen the smart home system was developed in a laboratory environment in parallel with the construction of the building.

The difference in the organisation between the two sites, Vallgossen and Smart Living, during the planning and production phases is informative. New actors were introduced into the construction process, but to different extent, in order to realise intended smart home functions. This part of the venture was relatively easy to plan and appraise, at least in comparison to more unpredictable circumstances later on.

Thus, the next section will focus on the post-occupancy phase, where the principal theme for this thesis – the user values of smart homes – again will be brought into the forefront. The new actors were to meet new challenges, as the focus moved from development to use.

4.3.4 Roles and actors for long-term viability

Results from first and second phases of this investigation revealed that the smart home technology is believed to deliver usefulness, in principle without malfunctions. If problems did occur, still, the users preferred to have only one specific number to call, regardless of the kind of trouble. The possibility to connect one's house to a service operator pleased all six residents of Smart Living. In addition, the capability of the system to allow for error detection and monitoring the EIB system at a distance was seen as an attractive quality. A similar service was not available at Vallgossen.

In section 4.3.1 a service delivery model to the consumer in her home developed by Keijer and Nilsson (1996) was presented, see figure 13. The model defines roles to be fulfilled by different actors if services are to be offered based on end user preferences. In order to establish a long term viability service structure these actors must be profitable over time. The four different roles that could be identified in both Vallgossen and Smart Living during the post-occupancy process are given in table 11.

Table 11. Description of different roles on the market during the post-occupancy process according to figure 13.

Role	Code	Task
Local Consumer Operator	LCO	Co-ordinates services to the end users on request.
Service Provider	SP	Provides merely cable-TV and broadband services.
Technical Provider	TP[70]	Provides communication infrastructures and network.
Local Technical Service Provider	LTSP	Technician available on request.

These roles were realised by actors already engaged in the construction process. The organisation schema in Vallgossen, presented in figure 17, shows that the SSH actor took three roles in the post-occupancy process; the LCO, the TP, and the Local Technical Service Provider, LTSP. It is easy to imagine how vulnerable the post-occupancy phase was; a failure or drawback by SSH, i.e. the e2-Home, would jeopardise the existence of the whole smart home system.

[70] The two roles, IP and NP, in the Keijer-Nilsson model (figure 13) are merged into one single role, the Technical Provider, TP, in the following, in order to simplify the presentation.

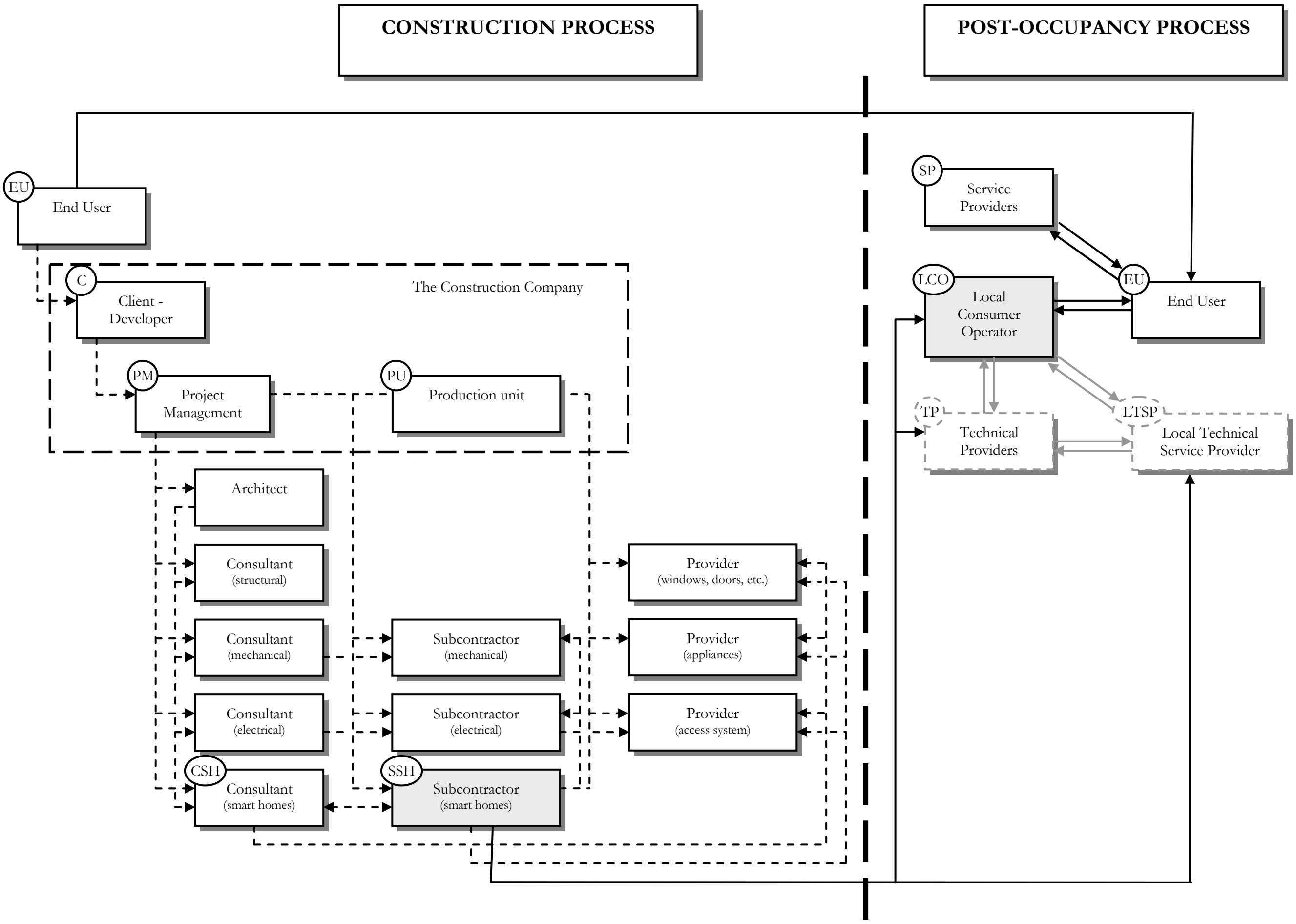


Figure 17. Co-ordination and dependencies in the construction/post-occupancy process in Vallgossen. Left part from paper ii). Right part illustrates the long-term role structure.

The boxes "Technical Providers" and "Local Technical Service Provider" are dashed in figure 17 as actually non-existent, as the SSH alone had knowledge enough to fully understand the smart home system. The SSH was the only point of call if help was required.

The construction company had a customer service for the residents (the end users), but that did not include the functions of the smart home system. Broadband and cable-TV were also directly offered to the residents and not via the smart home system.

For Smart Living the roles in the construction and post-occupancy process are depicted in figure 18. Here, the construction company took the role as the LCO during the first two years after occupancy. If the residents (end users) needed help with the smart home system they called the LCO who, in turn, contacted the LTSP. The LTSP role was realised by the actor SPro, who installed the EIB system. The residents were able to call the LTSP directly, as well. All necessary technical items were generally available on the market by several Technical Providers. Knowledge of the EIB system among electricians became more widespread at the time. A replacement of the actor SPro was therefore practically possible. The users were not locked in with an expert of a particular one-of-a-kind system. As in Vallgossen, however, there were no services such as Internet and cable-TV offered by the LCO in Smart Living.

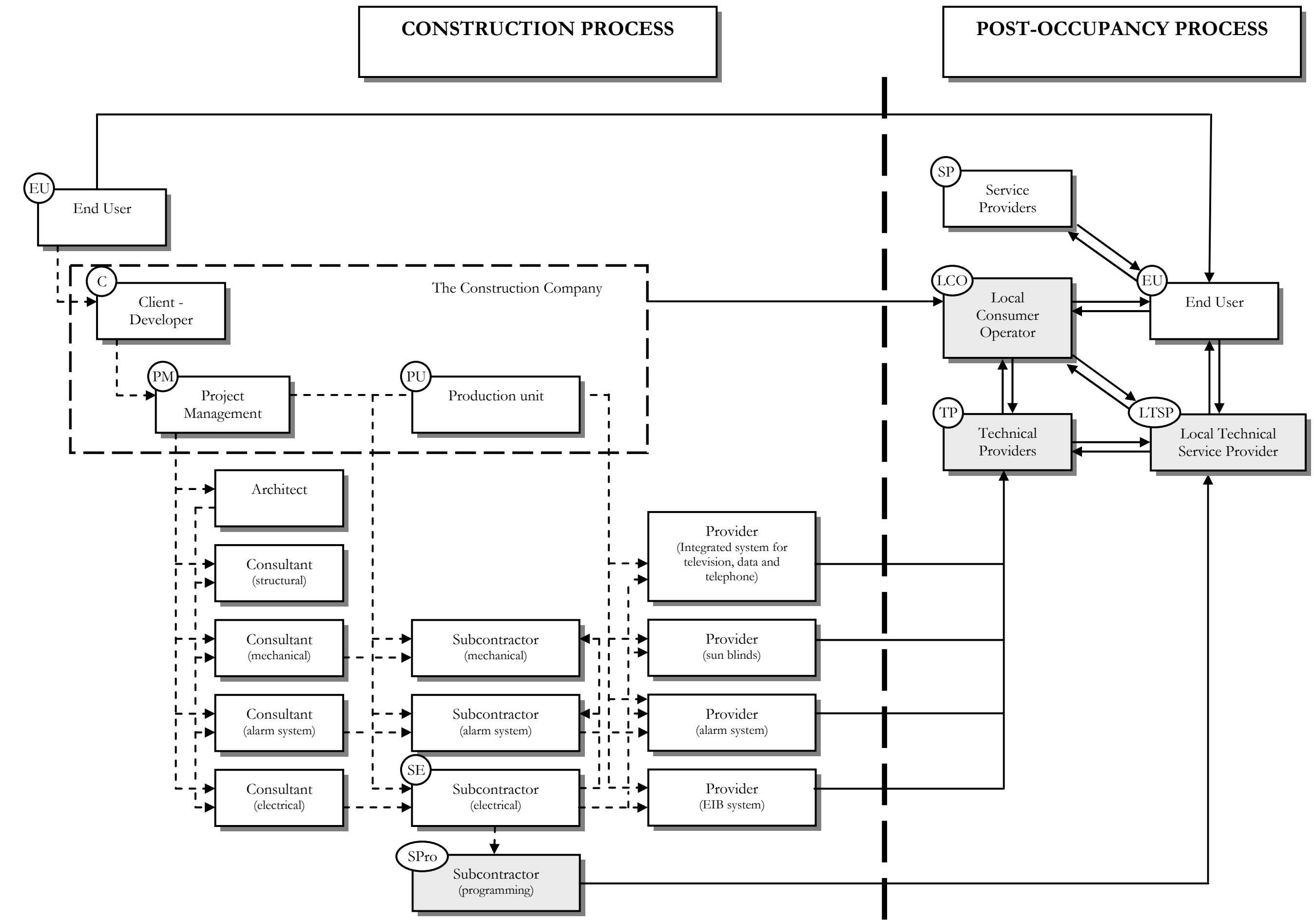


Figure 18. Co-ordination and dependencies in the construction/post-occupancy process in Smart Living. Left part from paper iii). Right part illustrates the long-term role structure.

With the investigation performed above concerning the organisation of smart home service delivery, especially for the post-occupancy phase, it is now possible to take the obtained findings a step further and examine how user values, the main theme for the thesis, are maintained or not during the occupancy phase, see also paper iv).

4.4 AN INCOMPLETE PERFORMANCE MODEL FOR SUSTAINING LONG-TERM USER VALUES

4.4.1 The user model and user requirements recalled

In chapter 2 and paper iv) three central concepts (which also could be denoted as user requirements) is presented; *usefulness, usability* and *accessibility*. The concept usefulness determines if a product or a service supports the user in fulfilling a task, satisfying a need or solving a problem. But if a function would offer usefulness it demands both usability and accessibility, not just one of them, see figure 4. In addition to these requirements the model also has to be placed in a context involving different aspects of trust discussed in section 3.3.1 above. The next section will make an attempt to link these concepts together in order to demonstrate that long term user values are not only based on proper design of the smart homes functions discussed in chapter 2 and 3, but also rely on a viable organisation supporting the user over time.

Table 12. Merging of the Evaluation model (functionalities, figure 4), the Construction Organisational Model (actors) and the Service Delivery Model (roles) for long-term functionality. Only roles and actors of interest are displayed, (An asterisk indicates an actor.) Red-marked boxes indicate a missing and not replaced actor.

EVALUATION MODEL	FUNCTIONALITIES	CONSTRUCTION PROCESS				POST-OCCUPANCY PROCESS			
		Vallgossen		Smart Living		Vallgossen		Smart Living	
		role	*actor*	*role*	*actor*	*role*	*actor*	*role*	*actor*
1	**Usefulness**	C	SSH	C	C	End User		End User	
2	**Usability**								
3	Physical / technical usability								
4	*Expandability*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
5	*Integrateability*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
6	*Adaptability to individual needs*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
7	*Upgradeability*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
8	Cognitive usability								
9	*Easy to learn*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
10	*Intuitive*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
11	*Easy to understand*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
12	*Easy to use*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
13	**Accessibility**								
14	Response time	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
15	Set-up time	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
16	Availability								
17	*Up-time*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
18	*Mean time to repair*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro
19	*Mean time between failures*	C	SSH	C	CE	LCO	SSH	LCO	C / SPro

C = Client-Developer, CE = Consultant (electrical), LCO = Local Consumer Operator, TP = Technical Provider, SPro = Subcontractor (programming), SSH = Subcontractor (smart homes).

4.4.2 Matching of user requirements to available roles

The concepts usefulness, usability and accessibility are placed to the left in table 12. The different roles mapped in figure 17 and figure 18 are also placed in the same table with the purpose to show the roles supposed to fulfil the requirements in the evaluation model at different points of time, viz. in the construction process and in the post-occupancy process. Further explanation of the table is made below.

<u>During the construction process</u>

Usefulness

In the early stages of the construction process, long before the end user had procured the house or the flat, the responsibility to develop attractive homes both in Vallgossen and Smart Living relied on the role Client-Developer. In the same way the Client-Developer also had to take the responsibility to choose functions offering usefulness to the end user when installing a smart home system, see footnote 64.

In Vallgossen, the Client-Developer took part in the discussion of potential functions in the smart home system. In the end, however, the actor Subcontractor (smart homes) decided on the kind of functions that were reasonable – and possible – to implement.

In Smart Living, the Client-Developer performed thorough discussions with both the Consultant (electrical) and the Technical Provider regarding possible functions in a smart home. In the end, it was the Client-Developer who decided which functions that were to be implemented.

Usability and Accessibility
The responsibility for fulfilling demands on usability and accessibility during the construction process rested on Client-Developer's. The responsibility could have been transferred to the role Technical Provider. This actor, however, had already fulfilled its task during the development of the technology, prior to the construction process, and had no formal duty to deliver further support without compensation.

In Vallgossen, the responsibility for usability and accessibility fell upon the actor Subcontractor (smart homes), which developed its own technical solution for the smart home system, both software and hardware. The smart home system was developed concurrently with the construction process.

In Smart Living, the corresponding responsibility was taken by the Consultant (electrical). The range of functions was decided by the Client-Developer while the Consultant (electrical) proposed the EIB system which was chosen. By recommending a certain technical solution the Consultant (electrical) accepted his responsibility for fulfilling the usability and accessibility requirements.

During the post-occupancy process

Usefulness
Some of the actors which were participating in the construction process took new roles during the post-occupancy process. From now on the judgement of the end user, not the Client-Developer, will imply if usefulness is achieved or not.

Usability and Accessibility
The Local Consumer Operator role in Vallgossen was taken by the actor Subcontractor (smart homes), SSH. However, the SSH was not able to meet any further requirements regarding Physical/Technical Usability. The smart home system developed by SSH could neither be expanded with new functions nor integrated with any new technology, despite that such a possibility regularly is expected by the end user after some experience of a system. Effectively, the system was a closed entity. In table 12 four yellow boxes on row 4-7 indicate this incapacity of maintaining physical/technical usability over time. SSH was only able to support the cognitive usability to some extent, chiefly the graphical user interface (row 9-12).

In Smart Living the Client-Developer took the role as the Local Consumer Operator, LCO, (see figure 17) during the first two years in the post-occupancy process. The end users called this actor when a problem occurred, and the Client-Developer in turn forwarded the event to the actor SPro, who took the role as the Local Technical Service Provider, LTSP.

The main difference between Vallgossen and Smart Living was that the actor SSH in Vallgossen did not provide for a long term general availability, row 17-19 in table 12. The system was not stable and failed occasionally. Consequently, the residents in Vallgossen lost their trust in the system and successively the smart home system was used very little; in the end only the booking of the common laundry room once or twice per month remained. In Smart Living, on the other hand, the SPro carried on, and was on hand when needed. A remaining snag, however, was that it could be rather costly for a household to call in the service, also for measures anticipated to be of a minor degree of complication.

4.5 SUMMING UP

The chapter began with a review of how consumers adopt new innovations. The consumers, also called adopters, were categorised in five distinct groups and every group adopts new innovations for different reasons according to the diffusion of innovation theory. Later a chasm between the early adopters and the early majority complemented the model. If a new innovation will reach the mass market it is necessary to bridge the significant gap between these two groups. The company e2-Home had this gap in mind when the smart home system was developed. Large efforts were definitively put on the end user demands on design and applications.

The innovation e2-Home, introduced into Vallgossen and Ringblomman, was examined according to the competence bloc theory. It was shown that the market at that time lacked the venture capitalist. Consequently the exit market and the industrialist were never explored. This fact could be a contributing explanation why the venture e2-Home, with its early realisations in Vallgossen and Ringblomman did not take off. Further, the origin of the dot.com bubble in the beginning of the 21st century slowed down the activity within the IT sector. There are reasons to believe that this hurt the ongoing smart home development in Sweden.

A performance model for IT-based home services was described. The model, with the end user in focus, defines several independent business roles and actors necessary to fulfil viable services offered to the end user living in her own home.

The ordinary housing construction process with its habitual roles/actors was described. Further, it was shown how this regular process was influenced by new roles and actors entering with the smart home systems installations in Vallgossen and Smart Living.

When the residents moved in into Vallgossen and Smart Living the buildings entered the next phase – the post-occupancy process. Some of the actors in the construction process took or should have fulfilled their roles into the post-occupancy process. The performance model was used to show the differences in this respect between Vallgossen and Smart Living, and how these differences affected user values.

In the last section the concepts in the evaluation model, presented in paper iv), the different roles of the service delivery model and the actual actors in Vallgossen and Smart Living in both the construction process and the post-occupancy process were brought together. By doing so, it became possible – at least tentatively – to explain, why the smart home system in Vallgossen eventually failed and was replaced by an ordinary less glossy Internet service, while Smart Living could survive after the construction company's responsibility was dropped after the contracted guarantee in due time.

The chapter introduced the notion of abduction, as a method to reason about different phenomena related to the studied cases, in particular phenomena going on simultaneously with the construction process, or raised organisational concerns. Such phenomena are by nature often interrelated. The purpose was to bring the issues to the fore and by attentive reasoning arrive to a balanced judgement. As said, the e2-Home venture in Vallgossen and Ringblomman failed while the Smart Living continued. The explanation for this outcome lies inevitably – at least to some extent – in the eye of the beholder. The adopted perspective is important.

The author, however, would like to emphasise the fact that no one was prepared to take the long term responsibility for the viability of the basic solution for the smart home system in Vallgossen and Ringblomman (the e2-Home system), while Smart Living was based on commercially available products. Yet if the economic prerequisites had been more favourable in the first half of the first decade of the new millennium – especially no bursting dot.com bubble – the e2-Home venture would certainly have run into trouble with time, anyway. In fact, nobody was really prepared to take on the huge task of serving the users with support and maintenance and to continue to offer user values over time.

5 DISCUSSION AND CONCLUSIONS

The chapter concludes the results from the three phases of the research. Important topics for the development of a smart home market are discussed. The chapter ends with some hints on possible areas for future research.

5.1 DISCUSSION OF PRESENTED RESULTS

5.1.1 General

Detailed results from phase one, two and three are presented in section 2.6.2, section 3.6.2 and section 4.5 respectively. This section will discuss and emphasise some principal findings especially pertaining to the users' valuation of living in smart homes.

At first, a remark must be made, not explicitly brought forward in the forgoing. User satisfaction investigations are commonplace in research as well as in industry. Such investigations pertain to distinct products, single services and stand-alone systems for both professional and informal use. Many products and some services are mainly intended to be used at home, and have consequently often been objects for user evaluations in one way or the other. The unique character of the present investigation, which is emphasised, is that a *complete system* (the smart home system) have been tried and assessed by ordinary residents living in their own homes. The informal character of the processes going on inside the four walls of a home allows the respondents to express in words and deeds exactly their opinions of any function. The professional situation is different where the ultimate goal is to accept the new artefact after the design and evaluation of it, although it might still take shorter or longer time to learn how to use it. At home there is an option to drop the service completely, if it is not up to expectation. Further, the fact that the residents did not pay any extra for the smart home facilities – the price tag was the same for smart home flats as for ordinary flats – also contributed to the possibility to make unbiased judgements of the behaviour of the users.

5.1.2 Expectations and use of smart home functions

The difference in outcomes of the interviews of the residents between phase one and phase two shows the effect of getting used to a smart home system. The first curiosity, sometimes excitement, abates gradually into routine manners. The end user tends successively to use functions that appear to be useful for her or for him. The concepts of accessibility and trust, brought forward in the foregoing, are essential in order to achieve usefulness.

In Vallgossen and Ringblomman, essentially identical smart home systems were installed; only minor aspects differed, chiefly the interactive screen solution. In Vallgossen a laptop was the operating device, regularly set to surfing on the Internet, while in Ringblomman a touch screen on the wall, always connected to the smart home system, served as the interface to the system. The difference in accessibility to the specific smart home functions resulted in different use. The residents of Ringblomman used the smart home system more often than those of Vallgossen. The latter used the system for infrequent tasks like booking common facilities, while the respondents of Ringblomman used the system every day for everyday functions like weather forecasting and time of the day.

Trust affected the use of the energy measurement and the away lock. The energy measurement function had some initial problems and, during the interviews in phase one, most of the respondents had adopted a wait-and-see attitude for the time being, awaiting the function to be put in order. In phase two interviews most respondents revealed that they had not resumed using the function, although it functioned since long. Lost trust takes time to restore.

The away lock function, the second example, was found to be used more frequently in Vallgossen than in Ringblomman. In Ringblomman the away lock was not perceived as fully reliable and a reluctant attitude to the function prevailed. Trust could not be maintained. In Vallgossen the away lock functioned as expected and was obviously trusted correspondently.

5.1.3 Long-term viability of smart home systems

In the last phase of the research a radical change of view took place. Instead of looking at the users' experiences of specific smart homes functions, it turned out to be logical to look at other, yet adjacent, phenomena with possible influence on the obtained results and the development of the studied cases in general.

The conclusion out of the author's perspective from a broad and open scrutiny was – beside useful and easy accessible smart home functions – the ability to offer user value over time. An effective service delivery model must be in place. It must have the ability to support, maintain, and regularly update the system and modify and add services according to the users' changing needs over time. The lack of such a service model and no appointed actor to fill a services-oriented role were regarded as the principal cause for not advancing the innovative initiative to a viable and ongoing business.

In Smart Living, the situation was opposite. The smart home system continued to be usable. The system is based on a technology supported by many companies and installers. So, the residents could find both support and spare parts. The installer (called Subcontractor Programming in figure 17) was also present in the post-occupancy process. Eventually this body fulfilled the role of the local technical service provider, LTSP.

Complex smart home systems require specific knowledge about the integration and installation of the technology, a piece of knowledge that traditional actors involved in the building process do not possess. Neither are these latter bodies particularly apt to offer service to their customers after occupancy. These actors include owners, occupiers, housing construction companies, technology providers, installers, financiers and insurers, just to mention a few. Owners of residential housing may constitute an exception; it is, however, doubtful if the residential service includes advanced functions like those studied in this work. Actors oriented towards social services, including facilities providers, are other possible agents with a clear mission to support old, handicapped or otherwise frail people in their daily living, and therefore might take the role as a smart home consumer operator, a LCO.

Obviously there is a knowledge gap to be filled if user satisfaction from smart homes solutions shall be maintained. There are several possible directions to consider in order to bridge the gap. One solution could be to create a new actor, a system integrator bridging the gap between each of the traditional actors in the construction industry; e.g. offer advice on applications, perform individual configuration of smart home systems, installation and after-sales services. The snag, however, is that a sufficiently large customer base is required before any service provider dare to enter such a business. Other alternatives should be imagined, too.

One possibility is to expand the business model for housing construction companies. Their business model originates from conventional project development. These companies may profit from scale effects by taking the whole product cycle in consideration, from planning to construction and maintenance. The markets for after-sales services are essentially, so far, neglected by the housing construction enterprises. If such a company can present and implement an elaborated strategy, with an overall picture of commitment and cost, it will also facilitate the further introduction of smart home technology into housing and arrive to market acceptance.

Another possibility is the wait-and-see strategy. New technologies may mature. Internet and wireless technologies could be expected to cause major break-through in a not too distant future, especially if version 6 of the Internet protocol is implemented. However, adopting such a strategy will not allow the market-oriented construction company, or anybody active in the building sector, to stay idle. The IT development will offer surprises henceforth, too.

Despite lacking functionality in many respects, the three projects, Vallgossen, Ringblomman and Smart Living, with their unique smart home systems have offered an unusual opportunity to study and learn what requirements must be put on technological systems if they are to offer user value in a generally unpredictable environment, the home.

5.2 QUALITY OF SYSTEMS AND SERVICE DELIVERY

5.2.1 Development of services to the home

Almost everything is possible to offer via smart home technology; our imagination only sets the limits. Today, we are all rapidly acquiring technological artefacts to connect to communication infrastructures that allow us to consume and communicate with different media – e-mail, personal digital video recorders, cell phones, web-cams, etc. But, it is important to focus on the end user, the adaptation to end user's needs and the environmental settings, the whole context. Also, buildings change slowly and there is a difference between the quickly developing services and what could be integrated in buildings.

Smart home technology offers improvements in living standards not only for the mainstream market but also for older and disabled people who are heavily reliant on home care. However, the benefits of the technology for the latter groups can only be realised if a mainstream market develops which, in turn, require improvements in both availability and affordability of the technology.

An area not mentioned much in the thesis is energy consumption and energy efficiency. Smart home systems can be used to reduce energy consumption in design, commissioning and operation. It can automate services such as lighting, heating and cooling, e.g. sensors for remote monitoring and measurement. Smart homes can help to raise awareness of energy waste and provide useful information to trigger action, e.g. smart meters indicating individual appliance consumption.

Utility companies can stimulate energy conservation by informing users of potential savings as part of demand-side management. Utilities could also alert users to excessive consumption by providing comparative information about energy use on the bill. This can show whether the bill payer uses more energy than other homes of a similar size and style.

5.2.2 Education and marketing of benefits

Although every new innovation is unique and its adoption by the consumers is different, there are lessons that can be learnt from looking at how quickly other technologies managed to reach mass markets, and what factors that influenced the pace.

Adoption of new consumer products usually follows a standard pattern – the so-called S-curve (Pragnell et al., 2000). Figure 19[71] demonstrates how adoption of different consumer technologies has changed over time. The curves illustrate that the introduction and maturation of most successful technologies are S-shaped: slow take-up in the beginning, followed by a steep adoption rate that moves the product into the mass market domain. Finally, as the market matures the gradient of the S-curve decreases when the product approaches its maximum level of market penetration.

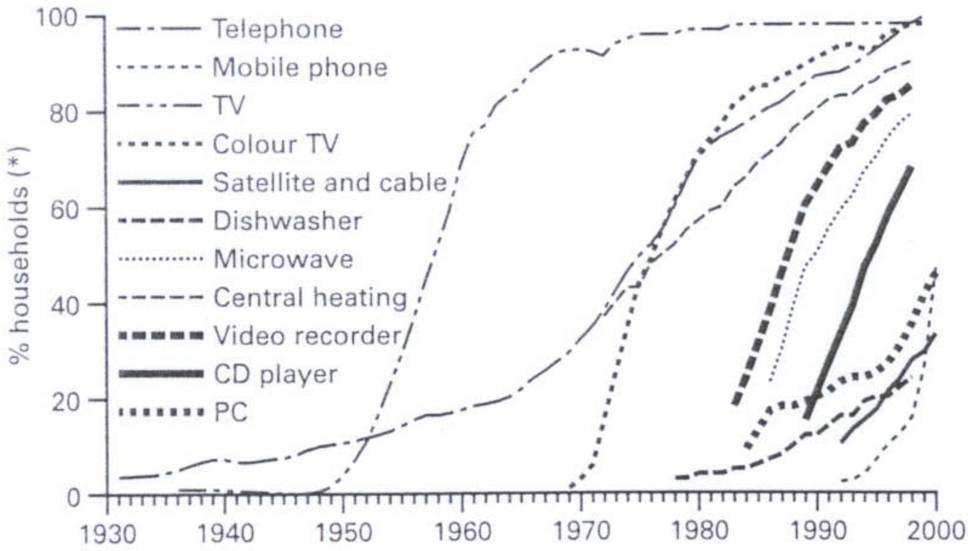


Figure 19. Adoption curve of new technologies over time (Pragnell et al., 2000).

Consumers' attitude towards new technologies is the key to determining the speed of the take-up. According to Mundorf and Westin (1996), consumers accept new technologies more freely during the latter years which have led to steeper adoption curves for newer technologies.

There are several factors that influence the speed of take-up of new technologies, e.g. *economic* (price, availability, income level), *social* (gender, roles), *consumer* (attitudes, needs, wants), *technological* (degree of innovation, development of competing and complementary technologies), *global/political* (environmental concerns, world events). These factors work together to determine the final shape of the adoption curve.

Another notion is the *killer application* (sometimes *killer-app*). A killer app is characterised by its convenience both to open up an initial market segment and to be able to cross the chasm, see section 4.2, and bring the technology into the mainstream market. According to the Computer Desktop Encyclopedia (Freedman, 2001) a killer-app is defined as: "An application that is exceptionally useful or exciting". A killer app is exciting to some and threatening some others. It may be the origin of a paradigm shift and, as the name seems to imply, the death of an order gone by.

The killer-app notion for the smart homes market was very much in focus when decisions were made about how to equip the three housing units investigated and described in this thesis.

[71] The figure refers to the picture in Great Britain; the graphs are very similar in most western countries.

However, no particular function was identified as such; this is indirectly indicated by the relative extensive set of functionalities that were introduced, see section 2.2 above. No particular function was considered attractive enough to bring the venture to success.

There is no doubt smart home systems deliver usefulness to end users, if designed and maintained appropriately. But, today there is a gap between technology companies and the market (the end users). One way to bridge this gap is to educate the market. Whilst education can be very technical and professional there is also a need to educate the end user to know what is possible, what is available, what is affordable, what is realistic and what the benefits are. In other words the end users should be empowered to make their own choices, to help themselves where possible, and to demand additional or modified services.

5.2.3 Standards and industrial monopoly

Every aspect of our life is supported and often controlled by standards. An example is all electrical appliances in our homes that share the same electric current. You can move the coffee maker from the kitchen to the balcony, plug it in, and enjoy fresh coffee in the sun. But when it comes to smart home technology things are different.

In 1990, the International Organisation for Standardisation and the International Electrotechnical Commission (ISO/IEC) published a joint study entitled "A Vision for the Future: Standards Needs for Emerging Technologies." (Committee on Science, Space and Technology, 1994) It was a forecast of the needs for international standardisation based on a comprehensive global survey covering 12 major technology sectors. One of the listed areas was Home Automation.

Developing a standard for smart homes, covering so many different aspects and applications has proven to be difficult. But, systems based on open standards are the most beneficial for the end users. If end users choose systems with only one or a few suppliers they are dependent on the suppliers for management, extensions and repair. The authors view is that systems based on open standards provide end users with greater freedom of choice in relation to suppliers, or in choosing another supplier or service company.

5.3 FUTURE RESEARCH

It has been a unique opportunity to follow the residents and their occupancy during more than five years in these three smart home projects. Knowledge of the residents' short-term and long-term use has been acquired. How trust affects the use of different functions, likewise how usability and accessibility affects usefulness, were other findings. However, there are still important questions to go on with. A few are mentioned below.

One important aspect to consider is how our dwellings will be used in the future. Will we perform other or different activities in our homes than today? Do we need support from technology in order to perform such new activities?

It is important to inform the end users, designers, and e.g. the caring profession and show what is possible with the technology and how it could be developed and applied. Is there a curriculum for the schools or a subject for the university?

Another question to consider is the end users' willingness to pay for the smart home technology – and in what ways. If the end users' willingness to pay does not correspond to the cost for smart home systems then no homes will be equipped with such a technology.

Further, to what extent is the user allowed to change the design of a function and to add individual services in a smart home system? Existing smart home systems on the market need further development. A specific research area would be to formulate demands on future smart home systems. "How and for whom?", will be the obvious additional question.

Not only the very systems but also operation and maintenance of installed systems need services actors. It was shown that the market is short of trained competitive service providers. If a resident needs help, who shall she or he call, the house owner, the housing association, a service provider, a local technician or some other body? Here it is important to consider the availability of competent procurers.

Many actors in the building sector have extensive experiences of directing and – depending on their roles in the building process – procuring architectural and structural solutions; when it comes to installations the understanding decreases, especially concerning sustainability. Construction companies that move in a direction to include services in their core business, also known as facilities management, automatically have to advance into the crucial field of building installations. During a short period of time such traditional installations have become equipped with electronically controlled systems and devices. Signals from sensors, camera surveillance and actuators of different kinds monitor the state of the building and its use. For the time being, this kind of business relate to commercial buildings of different kinds, not to homes. Is there perhaps a sleeping business which yet has to find its proper structure?

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SVENSK SAMMANFATTNING

Ledande byggbolag i Sverige genomförde vid millenniumskiftet 1999/2000 tre mycket omfattande satsningar på Smarta hem (Smart homes) i Stockholmsområdet. JM utvecklade projektet Vallgossen på Kungsholmen i Stockholm som omfattade 126 bostadsrätter och projektet Smart Living på Värmdö, där sex friliggande villor utrustades med smarta hem-teknik. Skanska genomförde projektet Ringblomman, 59 bostadsrätter, på Söder i Stockholm, där tekniken med små avvikelser var densamma som i JMs satsning i Vallgossen. Dessa tre projekt gav en unik möjlighet att studera de boendes förväntningar på ny teknik i den egna bostaden och en ovanlig god möjlighet att följa upp användning och nytta för användarna i hemmiljö över tid. Vid den aktuella tidpunkten fanns internationellt inga andra jämförbara projekt med motsvarande industriellt engagemang, med inriktning mot den kommersiella bostadsmarknaden. Ett undantag må vara den exklusiva villamarknaden i USA, där speciellt säkerhetsaspekterna är ett starkt argument för att installera avancerad teknik i dyra bostäder.

Studien omfattar närmare 200 familjer i de tre bostadsprojekten. Dessa familjer har följts under närmare fem år av deras första tid i boendet. Dessa projekt är utrustade med olika smarta hem-funktioner utformade för att endera öka tryggheten/säkerheten, öka bekvämligheten eller sänka kostnaderna i boendet.

Lägenheterna i Vallgossen och Ringblomman var utrustade med ett hemmanät som styrdes via en terminal i respektive lägenhet. Terminalen i Vallgossen var en bärbar dator och i Ringblomman en pekskärm på väggen. Utöver hemmanätet hade de boende tillgång till bredband, leveransboxar, kombinerade uttag för data och telefon, porttelefon med bildskärm[72] samt elektroniska nycklar. Funktionerna i hemmanätet bestod av brand-, inbrotts- och läckagelarm, status på energiförbrukningen med individuell mätning av vatten, el och gas[73], inomhustemperatur, bokning av tvättstuga, samlingslokal, leveransboxar[74] och övernattningsrum[75], elektronisk kalender med påminnelsefunktioner samt funktioner som kallas för Listan och E-notes. De inbokade aktiviteterna kunde de boende få som en påminnelse om i form av ett SMS till mobiltelefonen eller som ett meddelande till terminalen. Listan kunde t.ex. vara en inköpslista som den boende fyllde i under veckan och, när det var dags för att handla, kunde listan skickas till deras mobiltelefon. E-notes, kan man säga, var elektroniska "postit"-lappar som kunde skrivas för att endera påminna sig själv eller någon annan i familjen. Väderinformation gavs i form av dagens temperatur inne och ute samt lufttryck och en väderprognos för morgondagen. Här fanns även en klocka. I Ringblomman hade de boende även tillgång till eluttagsstyrning och styrning av inomhustemperaturen via terminalen.

I Smart Living var vatten, uppvärmning, ventilation, belysning och passagesystem integrerade med varandra med ett buss-system som kontrolleras bl.a. via en display i hallen. För att öppna dörren användes en elektronisk nyckel. Passagesystemet var indelat i två olika scheman – "Hemma" och "Borta". Dessa scheman kontrollerade vattnet, elektriciteten till spisen, inbrottslarmet, ventilationen och eluttagen. Allt detta styrdes via låset i ytterdörren. När ytterdörren låstes stängdes vattnet av (efter två timmar så att tvätt- och diskmaskin skulle hinna avsluta sina program om de var igång), elektriciteten till spisen slogs av, ventilationen gick ned på halv fart för att spara energi och inbrottslarmet aktiverades på. Vid ett eventuellt larm kunde den boende välja mellan att få larmet som ett SMS till sig själv eller att larmet skulle gå direkt till ett

[72] I Vallgossen var det bara 21 lägenheter som hade porttelefon med bildskärm.

[73] Gas fanns enbart i Vallgossen.

[74] I Vallgossen var det bara 21 lägenheter som hade access till leveransboxarna.

[75] Fanns enbart i Vallgossen. Via övernattningsrummet hade släkt och vänner som färdats långväga en möjlighet att övernatta på plats istället för att ta in på hotell.

vaktbolag. När den boende kom hem tändes belysningen automatiskt i hallen, vattnet slogs på likaså elektriciteten till spisen. Via displayen i hallen kunde de boende, med en knapptryckning, släcka all belysning i hela huset innan de gick hemifrån. I anslutning till garaget fanns en leveransbox. I flertalet rum var det även förberett för installation högtalare. Utöver detta fanns det ett gemensamt system för TV, data och telefon där samma uttag kunde användas för alla tre medier.

Målet med studien var dels att undersöka vilken nytta boende i så kallade smarta hem har av olika typer av IT-lösningar i hemmet, vilka IT-tjänster i hemmet som de boende vill ha och vilka krav de ställer på IT-lösningarnas utformning och funktionalitet. Dels var också syftet att ge underbyggda viktiga förutsättningar för att byggindustrin och byggsektorn i stort ska kunna utveckla gångbara smarta hem-projekt framöver. Resultaten av studien vänder sig således till byggare och förvaltare och deras rådgivare bl.a. arkitekter, andra projektörer och konsulter i övrigt.

Studien har stötts genom det nu avslutade forskningsprogrammet Competitive Building och genom SBUF och JM AB med finansiering av forskaren/industridoktoranden Greger Sandström samt KTH genom forskningshandledning.

Centrala begrepp i studien har varit *användbarhet*, *nytta*, *tillgänglighet* och *tillit*. På olika sätt undersöks och diskuteras dessa begrepp i samband med studiet hur användarna uppfattar smarta hem-funktioner i boendet. Definitioner av begreppen redovisas. Användarvärde (user value) definieras däremot inte explicit i avhandlingen utan växer fram och inringas som ett integrerat begrepp som omfattar tekniska lösningar, system, service i relation till användarens behov, krav och önskningar i boendesituationen.

Metoden i studien har varit såväl intervjuer med enskilda hushåll som enkäter riktade till den större populationen av informanter i de tre projekten. Första intervjuomgången genomfördes år 2002, till viss del före inflyttning, i andra fall strax efter inflyttning i de nya bostäderna. I avhandlingen har denna del benämnts fas 1. Totalt 26 hushåll (elva i Vallgossen, nio i Ringblomman och sex i Smart Living) deltog i denna första omgång. Undersökningen i detta skede fokuserade på de boendes attityder vis-à-vis smarta hem-funktionerna, vilken nytta funktionerna förväntades erbjuda eller faktiskt erbjöd och på de krav på utformning och funktionalitet som de boende ville ställa. Intervjuerna var semistrukturerade, d.v.s. ett förberett frågebatteri för att få en enhetlig utgångspunkt i samtliga intervjuer, men möjlighet att gå vidare och fördjupa olika frågeställningar som kunde uppkomma i intervjusituationen.

Funktioner som ökar tryggheten och säkerheten, dvs. larmsystemet, bortalåset, de elektroniska nycklarna och portkameran med bildskärm, värderades genomgående högt av de boende. Likaså funktioner som ansågs spara tid för de boende, dvs. bokningssystemet och bredband. Bokningssystemet medförde att de boende inte behövde gå ner till tvättstugan för att boka tvättid. Påminnelsefunktionen medförde att de inte behövde gå ner till tvättstugan förrän tvätten var klar. Andra funktioner som ansågs vara användbara var det kombinerade systemet för data och telefon (och TV). När det gäller energifunktionerna gick åsikterna isär mellan Vallgossen och Ringblomman. I Vallgossen ansåg en del av de intervjuade personerna att den individuella energimätningen av energiförbrukningen var en mycket användbar funktion medan andra hade en diametralt motsatt åsikt. Denna åsiktsskillnad fanns även i Ringblomman. Även mellan de båda fallen Vallgossen och Ringblomman var skillnaden stor. De boende i Ringblomman var i högre utsträckning positiva till energimätningen än de boende i Vallgossen. En förklaring skulle kunna vara att denna funktion inte riktigt fungerade inledningsvis i Vallgossen vilket gjorde att en del av intervjupersonerna redan från början intog en avvaktande inställning till användningen medan motsvarande funktion i Ringblomman fungerade från början. I Smart Living var de boende positiva till att kunna spara energi och därmed sänka sin boendekostnad.

En andra intervjuomgång genomfördes år 2005, studiens fas 2. Totalt intervjuades åtta familjer i både Vallgossen och Ringblomman samt samtliga sex familjer i Smart Living. Syftet var att undersöka om de attityder och beteenden hos de boende som redovisades före inflyttning eller relativt snart efter inflyttningen kvarstod eller om de förändrats efter några års användning.

Under år 2005 skickades också en enkät ut till de boende i Vallgossen och Ringblomman samt till bostadsrättsföreningen Fatbursstranden (även det beläget på Södermalm i Stockholm). Fatbursstranden, med 180 lägenheter, hade inte något smarta hem system installerat och utgjorde därmed ett referensprojekt i förhållande till de två andra projekten. Syftet var att jämföra de boendes uppfattning i Fatbursstranden om smarta hem-system (som de inte fått prova) med de upplevda och redovisade erfarenheterna från de boende i Vallgossen och Ringblomman.

Resultatet från undersökningarna visar att smarta hem-funktioner har boendevärde. Funktioner som ökade trygghet och säkerhet (t.ex. larm), som sparade tid (t.ex. tvättstugebokning) och som ökade bekvämligheten (t.ex. markisstyrning) är funktioner som värderats förhållandevis högt. Energisparande funktioner värderades lägre vid denna tidpunkt. Genomgående konstateras dock att IT-funktionerna i sig knappast på något avgörande sätt påverkat bostadsköparnas val av ny bostad. Det skall också nämnas att priset på de IT-utrustade bostäderna var detsamma som för motsvarande bostäder utan IT-teknik.

Skillnaden i resultat mellan intervjuomgångarna demonstrerar vad som händer när de boende vant sig vid ett smarta hem-system. Den första nyfikenheten övergår successivt till en vardaglig rutin där de funktioner som ger faktisk nytta för de boende fortsätter att användas, andra sorteras bort. Begreppen *tillgänglighet* och *tillit* är viktiga, om inte helt avgörande, för att nyttan skall realiseras. Såväl kvalitativa som kvantitativa analyser genomfördes på grundval av de primära resultat som kom fram från intervjuer och enkäten år 2005.

Vallgossen och Ringblomman hade i stort sett samma typ av smarta hem system, men de skillnader som förelåg kunde utnyttjas på ett intressant sätt i den kvantitativa analysen. Skillnaden låg i typ av skärmlösning (för att använda smarta hem systemet) samt i en del funktioner, exempelvis värmestyrning. I Vallgossen hade man en bärbar dator från vilken man använde smarta hem systemet. Oftast var denna dator inställd på att surfa på Internet. I Ringblomman hade man en pekskärm på väggen, alltid uppkopplad mot smarta hem systemet. Den statistiska analysen påvisade signifikanta skillnader i vissa avseenden mellan Vallgossen och Ringblomman. Skillnaden i tillgänglighet medförde t.ex. att de boende i Ringblomman använde smarta hem systemet mer frekvent. I Vallgossen loggade de boende bara in i smarta hem systemet när det t.ex. var dags att boka tvättstugan. Här översteg således boendevärdet av denna funktion besväret att göra en särskild uppkoppling. I Ringblomman användes smarta hem systemet i stort sett varje dag, t.ex. för att titta på så triviala ting som väderprognosen och för att se vad klockan var. Tillgängligheten var nästan total, och nyttan/värdet behöver uppenbarligen då inte vara särskilt stor.

Tilliten till systemet påverkade tydligt användningen av viss andra smarta hem-funktioner, t.ex. energimätning och bortalås. Till en början uppstod problem med energimätningen och de flesta informanter vid första intervjuomgången hade intagit en inställning karaktäriserad av "vänta-och-se", till dess funktionen skulle fungera som utlovat. Vid den andra intervjuomgången hade de flesta fortfarande inte börjat använda funktionen, trots den nu hade fungerat under en längre tid. Man vågar dra slutsatsen att ett smarta hem system måste fungera väl från början för att vinna de boendes tillit, och därmed kunna integreras i vardagslivet. Hemma finns inte något krav på att använda något som fungerar dåligt.

Bortalås-funktionen, det andra exemplet, användes mer frekvent i Vallgossen än i Ringblomman. Detta berodde uppenbart på att de boende i Ringblomman inte riktigt litade på bortalåset. I Vallgossen fungerade funktionen utan större problem vilket gjorde att tilliten till funktionen upprätthölls över tid.

Fas 3 av studien behandlar den långsiktiga förvaltningen av smarta hem system i bostäder. Det blev tydligt under de 4 à 5 årens observationstid att inte enbart den tekniska utformningen av smarta hem systemen spelade roll för hur de boende använde systemen och värderade dem. Organisatoriska frågor, t.ex. hur service och underhåll är tillgodosedda i ett längre perspektiv och utveckling av nya tjänster inom ramen för den befintliga tekniska plattformen blir viktig. Utan en genomtänkt strategi på detta område kommer förvaltningen av systemen försvåras, och utvecklingen på området sannolikt att hämmas.

Genom olika modellansatser i avhandlingen har problembilden demonstrerats och förklarats.

Idag är marknadsstrukturen för smarta hem otydlig. En tydlig värdekedja saknas vilket gör att beställare och byggherre har svårigheter att ta investeringsbeslut på samma sätt som vid en tydlig marknadsbild. En effektiv tjänsteleveransmodell bör utvecklas där service, support, underhåll och regelbundna uppdateringar av smarta hem systemet ska kunna erbjudas samt där smarta hem systemet kan modifieras efter de boendes förändrade behov över tiden. I avhandlingen visas att en sådan aktörsmodell saknades för två av projekten, Vallgossen och Ringblomman. Vidare saknades åtminstone en nyckelaktör som kunde garantera det långsiktiga underhållet av smarta hem systemen. Dessa förhållanden förs fram i avhandlingen som dominerande orsak till att den omfattande gemensamma satsningen från två av Sveriges allra största industriföretag inte kunde föras från innovationsstadiet till en färdig produkt på marknaden.

Smarta hem systemet i Smart Living hade andra förutsättningar. Tekniken var allmänt accepterad av flertalet tillverkare och installatörer. Det gjorde att de boende kunde erhålla både support och få tag på reservdelar under bruksskedet. Den aktör som installerade systemet var också tillgänglig för de boende under bruksskedet; benämns i studien som den lokala serviceteknikern.

Komplexa smarta hem system kräver speciella kunskaper om både integration och installation, en kompetens som traditionella aktörer i byggprocessen inte besitter i någon större utsträckning. Dessa aktörer, t.ex. fastighetsägare, byggföretag, teknologiföretag, installatörer och finansiärer, har hitintills inte heller varit speciellt intresserade av att erbjuda smarta hem-tjänster till de boende under bruksskedet.

Detta kunskapsglapp kan överbryggas med hjälp av ett antal potentiella lösningar. Den ena lösningen är att skapa en ny aktör, en systemintegratör, som syr ihop glappen mellan de traditionella aktörerna i byggindustrin; t.ex. erbjuda tips och råd om applikationer, genomföra individuella inställningar i smarta hem system, installera smarta hem system samt erbjuda service efter installation såsom garantiåtagande, reparation och eftermarknadsförsäljning. Tyvärr är det så att det krävs en relativ stor kundbas för att någon aktör ska våga sig in i ett sådant kunskapsmässigt krävande åtagande.

Den andra möjligheten är att byggföretagen ser sin chans att expandera på sin egen affärsmodell. Dessa företag kan skapa skaleffekter genom att ta hand om hela produktcykeln från planering av ett bostadsprojekt, till byggnation och förvaltning. Marknaden för att erbjuda service och tjänster efter inflyttning i bostäder har hitintills negligerats av byggföretag. Kan bygg- och bostadsföretagen erbjuda en genomtänkt strategi på detta område, där åtaganden och kostnader kan överblickas, kommer acceptansen på marknaden för denna typ av nya system i våra bostäder underlättas i betydande grad.

En viktig slutsats är att smarta hem system måste utvecklas från användarnas genuina behov. Tillgängligheten till systemet styr i stor utsträckning hur ofta den boende använder systemet. Tilliten till systemet måste säkerställas för att den boende överhuvudtaget ska kunna tänka sig att använda systemet. Dessutom måste affärsmodellen för långsiktigt hållbara smarta hem system inkludera bruksskedet. Underhåll och uppgradering av systemet måste kunna säkerställas över tid.

Trots bristande funktionalitet i vissa avseenden, eller kanske just därför, har de tre projekten Vallgossen, Ringblomman och Smart Living med sina unika smarta hem system erbjudit en ovanlig möjlighet att studera och dra lärdom av vilka krav som måste ställas på denna typ av nya artefakter om de ska kunna erbjuda någon form av nytta i en miljö som i praktiken är oförutsägbar – den egna bostaden.