UNIVERSIDADE TÉCNICA DE LISBOA
INSTITUTO SUPERIOR TÉCNICO

A transformation grammar-based methodology for housing rehabilitation: meeting contemporary functional and ICT requirements

Sara Eloy Cardoso Rodrigues Freire da Cruz

Supervisor: Doctor José Manuel Pinto Duarte
Co-Supervisor: Doctor Maria Isabel Plácido Barbosa
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Thesis approved in public session to obtain the PhD Degree in Architecture
Jury final classification: Pass with Merit

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ABSTRACT

Title: **A transformation grammar-based methodology for housing rehabilitation: meeting contemporary functional and ICT requirements**

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PhD: Architecture

Supervisor: Professor Doutor Arq. José Pinto Duarte

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This research starts from the premise that the future of the real estate market in Portugal will require the rehabilitation of existing residential areas in order to respond to new life-styles and dwelling requirements that have emerged in an era in which information plays a structuring role in society.

The goal of this research is the definition of design guidelines and a rehabilitation methodology to support architects involved in the process of adapting existing dwellings, allowing them to balance sustainability requirements and economic feasibility with new dwelling trends such as the incorporation and updating of Information Communication and Automation Technologies and the need to solve emerging conflicts affecting the use of space prompted by the introduction of new functions associated with such technologies.

In addition to defining a general methodology applicable to all the building types, the study focuses on a specific type, called "rabo-de-bacalhau" ("cod-tail"), built in Lisbon between 1945 and 1965 for which a specifc methodology has been generated. Both shape grammar and space syntax were used as part of the rehabilitation methodology as tools to identify and encode the principles and rules behind the adaptation of existing houses to new requirements.

Keywords: Housing Rehabilitation; Domotics; Information and Communication Technologies; Transformation Grammar; "Rabo-de-bacalhau"; Rehabilitation Methodology; Shape Grammar; Space Syntax; Information Society; New lifestyles.

RESUMO

Título:	**Metodologia de reabilitação habitacional baseada numa gramática de transformação: resposta às exigências funcionais e de TIC contemporâneas**
Nome:	Sara Eloy Cardoso Rodrigues Freire da Cruz
Doutoramento em:	Arquitectura
Orientador:	Professor Doutor Arq. José Pinto Duarte
Co-orientadores:	Professora Doutora Arq. Isabel Plácido
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Esta investigação parte do pressuposto de que o futuro do mercado imobiliário em Portugal irá passar pela reabilitação e requalificação das áreas residenciais, de modo a responder aos novos modos de vida e exigências da habitação que surgiram numa era na qual a informação desempenha um papel estruturante na sociedade devido às novas tecnologias.

O objectivo desta investigação é a definição de uma metodologia de reabilitação que apoie os arquitectos na adaptação do parque habitacional existente, permitindo-lhes compatibilizar as exigências de sustentabilidade e de viabilidade económica com as novas tendências do "habitar" nomeadamente no que respeita à integração/actualização de Tecnologias da Informação, Comunicação e Automação e à necessidade de responder a conflitos emergentes no uso dos espaços originados pela introdução de novas funções associadas ao uso dessas tecnologias.

Para além da definição de uma metodologia geral aplicável a todos os edifícios, este estudo focou-se num tipo específico de edifício, designado na gíria profissional por "rabo-de-bacalhau", que foi construído em Lisboa entre 1945 e 1965 para o qual é proposta uma metodologia específica.

As gramáticas de forma e a sintaxe especial foram utilizadas como parte da metodologia de reabilitação enquanto formalismos para incorporar os princípios e regras definidos para a adaptação das habitações existentes às novas exigências.

Palavras chave: Reabilitação Habitacional; Domótica; Tecnologias de Informação, Comunicação; Gramática de transformação; "rabo-de-bacalhau"; Metodologia de reabilitação; Gramáticas da forma; Sintaxe espacial; Sociedade da Informação; Novos modos de vida.

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I am grateful to António Baptista Coelho and Vasconcelos Paiva who agreed to host my PhD research at the Laboratório Nacional de Engenharia Civil (LNEC – National Civil Engineering Laboratory), thus allowing me to benefit from the knowledge of this institution.

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List of acronyms

LNEC – *Laboratório Nacional de Engenharia Civil* / National Laboratory of Civil Engineering

IST-UTL – *Instituto Superior Técnico, Universidade Técnica de Lisboa* / Superior Technical Institute, Lisbon Technical University

FAUTL – *Faculdade de Arquitectura, Universidade Técnica de Lisboa* / Lisbon Technical University Architecture Faculty

ISCTE-IUL – *ISCTE Instituto Universitário de Lisboa* / ISCTE Lisbon University Institute

INE – *Instituto Nacional de Estatística* / Statistics National Institute

CML – *Câmara Municipal de Lisboa* / Lisbon City Council

ICT – Information and Communication Technologies

ICAT – Information, Communication and Automation Technologies

The acronyms used in the transformation grammar rules are explained in Part2: Chapter 4.

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INTRODUCTION

RESEARCH PROBLEM AND PROPOSED SOLUTION

This doctoral thesis begins with the premise that a large amount of the housing stock in Lisbon requires rehabilitation, either due to constructional anomalies or difficulties in meeting present-day requirements. The problem it aims to address concerns the need to adapt the existing housing stock to contemporary lifestyles and functional and constructional requirements arising out of the use of technologies in housing.

Within the present-day context of construction in Portugal and, more specifically, in Lisbon, rehabilitation is the future for the housing market. On the one hand, it is known that the number of residents in the city of Lisbon has fallen by approximately 15% in the last 10 years (INE, 2002). This population loss has been accompanied by the gradual deterioration and abandonment of the housing stock in the city and a consequent increase in the amount of vacant accommodation which, according to the 2001 Census, totalled 14% (CML, 2002a). In 2001, there was far more vacant accommodation than housing needs in the city.

In addition, it cannot be denied that construction has an enormous negative impact on the environment, since it consumes and wastes resources. Therefore, from this perspective, rehabilitation reduces the waste created by buildings, given that it involves less demolition. Even if a building has reached its functional limits, this does not mean that it cannot be upgraded to meet current needs and requirements (Durmisevic and Ciftciolu, 2007).

The need to carry out rehabilitation work arises out of the fact that a large amount of the housing stock in Portugal, particularly in the big cities, urgently requires intervention work of this kind. Recent data indicates that 55.9% of the residential buildings in Lisbon need repairs and 5.3% are in a state of serious decay (INE, 2002).

In terms of population, the traditional family structure which includes one man, one woman and their children does not necessarily reflect the family life of many households. In fact, the traditional nuclear family consisting of a couple with children has become less important and the presence of other groups has increased in society. Elderly people (aged over 64) represent one quarter of the Lisbon population, and the most representative families consist of two individuals, followed by 1 individual (INE, 2001). The number of single parent households has been increasing in recent years, totalling 18% of the nuclear families in Lisbon.

This data has major consequences for the dynamics of neighbourhoods and their residential buildings, both now and in the future. The need to consider these domestic groups is reflected in the need to understand different ways of living and to incorporate these needs into housing.

Parallel to this increase in new forms of co-residence, the emergence of Information and Communication Technologies (ICTs) and their mass use has changed social relationships amongst individuals and between individuals and the surrounding space, on different levels. The use of technology has introduced numerous new possibilities in everyday life that enhance human capacities and allow for greater autonomy and comfort.

The use of these ICTs is of the utmost importance and their incorporation in homes is a priority which must be complemented by home automation in order to provide better quality of life for residents and sustainable use of energy.

It has been calculated that by 2050 almost one third of the Portuguese population will be aged over 65 (INE, 2003). Portugal has never had such a high percentage of potentially dependent citizens and the entire care sector has to be prepared for this fact. For these groups, the use of home automation technologies is becoming a viable option in terms of remaining in the comfort of their own homes rather than moving to a healthcare facility.

The aim throughout this thesis is to define a methodology that enable the existing housing stock to be adapted to contemporary's living requirements in order to provide comfort, sustainability and the social integration of citizens. The definition of this methodology is the key factor that allows the adaptation of a dwelling to the requirements of contemporary lifestyles. By contemporary we mean the time when the adaption is performed which implies that the methodology still maintains its accuracy if different future parameters are used.

GOALS

Present day society is totally reliant on technology. It is therefore inevitable that Information, Communication and Automation Technologies (ICAT) is applied to housing and nowadays this is no longer restricted to conventional products such as lighting, washing machines and fridges but has begun to spread throughout the home. Technology is starting to change people's ways of life and access to technology has created imbalances in society.

Just as the use of technologies is changing lifestyles, the intention here is to demonstrate that the incorporation of technologies within housing is leading to changes in spatial/functional organisation. In addition to these changes, the inclusion of technologies and functional changes may also have constructional consequences, which will be analysed.

Whilst it may be considered easy to integrate these changes into a new housing programme, the same programme will be subject to restrictions and limitations if it is intended for an existing dwelling designed in a different period of time and for another residential context. The intention here is also to demonstrate that integration is possible and that dwellings which are several decades old can be adapted to current lifestyles.

This research has three main objectives:

1. Firstly, to identify how the use of technology influences life-styles and creates new dwelling requirements, and how this affects the spatial and functional organisation of dwellings. This work complements Pedro's (2000) and Duarte's (2001) frameworks for incorporating new dwelling modes, new domestic groups, and ICAT-related demands;
2. Secondly, to define appropriate ICAT sets to incorporate into the spaces in dwellings so as to guarantee environmental sustainability and the social integration of citizens, by adapting them to individual households according to present and future needs. These ICAT sets apply to the dwelling as well as the building, including existing rehabilitated residential stock and new buildings;
3. Thirdly, to define design guidelines and a methodology to support architects involved in the process of adapting existing dwellings and incorporating ICAT technologies, allowing them to balance new dwelling trends with sustainability requirements.

The objective of this methodology is to contribute towards the effective integration of ICAT within housing, acknowledging that it can be applied to adaptation projects for the existing housing stock, reflecting concerns for economic viability with regard to multiple ICAT installations.

WORKING METHODOLOGY AND AREAS OF EXPERTISE

The working methodology consisted of 4 phases (Figure 1):

Fase 1. Compilation and analysis of bibliography

Fase 2. Definition of current functional and technical requirements associated with the incorporation of technologies, in particular ICAT within housing

Fase 3. Definition of intervention criteria and general rehabilitation methodology

Fase 4. Case study: selection, characterisation, definition and testing of specific rehabilitation methodology

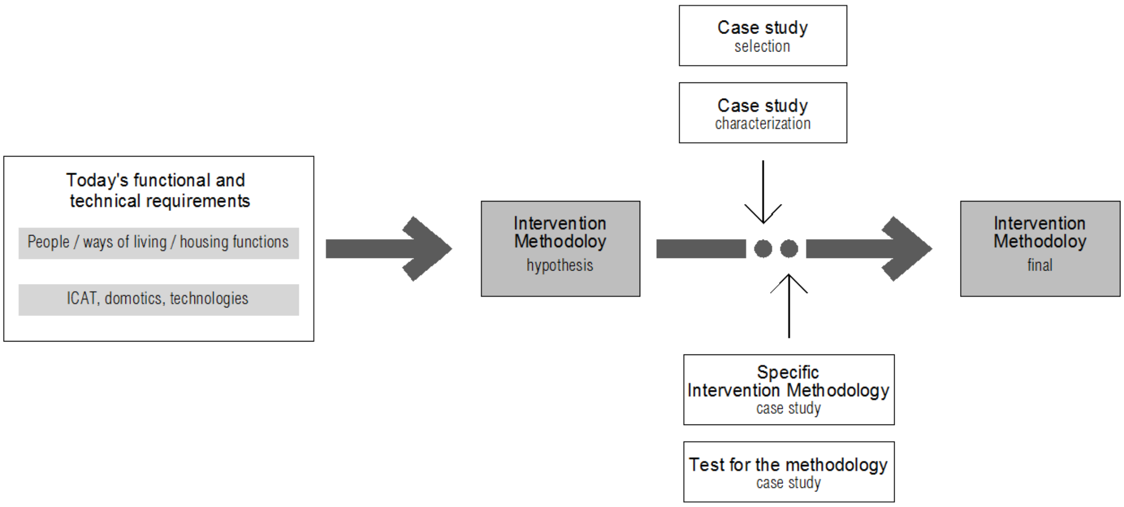

Figure 1 – Diagram illustrating working methodology.

The first phase involved compiling and analysing the bibliography for the main themes covered in the thesis: ICT and domotics, housing, rehabilitation, the design process and support tools for design (shape grammar and space syntax). Curriculum units and other training sessions were also included in this initial phase, with the aim of extending knowledge in areas related to the subject of the thesis.

The aim of the second phase was to characterise the current situation regarding patterns and ways of living from the following points of view: a characterisation of the present social context regarding families and new lifestyles; a characterisation of the role of technology, namely ICAT, in everyday domestic life and its functional and constructional implications for housing; the definition of new housing requirements and functions.

With regard to the characterisation of the current social context, the evolution of families and lifestyles was studied and a characterisation of the households most representative of the situation in Portugal and in Lisbon was produced. No specific studies were undertaken for this purpose, but existing studies in the fields of sociology, statistics and architecture were consulted, including those produced by Wall (2005), Pereira (2006), Pedro (2000), Cabrita (1995), Coelho (2000), Morgado (2005) and Oliveira (2000).

The characterisation of the role of technology within a domestic context was undertaken in terms of the market available in Portugal today. Within this context, the technologies designed for such varied purposes as serving individuals with reduced mobility, providing access to information, quality of life, comfort, safety, entertainment and reducing the environmental impact of buildings were characterised. Studies currently exist on the characterisation of domotics and the impact this has on housing, but this information is very scattered. The intention was therefore to systematise and unify it in terms of the effects on architecture. This phase of the study culminated in cross-referencing the previous characterisations with the aim of determining the ideal scenarios for integrating the technology in accordance with the various households and their needs.

In the third phase of the study the main guidelines for rehabilitation were defined from a functional, constructional and technological point of view in the light of the concepts obtained in the previous phases. These principles took the form of a design methodology in which the general guideline criteria for rehabilitation were presented.

The criteria followed three different but complementary methods, through which the guideline principles for intervention were defined: i) a functional method for the various functional areas of the dwelling and the various rooms which define it; ii) a constructional method for the construction components to be rehabilitated due to functional changes or the integration of ICT and domotics; iii) a technological method for the integration of the various systems/functions, networks and equipment that comprise the domotics system.

These principles or intervention criteria were incorporated into a general design methodology.

The fourth phase of the study consisted of several steps: choosing the case study "rabo-de-bacalhau" ("cod-tail") building type; characterising the case study; developing a specific rehabilitation methodology for the building type selected to enable the general methodology to be tested in a real world context; evaluating the methodology. In order to define this methodology, shape grammars and space syntax were used as tools to formalise the changes introduced into the original type and transformation rules were applied to this type.

MAJOR CONTRIBUTIONS

The research carried out for this thesis resulted in a varied set of contributions which will be fully clarified in the Conclusion:

1. <u>A characterisation of the "rabo-de-bacalhau" building type</u>.

   In this thesis, these buildings are characterised with the aim of understanding the design principles behind the building type in order to decide how they can be used today. It was therefore necessary to study the buildings from the functional, technical/constructional, stylistic and social perspectives of the time when they were built, as well as the current situation regarding the use of these buildings.

2. <u>A method for defining the ICAT packs to be integrated into the housing, according to family profiles</u>.

   To ensure that an efficient method was proposed for defining the ICAT packs to be integrated into the housing it was considered necessary to define certain premises for the definition of the ICAT packs in advance. These premises concern the definition of family profiles, the real needs of individuals and the technology generation. In addition to current resident characteristics, the method also anticipates future family needs and activities within the home.

3. The conception of a rehabilitation methodology based on a rigorous process

   Unlike traditional rehabilitation processes executed on an individual case basis for each family/dwelling combination, this thesis proposes a methodology to support a process which clarifies decision-making and speeds up the project.

   The benefit of the proposed methodology, intended for the first phases of the rehabilitation project, is its ability to impose a very precise and systematic form of intervention.

   Several phases are defined to complete the intervention, each with specific inputs and outputs from the client/resident following the rehabilitation assumptions defined – functional reorganisation and integration of ICAT.

   This methodology includes both the architect's knowledge and knowledge acquired from previous experiences of rehabilitation work in the form of principles and rules.

4. The development of a transformation grammar

   Within the context of research into shape grammar theories, this thesis proposes a new approach to their use in architectural rehabilitation processes.

   The grammar proposed in this thesis is called a transformation grammar, as it aims to transform dwellings in order to adapt them to contemporary user needs.

   Existing works on shape grammar explore the possibilities of generating designs based on rules using both an analytical approach (to understand existing design languages) and a generative approach (to generate new design languages). Work done by Colakoglu (2005) explores both the rules for generating traditional Hayat houses and the rules that enable the generation of these type of houses but conforming to a contemporary context. The current thesis proposes a different approach, in that it aims not to generate the design of the dwellings in the study or their design after transformation, but the rules that enable them to be adapted to new lifestyles. The transformation grammar is used as part of a proposed methodology that can be used to rehabilitate existing dwellings.

Organisation of the thesis

As previously described, this research intends to define a rehabilitation methodology for Lisbon's existing housing stock to enable it to respond to new technology requirements and new life-styles. This rehabilitation methodology is described in depth in the second part of this thesis.

The thesis is organised in a similar way to the proposed rehabilitation process, as schematised in Figure 2.

The first part of the thesis corresponds to the framework that forms the basis of the research. The justification for certain arguments used in the thesis is incorporated into the first part: the importance of information technology in present-day society (*Part 1: Chapter 1*); the importance of housing rehabilitation (*Part 1: Chapter 2*) and certain considerations pertaining to the building planning process and rehabilitation methodologies (*Part 1: Chapter 3*).

In addition to these arguments the data needed for the knowledge base to be used in the rehabilitation process is also incorporated in the first part: the household profiles (*Part 1:*

Chapter 4), the current housing functions (*Part 1: Chapter 5*) and the available ICAT set (*Part 1: Chapter 6*).

The first part of the thesis also contains a description of the existing residential buildings - the "rabo-de-bacalhau" type - used as the case study for the application of the rehabilitation methodology and in the definition of the transformation grammar (*Part 1: Chapter 7*).

The second part of the thesis corresponds to the rehabilitation methodology.

It starts with a definition of the rehabilitation methodology (*Part 2: chapter 1*) and follows with chapters on each of the steps in the process.

Firstly both the ideal and the adapted functional programme are defined in *Part 2: Chapter 2*. In the first section of this chapter, the household profile is used to determine the ideal functional programme for the dwelling. The functional programme in this case is a description of an ideal housing solution for the family that is not bound by any existing morphological structure or design language. In the second section, the existing dwelling and the ideal functional programme are used to derive a description of a compromise or adapted solution based on the existing dwelling.

Secondly, both the ideal and the adapted ICAT pack are defined, in *Part 2: Chapter 3*. In the first section of this chapter, the household profile is used to determine the ideal pack of ICAT functions. The ICAT pack in this case is a description of an ideal housing solution for the family that is not bound by any existing morphological structure. In the second section, the existing dwelling and the ideal ICAT pack are used to derive a description of a compromise or adapted solution based on the existing dwelling.

Thirdly the transformation grammar is defined in *Part 2: Chapter 4*. In this chapter the layout of a design solution for a particular family in a particular dwelling is obtained from the description of the adapted dwelling, including the ICAT components needed in the dwelling.

Finally the conclusions drawn from the research are presented, as well as some future lines of research.

The analysis of the case study sample is presented in *Appendix 1*. In *Appendix 2* Experiments 1, 2 and 3 are presented and in *Appendix 3* the shape rules for the transformation grammar. Finally, in *Appendix 4* a sample derivation is presented.

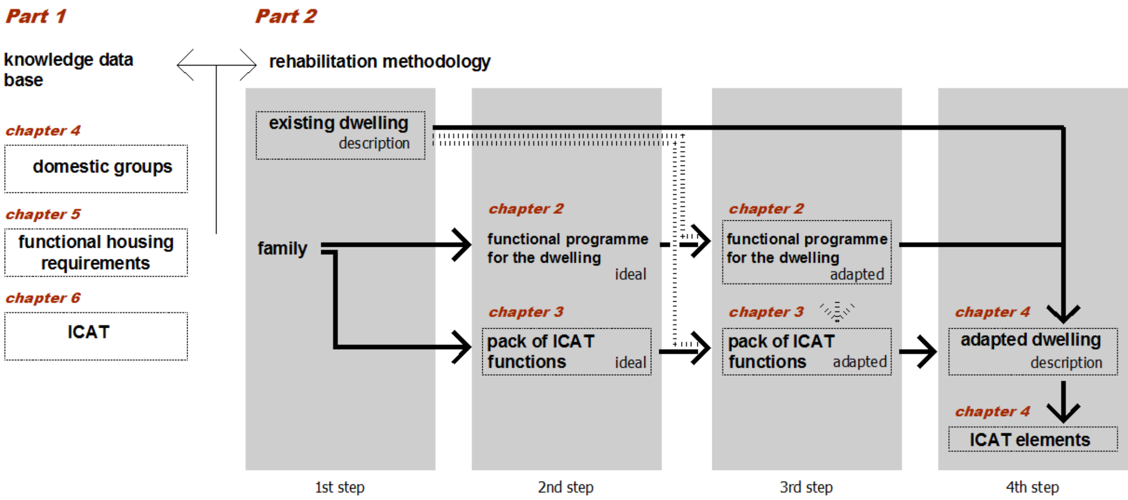

Figure 2 – Basic steps in the planned rehabilitation methodology

PART 1 Framework

1 THE INFORMATION SOCIETY

In the information age the creation of power and wealth is based on the exchange of information, mobility, and the ability to access, share and influence this new world, creating a global space for ideas, information and knowledge. Due to its ability to distribute the power of current information, Castells (2004: 15) compares the importance of the Internet to the electricity network and the electric motor in the industrial era. In fact, ICTs are already part of our everyday existence and have invaded homes, the workplace, leisure areas, the city and transport networks in such a ubiquitous way that this has been termed the Third Revolution. ICTs include all forms of making communications content physically manipulable and flexible through digitalisation and the use of network communications to hold, transmit and distribute information. The arrival of these technologies and their rapid diffusion and assimilation by society has led to the emergence of the Information Society (IS).

The Information Society, whose operations increasingly involve the use of digital information networks, may be defined as a form of social and economic development in which the acquisition, storage, processing, enhancement, transmission, distribution and dissemination of information that can be used to create knowledge and satisfy individual and corporate needs plays a key role in economic activities, the creation of wealth, the definition of quality of life and the cultural practices of citizens (MSI, 1997). In this new society, the information and knowledge component plays a central role in all types of human activity due to the development of digital technology, and the Internet in particular, leading to new ways of organising the economy and society. In its most complete form, the Information Society is characterised by the ability of its members (citizens, businesses and the state) to obtain and share any type of information and knowledge instantly, from any location, in the most convenient way (UMIC, s.d.: 1).

ICTs materialise as a set of equipment and services, some of the most common and accessible of which are computers, the Internet, mobile phones, GPS and video games. In addition, various technologies have enabled us to experiment with hybrid realities in a more profound and interactive manner. These include the immersive environments of Virtual Reality (VR), in which the observer is immersed in a virtual environment through the use of goggles, a helmet and gloves. In addition to VR, Augmented Reality environments bring the concrete and the virtual world closer together by superimposing virtual objects and information onto the former using, for example, reconfigurable touch screens that are sensitive to movement, touch or emotions, or even goggles or contact lenses.

For Huang *et al.* (2002), virtual space is digitalised on the basis of the characteristics of real space, which are transformed into virtual environments such as websites and games. Nowadays architecture and urban planning is not restricted merely to designing physical space but also includes the digital and virtual space that complements it. Architecture must respond to stimuli and interact with residents, thus enabling it to become an interface for cyberspace (Tramontano, 2007).

In this new context, the virtual world and the concrete world coexist and complement each other. From entertainment to work, healthcare and economics, the emergence of ICT as a knowledge and information mechanism has led to new forms of interaction between citizens and between citizens and urban space.

These systems are not expected to replace traditional options, but to increase their capacities and add to the range of options currently available. In fact, television, radio and the cinema have not replaced live entertainment, just as computers and the Internet have not replaced books and other traditional cultural agents.

The city has not dissolved in the digital era but has instead acquired new ways of supplementing its functions. New online services bring those who are already close and those who are further apart even closer together. Young people get together again after a day at school, colleagues finish off their work after they have gone home, friends in different continents meet up again and family members can chat to each other despite physical distances. Digital technologies allow for the appropriation of a space that is different from concrete reality, but which nevertheless completes and enhances it.

However, info-exclusion, in the form of a lack of infrastructures and means of accessing ICT, is still a reality for many people. Overcoming this need will depend on the evolution of technology to make it economically more accessible and on government initiatives that see it as a driving force for economic, social and cultural development.

ICTs have significantly altered the traditional limits and constraints on space and time in cities, and are also changing the spatial organisation systems used by societies. The city, as the place where social networks and the entire complexity of urban life unfold, is now intersected by omnipresent digital networks which people interact with, even without realising that they do so. The digital world is an integral part of our life and complements what we are physically unable to achieve.

1.1 THE INFORMATION SOCIETY IN PORTUGAL AND EUROPE

1.1.1 European Information Society initiatives

With the aim of helping to promote the spread of the IS in Europe, the European Commission has launched initiatives whose main aims are to bring all European citizens into the digital age and online by increasing Internet connections in Europe and to create a digitally literate Europe.

In the 1990s various projects emerged in Europe led by the European Commission and associated with the spread of the IS at city level through broadband Internet access. In 1999 the European Commission launched an initiative entitled *eEurope 2002* which aimed to make the Internet cheaper, faster and safer, to invest in individuals and their qualifications and to encourage use of the Internet. This plan enabled domestic use of the Internet to double, Internet access prices to fall and schools and business connections to increase, in addition to online state services and trading.

In 2002, as a follow-up to the previous plan, the Seville European Council approved the action plan for *eEurope 2005: An Information Society for all*. The aim of this plan was to increase economic productivity and improve quality and access to services for European citizens, supported by a secure (protected) broadband infrastructure available to the greatest possible number of citizens. The plan also aimed to promote access for all, in order to combat social exclusion, whether associated with special needs, disability, age or illness (EU, 2005). The final evaluation of the *eEurope 2005* plan revealed that the results of the action plan had been positive, particularly with regard to broadband connections and online public administration. Nevertheless, in 2004, only less than 20% of households in the EU15 had access to broadband.

This plan was followed by the *i2010 – European Information Society 2010* (EC, 2006a), the action programme extending to 2010, which gave priority to ICTs as a factor in stimulating European competitiveness. The initiative defined knowledge and innovation as the major driving forces behind sustained growth and considered it essential for the IS to be developed in an inclusive manner, based on the comprehensive use of ICTs in public services, businesses and households. In setting these targets, Europe hoped to promote innovation and investment by fostering economic growth and employment, the creation of a single information space leading to an open, competitive and content-rich internal market and the creation of an inclusive European IS which gave priority to improved quality of life.

The European strategy for 2020 was launched in 2010 as the successor to the i2010 plan and was called the *Digital Agenda*. The Digital Agenda is Europe's present strategy for a flourishing digital economy and aims to maximize the benefits of the digital revolution for all. The action areas of the Digital Agenda will be (EU, 2010):

- A digital single market (opening up access to content, making online and cross border transactions straightforward, building digital confidence, reinforcing the single market for telecommunications services);
- Interoperability and standards (improving ICT standard-setting, promoting better use of standards, enhancing interoperability through coordination);
- Trust and security;
- Fast and ultra-fast Internet access (guaranteeing universal and faster broadband coverage, fostering the deployment of NGA networks and an open and neutral Internet)
- Research and innovation (stepping up efforts and efficiency, driving ICT innovation by exploiting the single market, industry-led initiatives for open innovation);
- Enhancing digital literacy and skills as well as inclusive digital services;
- ICT-enabled benefits for EU society (ICT for the environment and sustainable healthcare and ICT-based support for dignified and independent living, promoting cultural diversity and creative content, eGovernment, intelligent transport systems for efficient transport and better mobility).

1.1.2 Portuguese Information Society initiatives

In Portugal government IS intervention strategies began in 1996 with the creation of the *Mission for the Information Society,* which aimed to initiate a broad national debate on the subject of the IS. The *Green Paper on the Information Society* (MSI, 1997), presented in 1997, included policy measures and contained examples of the experiences of the general government and businesses within the context of the Information Society. The contents of the Green Paper represented a first step towards the elaboration of Action Plans whose objective was to take suitable advantage of the window of opportunity offered by the emergence of the IS. Between 1996 and 1999 a series of key initiatives were adopted, including:

- The creation of the *Rede Ciência, Tecnologia e Sociedade* (RCTS - Science, Technology and Society Network) (Figure 10);
- The launch of the *Programa Cidades Digitais* (Digital Cities Programme - see *Part1:Chapter 1.3.1)*
- Approval for a system of tax benefits for the purchase of computers, software and domestic Internet access;

- The launch of the *Iniciativa Nacional para o Comércio Electrónico* (National Initiative for Electronic Commerce);
- The approval of legislation on *digital signatures* and *electronic invoicing*;
- The *Iniciativa Nacional para os Cidadãos com Necessidades Especiais* (National Initiative for Citizens with Special Needs) in the Information Society.

In 2000 the *Programa Operacional para a Sociedade de Informação* (Operational Programme for the Information Society - POSI) was approved and in the same year the government created the *Comissão Interministerial para a Sociedade de Informação* (Interministerial Committee for the Information Society) and launched the *Internet Initiative,* which encouraged state measures and private initiatives, mainly supporting social inclusion and boosting international cooperation (MCTES, 2005).

In 2002 the *UMIC – Unidade de Missão para a Inovação e Conhecimento* (Innovation and Knowledge Mission Unit) – was created. It produced the *Action Plan for the Information Society,* whose objectives were to digitally connect everything to everyone (technological investment), develop content appropriate to the experiences of people (social and cultural investment), qualify individuals to take the best advantage of the society in which they live (education and training investment), and reduce the cost of all the previous points (economic investment). The UMIC action plan was based on 7 pillars of action: (i) an Information Society for all; (ii) new skills; (iii) quality and efficiency of public services; (iv) better citizenship; (v) healthcare for all; (vi) new ways of creating economic value; (vii) attractive content (MCTES, 2005).

In 2005 the *UMIC* was re-named the *Agência para a Sociedade do Conhecimento*[1] (Knowledge Society Agency) and its mission became the planning, coordination and development of IS and eGovernment projects.

The Operational Programme for the Information Society (POSI), approved in 2000 and created with support from the *III Community Support Framework*[2]*,* allocated financial support from the Structural Funds (the ERDF and ESF) to projects associated with the Information and Knowledge Society and played a role in disseminating good practice in this area. The POSI supported countless projects in areas as diverse as *"mass broadband access, improvements in services provided by the state to citizens and businesses via eGovernment, the development of ITC skills and a digital culture, investment in ICT integrated innovation and the consolidation of the Knowledge Society as an support instrument for the decentralisation of the territory."*[3]

In 2004 the POSI was replaced by the Programa Operacional para a Sociedade do Conhecimento (Operational Programme for the Knowledge Society - POSC)[4], which had similar objectives[5]. POSC support was allocated to projects in the following areas: the creation of Internet areas; the production or provision of broadband content; the creation of broadband public access points; the creation of Digital Cities; the creation of Virtual Campuses in state and private universities and Polytechnic Institutes ("e-U"[6]); support and training in basic ITC skills; the promotion of ITC within the central public administration.

In 2005 the *Programa Ligar Portugal (Connect Portugal Programme)*[7] appeared, whose main aim was to encourage widespread access to the Internet and ICTs, as the Information and Knowledge Society was considered a key factor in the development of Portuguese society. The *Ligar Portugal* initiative had similar objectives to the previous programmes, which included promoting modern, informed, aware and active citizenship through the use of ICTs, guaranteeing the competitiveness of the national telecommunications market, ensuring general government transparency, promoting the increased use of ICTs in the business sector, and stimulating scientific and technological development (MCTES, 2005).

1.1.3 ICTs in Portugal

Despite the great range of ICTs available, in reality many are still restricted to technologies accessed by a minority, either for financial or cultural reasons.

The Internet and computers

Indicators from the *Observatório da Comunicação* (Communications Observatory) (Vieira, 2009) show that 52% of the Portuguese have never used the Internet. In addition, 3% of respondents had only had indirect, mediated contact, resorting to help from others and 4% stated that they had used the Internet only once in order to try it out (Figure 3).

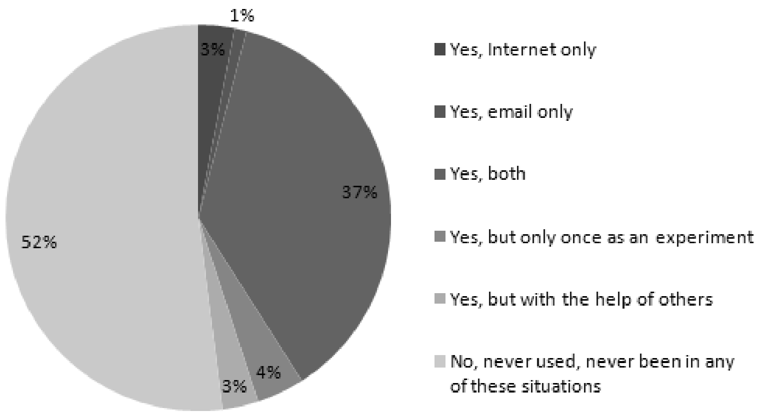

Figure 3 –Internet access in Portugal (Vieira, 2009: 5)

However, in recent years Portugal has witnessed a considerable increase in the use of digital technologies by citizens.

In 2009, 56% of households in Portugal had access to a home computer[8], 47.9% with an Internet connection and 46.2% with a broadband connection (INE, 2009b).

In the younger age groups computer use was above average, being highest in the 10 to 15 age group, the key age for first serious ventures into the use of NICTs: 97% used a computer and 93% had Internet access (INE, 2009a). There was a 6% increase in these figures between 2005 and 2008 with reference to computer use and a 26% increase in Internet use. Over the age of 45 the levels of use for both indicators were below the national average.

In comparison with the penetration of these technologies in the remaining age groups, it can be seen that current use decreases with age (with the exception of mobile phone use amongst 16 to 24-year olds). In fact, even in the 25-34 and 35-44 age groups computer use wavers between 74% and 53.5% and Internet use between 47.5% and 69.5%. The youngest age groups in society have come to play an important role in subscribing to ICTs, particularly in terms of adopting new services and functions.

The computer and Internet are used on a daily basis by 75.6% of computer users and 71.7% of Internet users (INE, 2009b). With regard to frequency of use in the 10 to 15 age group, the proportion of daily or almost daily users is below the national average – 57.8% for the computer and 54.5% for the Internet. Although young people essentially use the computer and Internet at school, as is to be expected, it is important to note that this is giving way to use in the home and houses of friends and family members, which increased significantly between 2005 and 2008.

The use of the Internet for leisure purposes has risen considerably; involving 89.1% of young people aged 10 to 15, although school work still ranks first in terms of use (94.5%). Another relevant factor is the major increase in Internet communications – a rise of 44% – and website browsing – which has increased by 30% – and a 10%, fall in gaming within this age range.

With regard to activities that fall within the definition of *user-generated content*, in the field of visual culture 21% of Internet users regularly share photographic productions on the Net (Vieira 2009: 10). Although a greater percentage have mastered the techniques of sharing music, only 14% do so on a regular basis. In terms of creating online content, there is a low culture of taking part in and producing content. Only 11% of Internet users have created and regularly maintain a blog and 11% also stated that they had created and updated a web page (Vieira, 2009: 10).

With regard to the use of the Internet for e-work, the data for 2006 (EUROSTAT, 2007) reveals that in Portugal approximately 36% of those who spend part of their working life outside the workplace access it using ICTs, whereas in Denmark the figure is 80% (the highest figure), in Hungary 1% (the lowest figure) and in the Europe 27 47%.

MOBILE PHONES

Portugal is one of the countries with the highest rate of mobile phone service penetration in Europe. In the first quarter of 2010 the penetration of this service within national territory rose to 148.9 per 100 inhabitants, which is higher than the European average of 122.9/100hab (ANACOM, 2010). As with computers and the Internet, the younger age groups are also the greatest users of mobile phones. 85% of individuals in the 10 to 15 age group use mobile phones (INE 2008), this figure having risen 36% between 2005 and 2008. The figures for the penetration of this technology within the remaining age groups do not vary as much as those for the use of computers and the Internet, but current use decreases with age from 24 years old onwards. Mobile phone use essentially involves making phone calls and exchanging text messages (95.2% and 96.1% respectively) with an increase in the exchange of content noticeable in recent years (61.6%). In 2007 Portuguese adolescents sent between 1 and 25 SMSs per day (Cardoso, 2007), whereas American adolescents sent an average of 50 SMSs per day in 2004 (Hoffman *et al.*, 2004). The number of voice calls is clearly lower, ranging from 0 to 3 in Portugal and 1 to 5 in the USA, according to the same data. This trend indicates the importance which young people attribute to rapid, instantaneous communication. Respondents of working age (25-44 years old and 45-64 years old) revealed a relatively high level of interest in functions that enabled them to manage their daily and professional life more easily (using the mobile phone as an ATM, videoconferencing, motorway toll payments, GPS and stock exchange opportunities) (Cardoso, 2007).

According to an OBERCOM study (Cardoso, 2007), mobile phones appear to facilitate personal communications, with the majority of calls directed to family and friends. The mobile phone has therefore become an item of digital equipment that favours a larger number of inter-subjective relationships, emphasising the individualisation of everyday activities which is typical of the IS. It should be noted that this trend towards using the mobile phone as a substitute for social relations is particularly marked amongst young people. As an example, 42% of respondents aged 17 or under stated that they had used a mobile phone to provide company when they were alone (Cardoso, 2007).

ACCESS TO TECHNOLOGIES

The Obercom study on ownership of technologies amongst the Portuguese shows that television and the mobile phone rank highest, at 99% and 88.7% respectively (Taborda, 2010).

With regard to other more recent and specific technologies, within the context of this research the ownership of home cinema by 11.5% of respondents and games consoles by 22.7% should be highlighted (Figure 4).

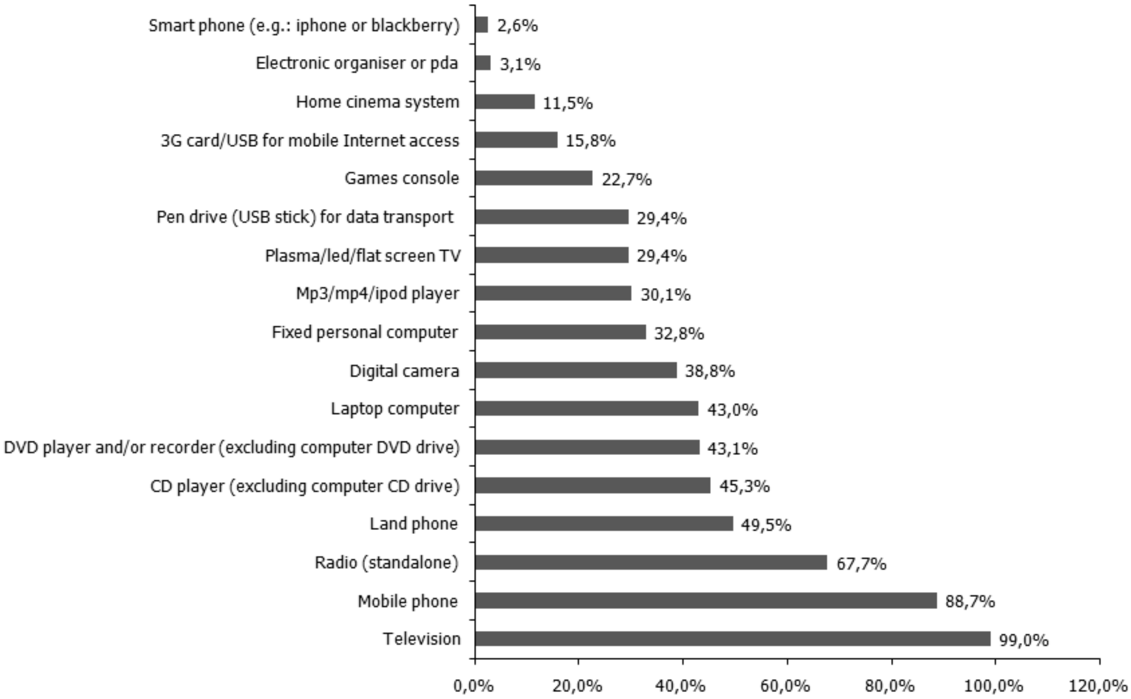

Figure 4 – Ownership of equipment (Taborda, 2010: 11)

VIEWING FILM CONTENT

According to OBERCOM studies on the figures for viewing films in Portugal, a sharp overall reinforcement of the process of private consumption of film content in the home can be observed (Cheta, 2007) (Vieira, 2009). When questioned about the ways in which they watched films, 94% of respondents who affirmed that they did so stated that they used television, 20% DVD/video, 3% a computer via Internet downloads and only 19% went to cinemas.

The mainstream profile, termed the 2nd technology generation by OBERCOM, is characterised by the heavy penetration and intensive regular use of DVD home viewing. This profile reveals a heavily domesticated consumption pattern, combined with occasional visits to cinemas. The profile which characterises the 3rd technology generation is still a minority profile, although it is becoming increasingly autonomous and established. It is characterised by the variety, personalisation and interactivity of its modes of consuming film content. For this profile, the mobile features of the technological equipment used to view film and multimedia content are very significant, in terms of stated future interest in actively seeking to purchase high definition mobile equipment and platforms for multimedia content (Cheta, 2007: 37). These are the consumers who are most exploring the possibilities afforded by digitalised content provided via webcasting and self media. They are also the ones who use multiple screens – cinema, computer, TV DVD – and want to try out new mobile integrated platforms, IPTV and digital television. The profile is composed of a group of younger individuals and some young adults, all of whom are Internet users.

Info-inclusion of the elderly in Portugal

The TIO (Terceira Idade Online – Senior Citizens Online) project emerged in 1999 with the aim of reinforcing the active participation of elderly people in the Information Society, promoting health and quality of life for the elderly and fostering inter-generational relationships and knowledge[9].

In 2005 the VIDA Association which manages the TIO Project produced an exploratory study on the use of the Internet by elderly Portuguese citizens using an online questionnaire on Internet user habits completed by individuals over the age of 55. The results revealed a major regional imbalance (73% of the replies came from the Greater Lisbon area and Porto), and the home as the centre for Internet access (in 84% of cases) (Projecto Tio, 2005). The most common Internet activities amongst this group of the population were: sending and receiving e-mails (96.9%); managing bank accounts (31.3%); state/local authority matters (26.6%); online shopping (10.9%). The most frequently searched areas were healthcare/illness (65.6%), holidays/tourism (54.7%) and rights (46.9%).

Since then some private association projects designed to digitally include the elderly have emerged, such as the "VIVER Project" and the "Info-Gerar – Gerar interacção através da Info-Inclusão" (Info-Management – Managing Interaction through Info-Inclusion)[10] project, both run by the VIDA Association. The latter aims to provide an approach that not only involves ICT training, but essentially the use of technology as a form of publishing testimonies or, in other words, the values and customs of the main participants – young people and the elderly population.

1.2 Hybrid realities: concrete reality and its virtual simulation

The city of today should be understood as a dynamic set of social networks, digital networks and physical infrastructures.

Addressing the dispersed nature and virtual provision of new forms of information and communication, Mark Poster (1999), in a context similar to Gleick (2003: 79), affirms our difficulty in understanding our actual place in the present day dimensions of the world. Is it the dimension of time, space or society that is important to us? Virilio (2000: 53) also reveals the alienation that can infuse virtual communications and which needs to be balanced with real-world contact.

Nowadays architects and urban planners do not only work with the physical space that provides shelter, comfort, quality and security but also with reconfigurable virtual elements. In fact, when the planning of a city or the design of a building is being considered, inherently technological issues have become as important as architectural matters. The digital and electronic domain has opened up possibilities in terms of physical domains, just as digitalised information has enhanced writing (e.g. books and the printed press).

The introduction of technology into the everyday life of societies has led to behavioural changes. Technologies such as radio and television have made a variety of cultural events such as theatre, concerts, opera and dance, formerly only enjoyed by social élites, accessible to all citizens. Supplementing this, other technologies such as digital television, video-on-demand, 3D cinema and virtual or augmented reality have enabled us to benefit from a reality that is almost identical to our actual presence in space. Pursuing this line of argument, we may be persuaded to believe that buildings destined for entertainment, such as theatres, cinemas, etc., will have a different impact on cities and will decline in importance. Parallel to entertainment, other activities and buildings such as financial institutions, prisons, schools, services and shopping centres may follow the same path.

As Mitchell (1999b) asks, will we continue to go to the cinema or use video-on-demand to watch films privately? Shop at the local bookshop or order through the Internet? Communicate and keep in touch with distant friends electronically or with our next-door neighbours? Study areas, schools and universities have also been supplemented by online services. Students and teachers do not need to meet in the same place if they have access to computers, the Internet, a camera and e-learning services. Healthcare establishments, ranging from central hospitals to small local units, are following the same trend, with the potential to be partially replaced by telemedicine and a consequent reduction in the need to transport patients. Buildings such as prisons may also be substantially reduced in size and number if prisoner monitoring systems that make use of electronic mechanisms such as tags are adopted. Banking services are already highly computerised and it is rare nowadays for citizens to go into town to visit the bank, leading to a reduction in the number of branches and subsidiaries. ATMs offering multiple functions, card payments that dispense with the physical presence of money and Internet and telephone transactions have almost entirely replaced the physical space occupied by banks (Figure 5).

However, this situation has not exactly led to the dissolution of the city as we know it. The city has not disintegrated or been destructured as a result of telecommunications networks. NICTs operate within structured spaces and need them to take shape and create locations for new activities and encounters. The coexistence of the concrete and the virtual creates a hybrid form of space which is slowly taking charge of our everyday life.

Figure 5 – Physical presence versus virtual presence in banking, supermarkets, theatres, clothing retail, the cinema and the city.

Traditional entertainment areas have to update and create new hybrid spaces in which, together with cinema, theatre, opera and dance, other events take place and attract groups of people. The spread of connections via wi-fi in various physical areas of the territory, or the simple use of the mobile phone to access the Net are factors which attract the public who, on the pretext of accessing the Internet, occupy spaces, consume and participate in the activities taking place there. Physical participation in an event is very often insufficient and the need or desire to share collective or private experiences with others also leads people to participate in the same event at the same time in a virtual sense when the experience is publicised on social networks (Figure 8). The sharing of photos on the Internet at the exact moment when a particular event takes place is a means of globally sharing our experiences and making a local event global. Yet do events have a concrete location? Is the reality of a rock concert greater or lesser if we are in visual contact with the musicians, in the stadium looking at the screens, or far away watching and listening to what is happening? The virtual and the real cooperate, complement each other and share information.

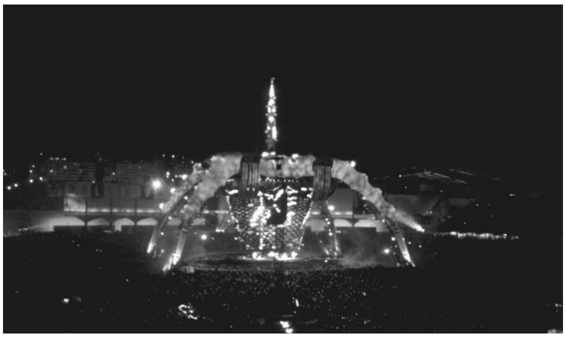

Figure 6 (top left) – Democratisation of access to culture. Free admission to dance and music on the patio of the São Carlos Opera House in Lisbon. (Jul 2008, source: http://leticiabarreto.blogspot.com/)

Figure 7 (top right) – Appropriation of outdoor spaces by visitors to parks, using floor cushions and shades. Gardens of the Calouste Gulbenkian Foundation, Lisbon (Jul 2010, photo: SE)

Figure 8 and Figure 9 – Images shared on Facebook during a U2 concert in Coimbra, October 2010. (source: facebook/Hugo Coelho)

Spatial dimensions may be extended beyond their physical limits by a virtual area supplemented by technologies such as augmented reality. Walls with touch reconfigurable devices enable us to interact with architecture, and devices built into goggles help us to explore a new urban environment. In this context, architecture can react to stimuli, interacting with citizens and responding to their emotions and states of mind or even reacting to stimuli from the surrounding environment. In the same way, augmented reality technology may take shape in the urban space of the city and, by superimposing itself onto it, become interlinked with it. GPS is a practical example of this interaction, but other more sophisticated devices such as glasses or contact lenses with built-in technology may guide us in performing tasks or add content to the concrete world. Electronic commerce envisages the use of a "data helmet" and "data glove" to allow consumers to make consistent and informed product choices and enable them to select any product without physical contact.

The Internet network defies physical geometry and its anti-space nature is one of its fundamental characteristics (Daniels, 2000). We may encounter texts, images and videos "on" the Internet without knowing for certain where they can be found or where they were uploaded from. E-mail messages themselves do not state where they are sent from. Physical space is no longer controlled and everyone who surfs the Net is indifferent to it. The actual identity of those on the Net may be concealed. Time is also an uncertain variable, since everything is simultaneously active and we can communicate with anyone who has asked a question online weeks, months or even years ago.

The new configurations of virtual space appear to be assuming a role of benign pressure and influence on the organisation of real space, in the sense that this is gradually taking shape as a leisure area, fostering social relations and extending democracy. One example of this is the possibility of citizens participating in the construction of the real city through the use of ICTs, in the Lisbon City Council participatory budget[11], for example, in which any citizen may propose projects they consider important for the city and/or vote on those they consider most relevant. Citizens may also take part in constructing a virtual digitalised city based on the real city, as in Google maps.

1.3 INFO-INCLUSION VS INFO-EXCLUSION

The current situation regarding the phenomenon of globalisation and the networked society does not allow everyone to take part in the global society. On the contrary, new technologies benefit those who are better prepared and informed. Those who have not mastered technology or who have been disregarded or even marginalised, are distanced from networks and consequently from social and employment spheres. Castells (2004) argues that exclusion from networks is one of the most serious forms of exclusion that can be experienced in our economy and culture.

In this context, the IS requirements we face have led to imbalances in society. They have raised questions of inequality between rich and poor countries, urban and rural societies and differences in economic development between social classes. The development of countries and regions is influenced by the way in which ICTs are introduced and assimilated and the success and speed of their absorption. Access to technology will always depend on various complementary factors: equal distribution of telecommunications infrastructures; digital literacy; the price of services and equipment; connection costs; development programmes. In this context, it is fundamental to develop strategic reflections aimed at overcoming the obstacles to taking advantage of the opportunities offered by ICTs.

The Internet, as the global vehicle for information and the promotion of freedom of expression, can become oppressive and overrule those who want to participate in society, but do not wish to use it. What would a banking institution be today without online services, a university without Internet facilities or a technology manufacturer without a description of its products that everyone can access? Institutions which do not have the Internet, "the incubator for communications tools" (Lemos, 2003), are automatically considered to lack credibility. Citizens' use of the Internet, whether as private individuals or professionals, through sites, blogs, discussion boards and social networks, generates dynamics that surpass all physical boundaries. Even the digitally illiterate are obliged to access state services via the Internet – including those relating to taxes and social security benefits. It is rare to find individuals without access to the Internet amongst the younger age groups and this distances them from an essential form of participation. Those who are not on the Internet are second-class citizens. Moreover, those who do not use the Internet are prevented from using countless services. Citizens who do not want or are unable to become part of the digital world are subject to bullying tactics by institutions which, rather than adapting to citizens, oblige them to adapt to technologies (Bennet, 2010).

1.3.1 Regional imbalances and competitiveness in cities

Telecommunications infrastructures act as a driving force for economic activity, since they are able to link various spaces together instantaneously and allow for more rapid flows than traditional forms of communication.

The development of online trading services, together with the opening up of international markets, has broken down the physical barriers to trade and services, meaning that companies have become global and operate beyond their apparent physical boundaries. The fact that they may be based in London, Paris or a small city is irrelevant to electronic commerce. The purchase and distribution of goods does not need to operate from one single place. Employees and customers do not need to operate from one geographical location, nor do they need to meet. Telecommunications allows for dispersed, decentralised transactions amongst populations and organisations and facilitates the emergence of new, flexible and efficient production, storage and distribution systems.

According to Castells, cities and their commercial zones have become complexes in which output is based on information (Castells, 2005: 503). They are places where company head offices and their financial services can find qualified specialist suppliers and labour and use them as required without employing them on a permanent contractual basis. Castells calls this phenomenon flexibility and adaptability.

In creating vast virtual markets Internet traders can reach a greater number of potential buyers. At the same time, consumers are provided with a wider and more detailed choice at any hour of the day, as well as the possibility of better prices.

Potential purchasers are those covered by the telecommunications infrastructure and consequently the Internet or, in other words, the entire infrastructured world. In some cases virtual markets, based on telecommunications, are hampered by traditional communications infrastructures. Services such as software purchases or banking transactions, for which the Internet is the only form of communication, operate in any part of the world that has a fixed or mobile telecommunications network. In addition, services involving the sale of products in bulk are subject to charges and schedules for land or air delivery that are based on a different, less rapid and less efficient type of infrastructure. These physical and virtual networks complement each other and, in the majority of cases supported by the Internet, cannot entirely replace each other.

Telecommunications infrastructures make businesses more mobile, and this mobility ensures major benefits for economic activities, freeing them from additional costs and consequently making them more competitive. This mobility has led to the decentralisation of economic activities.

Nowadays numerous companies no longer operate from physical locations (and others never have) and have begun to do business exclusively (or almost exclusively) via the Internet. It is easier today to purchase a specific book from a virtual store than a city centre bookshop.

These new possibilities have led to changes in the actual structures of companies and, in some cases, have been responsible for staff reductions or decentralisation, given that most of the business operations have now been computerised.

On a territorial level**,** these changes have led to the centralisation of management and the elimination of various intermediate points dispersed throughout the land (which had previously been used to reach out to citizens/customers). However, this does not mean that companies have closed down or become isolated in one place: on the contrary, their ubiquity and the territorial complexity within which they operate have never been greater. According to Branco-Teixeira (2003: 275), infrastructure networks grow when and where demand is solvent, meaning that markets have become demand driven rather than supply driven.

For companies nowadays telecommunications are equivalent to the transport networks of half a century ago, namely a determining factor in their success. The availability of fast reliable connections is essential and seen as a competitive advantage. In this context, areas supplied with good infrastructures have a great competitive advantage and generate large economic flows, whereas others with fewer infrastructures are threatened.

Cities which, in addition to the traditional infrastructures, have invested in developing their telecommunications infrastructures acquire new economic opportunities and promote productivity, competitiveness and quality of life.

Telecommunications infrastructures and information networks link various cities and countries in a cooperative and transactional network, creating a space for inter-regional cooperation based on common objectives, needs and strategies which is proving to be an essential resource in terms of the current challenges posed by urban and economic development.

In common with the development of all infrastructure networks – road, rail, telephone, electricity – the development of the telecommunications infrastructure in Portugal has been asymmetric, with the better positioned regions reinforcing their status through access to more competitive forms of communication and information linked to economic modernisation, whilst regions with few infrastructures are unable to make up the ground they have lost. In fact, the telecommunications infrastructure mirrors the coastal development of the country, leaving some areas in the interior with more difficult access and accentuating the regional discrepancies (north/south, coast/interior, more urbanised districts/rural districts) (Figure 10).

In spite of this, the availability of various services via ICT networks mainly benefits peripheral or more isolated areas where transport is less efficient and greater distances need to be covered. In these areas access to online services allows for fast, efficient contact when a certain level of frequent contact needs to be maintained, in addition to offering services without the need to travel (including home shopping and home banking).

Due to these issues, any assessment of the impact of ICTs on the economic development of a territory can be interpreted in various different ways. On the one hand, the availability of ICT is a factor that leads to the standardisation of conditions for development in a territory, given that the omnipresence of networks may decentralise activities and counter concentration within major urban centres. Thus regional imbalances, although not totally eliminated by TIC, may be reduced. On the other hand there is evidence of a negative discourse concerning the relationship between new ICTs and regional development. The new technologies may be associated with a polarised model that equates the global restructuring of present societies with a process that is termed techno-economics. In the absence of regulatory mechanisms for the distribution of wealth, we are witnessing the unequal growth and polarisation associated with economic policies in general[12].

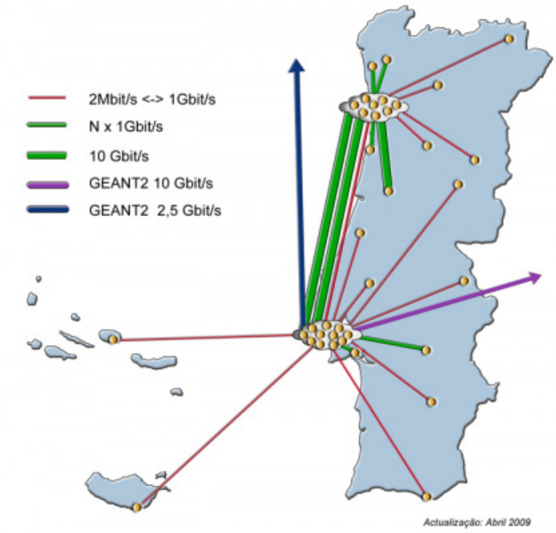

Figure 10 – The RCTS network –National Research and Education Network, NREN) April 2009 (source: http://www.fccn.pt/)

Figure 11 – Digital Cities and Regions in Portugal. (source: http://www.cidadesdigitais.pt/)

Digital cities and regions

The concept of *Digital Cities and Regions* was an initiative associated with the Information and Knowledge Society that aimed to foster *"new ways of organising the economy and society, contributing towards the creation of knowledge and economic value"* (POS, 2003) for regions, their citizens and companies. The *Digital City* is a system composed of individuals and (public and private) institutions linked by a digital communications infrastructure (the Internet) and referenced to a real city.

This project aimed to develop the Information and Knowledge Society on a regional level in order to create applied regional skills that could create economic value for the region, enhance quality of life for its citizens and foster competitiveness amongst businesses and sustainable development. The *Digital Cities* projects aimed, according to Gonçalo Furtado, to make a range of city information available on an interactive site and to create links with urban activities in the "real" city. These projects "*designed and produced a technological interface destined to boost the performance of activities in the city;* (...) *computerised access aims to meet the needs of citizens and the greater operational capacity of the various sectors operating within the city*." (Furtado, 2003: 242)

The digital space in these new cities represented a physical and geographical dimension. New digital content is "superimposed" onto the physical sites through cyberspace. The content, adapted to the networked community and conceived by it, is created in accordance with the needs of the real community and aims to emerge as an alternative to the physical territory.

However, the majority of experiments consisted only of databases for a particular urban space, gathering together information on leisure activities, tourist information, transport, cultural events, etc. for the respective municipalities. Digital cities have therefore become more of an advertising space for services and spaces than *"the creation of that which gives life to a city or, in other words, the creation of forms of free and democratic communication"* (Lemos, 1999), given that areas for social interaction with opportunities for two-way dialogue and community forums only exist on a small scale.

Moreover, digital city projects are undertaken by consortiums of local politicians, non-government organisations, online service providers and urban/regional government information offices. In general, therefore, the projects best serve the educated partners from the dominant economic and cultural group, rather than the social system as a whole. Attempts to "link everything to everyone" and "prevent social exclusion" were objectives that were beyond the scope of the digital city projects. In fact, the digital cities do not reach a large section of the technologically illiterate population and are directed towards an economically and technologically educated elite.

1.3.2 Network accessibility: the new barriers

Information technologies and principally the Internet, provide access to participation in society for individuals with special needs. Through ICTs citizens with special needs can access information, services and activities, in addition to contacting friends and family in any part of the world. Many of these activities, if they involved travel, would be impractical or would require complicated logistics. "*For many people it is the mobile technologies that enable them to go anywhere without leaving the house and feel the pulse of the world"* (Godinho, 2009).

However ICTs can raise serious problems in terms of access. Viewing a computer screen or using peripherals such as the mouse and keyboard are, for many elderly or disabled people, difficult tasks. Due to the sight, hearing, sensory or motor disabilities experienced by many, it is necessary to prepare technologies for universal use.

In terms of the digital content of the Internet, since 1999 investments have been made in Portugal in initiatives that promote access to the Information Society for citizens with special needs. Examples include programmes promoting access to government and public services Internet sites[13], the *Programa Acesso* (Access Programme)[14] that provides an online analysis in real time of the accessibility of any site and enables suggestions to be made, and the *Ler para Ver* (Read to See)[15] initiative for the visually impaired.

1.4 THE ROLE OF ICTS IN INDIVIDUAL DYNAMICS

"The best and worst of things? Information" ESOPO[16]

In cities of all sizes and even in smaller population groups, the new forms of urban lifestyles are marked by mobility. The emergence of ICTs and their mass use has changed social relationships between individuals by providing new opportunities for communication and interaction. These possibilities have enabled new spaces that configure social identity to emerge, but have not put an end to traditional social relations (Guerra, 2000). ICTs have a dual function in this sphere. On the one hand they are, in themselves, a meeting place and on the other hand they are a means of disseminating the digital information which shapes lifestyles. As meeting places, we have witnessed the rapid emergence of new online forms of entertainment – e-mail, blogs, online games, social networks, chat rooms, forums, etc – involving many citizens.

As the pessimistic view that linked the use of ICTs the isolation in citizens has been almost superseded, it may now be recognised that ICTs encourage sociability, since they foster social interaction even when it takes place online. Communications networks have opened up new social opportunities and no one wants to be excluded. Through resources that may be intrusive, ubiquitous or instantaneous to a greater or lesser extent, the possibilities of using these communications networks are so vast that they enable us to choose the type of profile that suits our personality. From the simple use of e-mail, which ensures a certain distance between the sender and the recipient, to channels such as Twitter and social networks such as Facebook, in which privacy in the majority of cases is not desirable, citizens have *x* hypotheses for choosing how they become involved in society. Other networks such as Youtube, which is growing at the rate of 20 hours of video per minute (http://www.geek.com/), are already part of the everyday life of cyber-citizens. We are witnessing the democratisation of the media "for all" in which the former idea of one sender and various recipients is being replaced by the new paradigm of everyone communicating with everyone else ubiquitously.

As previously stated, the use of ICTs is becoming increasingly widespread amongst the younger age groups in society. Children and young people use ICTs in an integrated and dynamic way and with a dexterity superior to most adults. Due to their immersion in technologies, the perception that these younger generations have of society and the world is necessarily different from that of previous generations. This rapidly shifting paradigm, which is growing continuously with the advent of new forms of virtual interaction, creates an insurmountable digital distance between younger and past generations.

Where would present-day society be without ICTs and, in particular, the Internet? The Internet is nowadays an essential asset for many citizens and, as such, the guarantee of access is linked to the concept of indispensability (Hoffman, 2004). If nowadays the Internet is indispensible for a considerable section of society consisting of the more technologically literate individuals with greater economic and social power, in the future will this dependence be substantially greater, given the growing skills of children today? In the event of the collapse of TICs, will those who are more adapted to the environment survive, paralleling the theory of evolution? Or will only those who do not use them, or make little use of them, adapt to the new world?

1.5 Remote control of space: are ICTs intrusive or do they facilitate daily tasks?

The introduction of automation in domestic areas and principally the hypothesis that this form of automation can provide for the remote control of applications, is a housing innovation that has introduced new possibilities into the lives of citizens (this subject is developed in *Part 1: Chapter 5*.

This involves two essential aspects which need to be analysed: automation for the ordinary citizen and automation for citizens with special needs.

In either case, housing is no longer a static space waiting to be used by residents, but has become an autonomous living space. Through the use of intelligent systems housing can manage ventilation throughout the day, control indoor temperatures by opening/closing windows, blinds and screens and can even manage energy waste and saving and make rational, scaled use of the energy available for operating equipment. Housing can read the outdoor atmospheric conditions and act accordingly, deciding whether or not to water the garden or close the windows. Housing can anticipate the arrival of residents and, if desired, switch on the air conditioning and lights and greet them with their favourite music.

We are now experiencing housing as an organism which, without any localised interaction by its residents, hosts countless activities essential to its performance.

For the ordinary citizen, remote communication with housing enables them to interact with the house, sending commands for such equipment as domestic appliances, blinds, lighting, air conditioning, alarms and video surveillance. Innovative applications such as kitchen management and the ordering of supplies, remote supervision of the performance of appliances in order to detect faults and even the reading and analysis of meters are all technologies which facilitate routine tasks.

Are these technologies considered intrusive by some? We believe not, if some of their true benefits are analysed.

In this respect it is worth reflecting on the applicability of home automation assistive technologies for individuals with special needs. In addition to the technologies already mentioned, other possibilities in terms of monitoring exist, currently used with the aim of virtually accompanying elderly citizens or those with physical and or cognitive disabilities. Records of water, electricity or gas may be essential indicators in detecting the illness or death of dependent single people. In addition, transversal to all citizens, monitoring the consumption of water, for example, may provide important indications of undetected leaks and allow for a rapid response.

Moreover, for individuals with special needs, the possibility of monitoring and remote action can enable them to remain almost autonomous in their homes or housing units, where they can remain practically independent without the need for constant support from others.

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[1] Information available at WWW: <URL: http://www.umic.pt/UMIC/> (accessed on 2008-10-19)

[2] Information available at WWW: <URL: http://www.qca.pt/index.asp> (accessed on 2008-10-19)

[3] Information available at WWW: <URL: http://www.posi.pcm.gov.pt/> (accessed on 2005-07-12)

[4] Information available at WWW: <URL: http://www.posc.mctes.pt/> (accessed on 2008-10-19)

[5] MCTES. *POSC, Programa, eixos prioritários e medidas.* Available at WWW <URL: http://www.posc.mctes.pt/?accao=paginaf&pag=pri3> (accessed on 2008-10-19)

[6] Available at WWW: <URL: http://www.e-u.pt/>

[7] Information available at WWW: <URL: http://www.ligarportugal.pt/> (accessed on 2008-10-19)

[8] "Computer" includes fixed computers, laptops and pocket computers (tablet, palmtop, PDA).

[9] Information on the TIO Project can be found at WWW: <URL: http://www.projectotio.net/> (accessed on 2008-10-16)

[10] Further information available at WWW: <URL: http://infogerar.blogspot.com/> (accessed on Dec. 2010)

[11] Further information available at WWW: <URL: http://www.cm-lisboa.pt/op/> (accessed on Sept. 2010

[12] CASTELLS, M.; HENDERSON, J. "Techno-economic restructuring, sociopolitical processes and spatial transformation: a global perspective", in *Global Restructuring and Territorial Development Sage*, London, 1987. Cited by Jacinto (2000)

[13] Information available at WWW: <URL: http://www.acessibilidade.gov.pt/> (accessed in Dec. 2008)

[14] Information available at WWW: <URL: http://www.acesso.umic.pt/> (accessed in Dec. 2008)

[15] Information available at WWW: <URL: http://www.lerparaver.com/> (accessed in Dec. 2008)

[16] ESOPO, cited by Paul Virilio (Virilio, 2000: 57).

2 HOUSING REHABILITATION

This thesis is based on the assumption that in Portugal the scope for building new housing in large cities has reached its limit and rehabilitation is the path that should be followed in future.

It is therefore imperative to reuse the city and the existing housing stock, introducing the improvements necessary for safe, more up-to-date use in terms of building quality and architectural functionality requirements.

The housing rehabilitation advocated here is not only of the kind promoted by private developers – the owners of one or more dwellings or one or more buildings – but also the kind that can be undertaken by state developers to tackle housing needs (which at present are more qualitative than quantitative, as we shall see).

Therefore the specific analysis of "rabo-de-bacalhau" buildings (*Part 1: Chapter 7*) is not restricted to the idea of individual rehabilitation projects on a dwelling-by-dwelling or building-by-building basis, undertaken by and for the middle and upper classes. The aim is to show how these buildings can accommodate different lifestyles and different types of households and how state intervention may prove profitable if the model for funding shifts from new buildings to rehabilitation projects.

In addition to the possibility of the aforementioned individual rehabilitation projects undertaken by private developers, the possibility is also raised of the acquisition of buildings by the state, similar to the recent work by EPUL (*Empresa Pública de Urbanização de Lisboa*), for rehabilitation and inclusion within the housing stock destined for low income families.

Throughout this thesis, emphasis is placed on minimal rehabilitation or improvement work, both from an economic, ecological and environmental point of view and from a functional perspective. In fact, interventions should not adapt the old to the new but rather the new to the old, enabling the material and technical features of the original solutions to be preserved and avoiding unnecessary destruction and demolition work. This idea of reducing intervention to the minimum and avoiding unnecessary destruction is related to the possibility of reversing interventions in the future. Reversible solutions allow for adaptability, since the decision not to impose single solutions, forms of use and functions enables the building to be readapted for other uses after rehabilitation.

This chapter aims to provide an overview of rehabilitation and housing needs in Portugal, and the opportunities for rehabilitation work as opposed to new construction work. It also analyses the potential offered by rehabilitation work in the search for ecological and social sustainability.

2.1 THE EXISTING HOUSING STOCK AND POPULATION

Although the existing housing stock in Portugal is capable of accommodating more of the population than it does at present, most of the dwellings in fact need constructional rehabilitation.

Approximately 64% of the housing stock in Lisbon is over 50 years old (Table 1) and therefore presents various constructional and functional problems which are the cause of its immediate unsuitability in terms of comfort. From a constructional point of view, according to the 2001 Censos (INE, 2002), in terms of building maintenance, 55% of the buildings constructed in

Lisbon between 1946 and 1970 needed repairs and 24% were in state of average to severe deterioration. This lack of maintenance work has led, in many cases, to the deterioration and obsolescence of materials, components and equipment.

In addition to constructional rehabilitation, the dwellings also need functional rehabilitation, which is more difficult to quantify in statistical terms. In fact, most of the existing housing stock does not meet current habitability requirements, either in terms of comfort or functionality.

Construction period	**Lisbon**
Built before 1919	18.28%
Built between 1919 and 1945	23.66%
Built between 1946 and 1960	22.01%
Built between 1961 and 1970	14.21%
Built between 1971 and 1980	8.96%
Built between 1981 and 1985	2.73%
Built between 1986 and 1990	2.94%
Built between 1991 and 1995	3.17%
Built between 1996 and 2001	4.04%

Table 1 – Dwellings in Lisbon, by construction period. Source: (CML, 2002a)

The city of Lisbon has been subjected to processes of occupation and urban growth that have led to a high level of depopulation in its central area. In addition to the fall in the number of residents, this is also reflected in the ageing of the resident population, the existence of vacant or underused housing stock and its deterioration (due to abandonment or lack of financial resources on the part of its owners).

This abandonment, which is more marked in the centre of the city, contrasts with the overcrowding in suburban areas, which have witnessed major demographic growth in recent years. The resident population of the city of Lisbon has been falling rapidly and totalled 564,000 inhabitants according to the last Census, representing a 14.9% decrease in 10 years (INE, 2002). It can also be seen that the full rate of occupation for existing dwellings, and those under construction, approved and planned, exceeds 930,000 inhabitants (Pinho and Aguiar, 2005) (signifying 1.65 accommodation units per inhabitant).

Within thirty years, from 1970 to 2001, the number of dwellings in Portugal doubled from 2.5 million in 1970 to 5 million in 2001 (Pinho and Aguiar, 2005), representing an average of 1.35 dwellings per family and 1 accommodation unit for every 2 residents.

Paradoxically, despite the large amount of dwellings currently available, Portugal continues to experience housing needs, since much of the accommodation does not meet the minimum conditions for habitability and there are many instances of overcrowding and co-residence (Table 2). In Lisbon, although 17% of the dwellings are overcrowded, the reverse situation of subletting totals 51.8%, reflecting the reduction in family size and the ageing population.

12.6% of the housing in Lisbon is used as seasonal accommodation and 11.6% is vacant (INE, 2002). A certain regional balance can be found in the statistics for vacant accommodation, with the figures for all regions close to the national rate (11%) (INE, 2002)[17].

Rehabilitation is one of the current responses that can meet ongoing housing needs. The existence of a very large number of vacant dwellings is considered by the *Plano Estratégico Nacional para a Política de Habitação* (PENPH – National Strategic Plan for Housing Policy) to be a wasted resource that should be optimised (PENPH, 2007).

A study carried out by Lisbon City Council (Caria, 2004: 163) concluded that the demand for rehabilitated housing remained lower than the demand for recently built housing.

Amongst the group surveyed, 28% stated that, given a choice between dwellings of the same quality in new and rehabilitated buildings, they would never opt for a rehabilitated dwelling.

Despite this, 31% of the respondents said they would give priority to location as a criterion affecting their choice.

	Portugal	North	Centre	Lisbon	Alentejo	Algarve
Non-standard accommodation	27 319	6 686	4 268	11 960	1 750	1 587
Classic families living in hotels or co-residing	8 178	1 938	1 947	1 981	981	738
Shared occupation accommodation for families	68 299	21 161	14 660	21 376	4 482	2 974
2% of the number of classic family residents	73 015	24 213	16 945	20 113	5 850	2 985
Total needed	**176 811**	**53 998**	**37 820**	**55 430**	**13 063**	**8 284**
Vacant accommodation (for sale, rent, demolition or other)	543 777	167 292	129 970	149 327	52 262	25 858
Vacant accommodation on the market	185 509	64 825	35 076	58 403	11 873	10568

Table 2 – Quantitative housing needs and vacant accommodation, by NUTS II (*Unidade Territorial de Nível II*), Lisbon, 2001. Source: (Rodrigues, 2002)

With regard to the conditions required to ensure the choice of rehabilitated housing, the responses from the CML study revealed that 45% would only accept this option if major rehabilitation work had taken place, involving maintenance of the façade and total reconstruction of the interior, 42% would accept if an average level of rehabilitation work had been carried out, including altering the infrastructures and finishings, and only 12% would accept if rehabilitation work was limited to the finishings. This data shows, on the one hand, the need to rehabilitate the existing housing stock to make it more attractive and, on the other hand, major reservations on the part of the predominant group regarding the quality of the buildings.

The most sought-after rehabilitated typologies are T1 and T2 dwellings (with 2 and 3 habitable rooms), since the main co-residing groups consist of 2 and 1 people (42% and 22% respectively), with the younger sections of the population (aged 18 to 24) most receptive to the idea of rehabilitated dwellings. Although this particular item of information concerning this age group was to be expected, the fact that, in terms of education, the group most resistant to the idea of living in rehabilitated dwellings was the most highly qualified, was unexpected.

It may be concluded that, in terms of actual need, the demand for housing is restricted to young people at the start of their adult life, the more underprivileged classes and small co-residing groups. It is therefore necessary to accommodate the supply of dwellings to the characteristics of the potential demand, basically involving state intervention in the form of policy measures to facilitate the purchase or renting of dwellings by these groups.

2.2 ASPECTS OF HOUSING REHABILITATION IN PORTUGAL

Rehabilitation of buildings and urban complexes is slowly gaining significance in Portugal. Although the building stock has suffered from a lack of maintenance and conservation for lengthy periods of time, society is nowadays becoming collectively aware of the value of these assets, both in terms of the economy of the country and in terms of social and cultural relations between citizens. One important aspect of this new awareness is associated with an understanding of the meaning of heritage, not only from a historical and monumental point of view, but also from a perspective that values present-day, contemporary buildings, whether they complement the historic areas of cities or not.

In terms of the rehabilitation and reuse of its existing building stock, Portugal has undertaken few projects in comparison with other European Union countries and in 2002 was the country in Europe least involved in rehabilitating its stock and most involved in promoting new construction (Pinho and Aguiar, 2005). Despite this, conservation and rehabilitation work has increased considerably in Portugal, and in 2009 represented 22.1% of the construction sector, according to INE data (in 2003 the figure was 15.7% and in 1998 9.6%). The new construction sector, in turn, fell 21.9% in 2009 in comparison with the previous year (INE, 2010). These figures indicate that, although rehabilitation is talked about a great deal, in reality new constructions continue to dominate the housing market overall.

Despite this trend towards more new constructions, it has been possible to identify areas in which rehabilitation work has become more significant (INE, 2009c).

According to the INE, in 2007 only 19.5% of the building work completed in Portugal involved alteration, extension and reconstruction projects. Also according to data from the INE (2009c: 4), in territorial terms building rehabilitation implies a process associated above all with strategies to develop under populated areas and their structural centres, in addition to work associated with the two metropolitan centres – Lisbon and Porto.

This lack of rehabilitation work is the result of various factors such as the lack of a market for rented properties, together with the difficulties experienced by owners, credit facilities for purchasing homes and the fall in interest rates, mainly at the end of the 20th. century, a factor which boosted housing construction. In addition, other reasons have restricted the development of the rehabilitation market, namely: the lack of public measures to provide incentives for rehabilitation work; economic developments; the large size of the entities involved in a process of this kind; the weak response from the construction sector and the lack of awareness, on the part of owners, of the importance of repair and maintenance work (Caria, 2004: 159).

It is acknowledged that the rehabilitation sector may develop as the rental market is revitalised, the construction of new housing slows down, the housing stock ages, various incentives are created for rehabilitation work and the concern for quality and comfort increases.

2.3 REHABILITATION AS A SUSTAINABLE STRATEGY

Urban regeneration or rehabilitation aims to maintain the morphology of sites and conserve and rehabilitate buildings in order to improve their habitability from a social, physical and functional point of view. Through these processes the intention is to promote a territorial balance with regard to the distribution of the population and productive activities, revitalise urban or low density areas and contain the territorial expansion of urban areas with a view to achieving greater social cohesion. In addition, the choice of rehabilitation rather than new construction work reduces the negative impact of the construction industry on the environment.

The environmental impact created by humans is increasing continually and its consequences, amongst many other phenomena, include the depletion of resources, scarcity of energy, excess emissions and the creation of waste. The construction sector is one of the areas of human activity most responsible for consuming resources and energy and for generating waste and pollutants. This consumer cycle continues throughout the time buildings are in use, becoming worse towards the end of their useful life, and is perpetuated in individual dwellings, buildings and entire cities.

According to Edwards and Hyett (2001:11), 50% of the world's material resources are destined for construction, 45% of the energy generated is used in buildings (for heating, lighting and ventilation) and 5% in their construction, 40% of the water consumed in the world is used to supply buildings, and 60% of the best arable land and 70% of timber is used to construct buildings.

With regard to promoting environmental quality, rehabilitation offers countless advantages in comparison with new construction. These include the fact that rehabilitation is based on land whose use is already predetermined, on the one hand allowing for the re-use of existing infrastructures and, in addition, the re-use of entirely or partly vacant buildings.

Since the end of the 20th. century, the rehabilitation of buildings has become a priority in sustainable urban development policies, as alternative to new urbanisation and the consumption of non-renewable resources (Mourão, 2005: 237). The existence of a large number of empty dwellings is considered by the *Plano Estratégico Nacional para a Política de Habitação* to be a wasted resource that should be optimised (PENPH, 2007).

The alternative to rehabilitating buildings is to demolish them and erect new buildings on the same site. Within this context, the impact of producing new waste that is difficult to remove or recycle (still not a common practice in Portugal) and is also energy-consuming, should be assessed. In fact, in cases where the intention is to opt for new constructions on sites where existing buildings stand, the economic and environmental cost of demolition, the removal of materials to landfill sites and the new construction itself must be considered.

In addition to the actual rehabilitation of buildings, urban rehabilitation must allow for the social integration of groups who face the greatest difficulties, either in terms of age or for financial reasons. This process will necessarily generate a more dynamic, safer, more attractive and lively future city.

The essential aspects involved in the rehabilitation of the city of Lisbon – in the search for greater social cohesion and greater economic sustainability – are the increasing population in built-up areas, the growing rental market and the fight against speculation in the real estate market, which includes vacant or deteriorated dwellings.

Housing rehabilitation promotes urban sustainability, since it renovates, dynamises and regenerates the city, promotes full occupation and revitalises residential use of the city centre.

In urban rehabilitation the aim is, whenever possible, to maintain the resident population and attract new occupants to vacant dwellings and/or buildings. Maintaining the local population (through public policies which, for example, subsidise the cost of rehabilitation), whilst at the same time creating the conditions to accommodate a new population are measures that can lead to greater age, economic and cultural diversification and help vitalise the city. This approach promotes the social integration of citizens and prevents the phenomenon of gentrification which is so common in areas subjected to rehabilitation work.

This study recommends that, in addition to the rehabilitation of dwellings at the request of families, the process can also be undertaken on a collective basis by the state or private developers. Within this context, the availability of rehabilitated dwellings for sale or rent at accessible prices through public or private initiatives, will provide accommodation for needy populations, create better living conditions for residents whilst enabling them to remain in the city and even preserve the owners' assets and make them more profitable (Caria, 2004: 165). State intervention in providing support for rented accommodation, through measures such as rent subsidies, would be essential in ensuring that the investment in rehabilitation is rewarded.

[17] In 2001, 34% of vacant accommodation was available on the market (19% for sale and 15% for rent), 5% was due for demolition and 61% came under the category "other". (INE, 2002)

3 THE BUILDING PLANNING PROCESS AND REHABILITATION METHODOLOGIES

The current state of the stock of residential buildings in Lisbon, the current pressure on the part of the real estate sector for old buildings in prime areas of the city and the functional inadequacies of many of these buildings given present-day lifestyles justify the proposal for a rehabilitation methodology. The methodology proposed in this research enables knowledge of ways of working with existing residential buildings to be systematised and applied whenever there is a need to functionally rehabilitate them and provide ICATs.

Establishing a methodology for rehabilitation is a strategy that aims to systematise and apply knowledge of rehabilitation effectively, coherently and justifiably, focussing on meeting requirements in terms of compatibility, durability, reversibility and economy**.** At the same time, it prevents negligence in interventions involving the built heritage.

The housing rehabilitation process, in the context of the case presented, is usually complex, small-scale, labour-intensive, and very constrained in terms of existing buildings. The definition of existing building constraints is a determining factor and should be carried out in the early phases of the process. Simultaneously, the existing conditions and characteristics of buildings should be used as part of the new situation.

However, the fact that these rehabilitations are generally undertaken on an individual case basis, involving one building or dwelling at a time, results in the application of isolated criteria which do not take into account what is happening in neighbouring buildings or in other dwellings within a building. This lack of common criteria for intervention work on the buildings leads to unsatisfactory results, both in economic and constructional terms, specifically with regard to infrastructure networks. Thus, the prevailing situation is that this kind of rehabilitation is generally performed inefficiently and at correspondingly higher costs (van Leeuwen *et al.*, 2000).

Moreover, the difficulty experienced by future residents in expressing exactly what their objectives are also frequently leads to unsatisfactory results (Huang and Shih, 2005).

The definition of methodologies to support rehabilitation work, together with the dissemination of information on the architectural features of existing buildings in terms of their typological, stylistic and constructional aspects, is an essential factor in obtaining good results for rehabilitation of the building stock.

Although the rehabilitation market is still less important than the newly-built market, the growing need for building rehabilitation makes rehabilitation and refurbishment design financially more attractive.

This chapter addresses the traditional planning process for buildings as well as providing an overview of some existing rehabilitation methodologies. The new proposals for rehabilitation methodology will be addressed in *Part 2: Chapter 1*.

3.1 THE PLANNING PROCESS FOR BUILDINGS

The design process, the focus of this research, is part of the planning process as a whole, which comprises five main stages: planning, intention, conception, construction, and maintenance (Figure 12) (Plácido, 1999: 91) (Paiva *et al.*, 2006) (Giebler *et al.*, 2009).

These stages are valid both for new constructions and for rehabilitation but, in the latter case, include certain differences, explained later, arising out of the specific nature of the work.

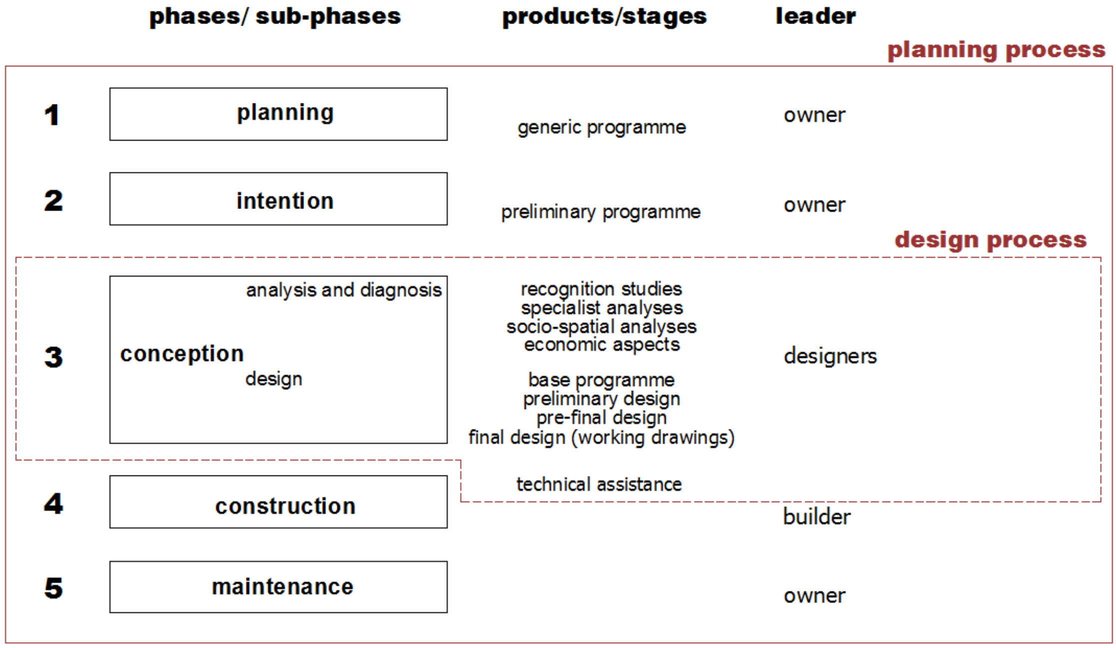


Figure 12 – Planning process for a rehabilitation intervention.

Planning a rehabilitation intervention is fundamentally different from planning a new building. The major difference is that the starting point for rehabilitation work is an existing building and not an abstract object. Thus, if the architect has been mainly concerned with new constructions up to this point, he must learn to rethink the planning process (Giebler *et al.*, 2009: 22).

The planning phase is the responsibility of the client and corresponds to the expression of needs. In this phase, needs are defined in terms of building, priorities, planning of available resources and measures to be carried out, and scheduling (Plácido, 1999: 92). After this phase, the intention phase follows, in which the client's objectives and intentions materialise in a document called the preliminary programme, produced by the said client or by a team working for him. The document supplied to the designer must define the objectives, organic and functional characteristics and financial conditions for the project, as well as the respective costs and schedules to be observed (Portaria 701-H/2008).

After the client's intentions have been defined, as expressed in the preliminary programme, the conception phase begins, in which the designers develop their work. Currently Portaria 701-H/2008 constitutes the legal document which establishes the procedures and norms to be adopted in the elaboration and phasing of public works projects, as well as the obligatory contents of the programme and the construction designs. In accordance with this Ordinance, the design process covers the following phases: i) base programme, ii) preliminary design, iii) pre-final design, iv) final design (working drawings) and v) technical assistance. Some of these phases may be exempted from formal presentation or adjusted in the contract specifications by agreement between the client and the designers.

When the aim of the project is rehabilitation, the conception phase includes two major steps or sub-phases: analysis and diagnosis/evaluation of the situation and the design phase itself (Paiva *et al.*, 2006) (Giebler *et al.*, 2009) (Teixeira and Póvoas, 2010). According to Paiva *et al.* (2006: 296), analysis and diagnosis/evaluation sub-phase includes four key stages:

- Recognition studies _ (analysis of the type of elements which constitute the building, the systems and materials used in its construction, major risk situations that may occur) analysis of existing anomalies and of the state of conservation and safety of the property, the level of housing comfort, any specific features and the implications of the surrounding environment;
- Specialist analyses _ more detailed analyses which must include architectural, historical, constructional or technological aspects, and may include testing and surveying of elements or parts of the construction;
- Socio-spatial analyses _ analyses which must include a study of the social consequences of the work in neighbouring residential contexts;
- Economic aspects _ analyses which must include management of the associated costs and resources feasibly combining the definition of the programme with the rehabilitation priorities and the available financial resources.

A detailed analysis allows project time to be reduced, the desired quality to be achieved and costs to be reduced at the process.

The analysis and diagnostic sub-phase allows the subsequent definition of the objectives of the project to be justified, in addition to the level of intervention that is needed. At the end of the rehabilitation process the diagnosis of the existing situation also serves as a tool to assess the ability of rehabilitation to resolve the problems detected in the initial phase.

After the analysis and diagnosis/evaluation sub-phase comes the design sub-phase in which the designers seek to develop appropriate solutions for the given requirements and goals. The design sub-phase begins with a summary of the results obtained during the analysis and diagnosis phase.

The design sub-phase includes the three following key stages:

- Base programme
- Conception
    - Preliminary design
    - Pre-final design
- Execution
    - Final design (working drawings)

In the base programme stage, the designers define the adjustments between the preliminary programme (what the owner wants), the rehabilitation priorities (diagnosis), the existing reality and the legal requirements. This stage corresponds to the reply from designers to the preliminary programme in the form of a feasibility study.

In this stage the priorities of the preliminary programme are analysed and the intended interventions are regulated in accordance with the potential and constraints of the existing building. Efforts are made to fully exploit the existing resources of the dwelling, both in terms of space and in terms of the possibility of not intruding on the structural system and using the existing building components. In this phase the client expects a report on the rehabilitation potential of the building regarding the given requirements, as well as answers to the questions: is it worth rehabilitating this building? What difficulties are likely to be encountered? What concessions must be made?

The base programme document is presented with the aim of providing the client with a clear understanding of the solutions proposed by the designer in accordance with the intentions expressed in the preliminary programme. Given the project hypothesis presented by the designer, the client may either accept these, request readjustments to the project, or accept alterations to the preliminary programme.

After the base programme has been approved by the client, this document serves as the basis for the development of the later phases of the project, functioning as a repository for all the agreed alterations.

The stages which follow the base programme phase may be divided into two major groups; firstly, the conception, which includes all the plans which give shape to the object as a whole and afterwards the execution, which includes those necessary for construction (Plácido, 1999: 92). Throughout the conception stage several design and decision-making steps are defined which include the output documents and sub-phases: the preliminary design, the pre-final design and a by-product document for building permission.

In the preliminary design the focus shifts from what the problems are to how they can be resolved. During preliminary design, the focus is on the scheme, or overall high-level design. In this phase, minor details are ignored in order to focus on creating a coherent solution that encompasses the project as a whole. The preliminary design is the definition of the solution proposed by the designers, and it will serve as a basis for project development after approval by the owner. In rehabilitation work it is vital from the initial conception phase that close links are ensured between the different specialists involved in the project. In this area, within the context of this study, greater emphasis will be placed on those associated with making the architectural project compatible with the ICAT network project. Throughout the preliminary design architects will conduct preliminary meetings with other specialists in the design team and the council authorities.

The elements included in this phase are written and drawn items and other items of information that facilitate the client's appraisal of the solutions proposed by the designer and his approach to the elements this contains.

The pre-final design corresponds to the complete definition of the solution presented in the preliminary design with any corrections that may have to be introduced after approval by the client. This stage enables the final solution to be defined by calculating the components and drawing up a preliminary budget. The documents for the building permission approval from the council authorities are a by-product of the conception stage.

After the production and approval of the pre-final design comes the execution stage. At this stage the focus shifts from design to communicating the design and providing all the information necessary for construction. The final design must make full use of the information from the pre-final design and add the elements required for its realisation by breaking the constructed object down into its component parts. This phase of the project has, according to Plácido (1999: 110) two essential objectives: to obtain a general idea of form through the planned representation of the object as a whole, and to break the object down into its component parts, identifying them by designs, maps and text (the contract specifications).

The definition of the final design culminates in the start of the construction phase. The construction phase**,** which is undertaken by a builder, also includes on-site assistance which is the responsibility of the designers, as the final part of the design process. As it is a very specialised process, different subcontractors are involved in rehabilitation work, which makes very strict planning of the building work necessary. The location of the buildings to be rehabilitated and any need for re-housing are also factors that must be taken into account in the construction planning phase as well as in the first phases of the planning process.

After the building work is complete, it is necessary to ensure regular maintenance of the building. For maintenance to be effective, it is important that the new life of the building is taken into consideration throughout the planning process and the most correct and suitable choices have been taken regarding the compatibility of the new building systems, materials and functions with the existing systems. The maintenance phase must include inspection/intervention cycles defined according to the building type and the expected deterioration of its elements. Cyclical maintenance enhances the investment in rehabilitation and prevents new signs of deterioration that frequently emerge when owners dismiss the need for maintenance. In order to prevent these situations it is important to implement a "maintenance management system" or a system based on a "User Manual" which provides information on how to manage the building (Paiva *et al.*, 2006: 738).

3.2 Analysis of rehabilitation methodologies

Various rehabilitation methodologies have been defined for working with buildings of important heritage value and for buildings which form part of the general urban fabric.

This chapter refers to some of these methodologies, which were used as case studies to define the methodology proposed here for the integration of ICAT and adaptation to the new life-styles.

The aim of this research was to understand certain aspects that would be analysed and discussed in the methodology proposed in the thesis. These consisted of proposals for a methodology for the first phases of the project and the proposed interaction between the client /future residents and the designers.

As defined in the previous chapter, in rehabilitation work the designers begin their activities after receiving the preliminary programme from the client, to which they respond with a pre-design document. Despite any meetings and exchanges of ideas which may be included in these two phases, mainly during the second phase, traditionally they constitute two monologues, one by the client and the other by the designers. This situation is aggravated by the fact that the client's monologue is frequently informed by utopian and unrealistic situations regarding the existing building.

Within this context, the concern is to analyse in particular proposals by van Leeuwen *et al.* (2000) and de Huang and Shih (2005) which include the client in the planning process, the methodologies of Giebler *et al.* (2009) and Teixeira and Póvoas (2010) which focus on the first phases of the planning process, and Durmisevic's methodology (2007) in terms of the evaluation of the building's capacity to accommodate spatial and technical transformations and their various sub-aspects.

The proposed rehabilitation methodology is addressed in *Part 2*.

Van Leeuwen methodology, 2000

Van Leeuwen *et al.* (2000) propose a Case Based Reasoning (CBR) system to define a methodology and a Decision Support System (DSS) for housing refurbishment so that use can be made of typical existing situations and preferred refurbishment solutions. Amongst the other DSSs which consider rehabilitation, Van Leeuwen *et al.* establish a DSS for refurbishment design and production planning and control in which both the existing building and the user requirements are considered.

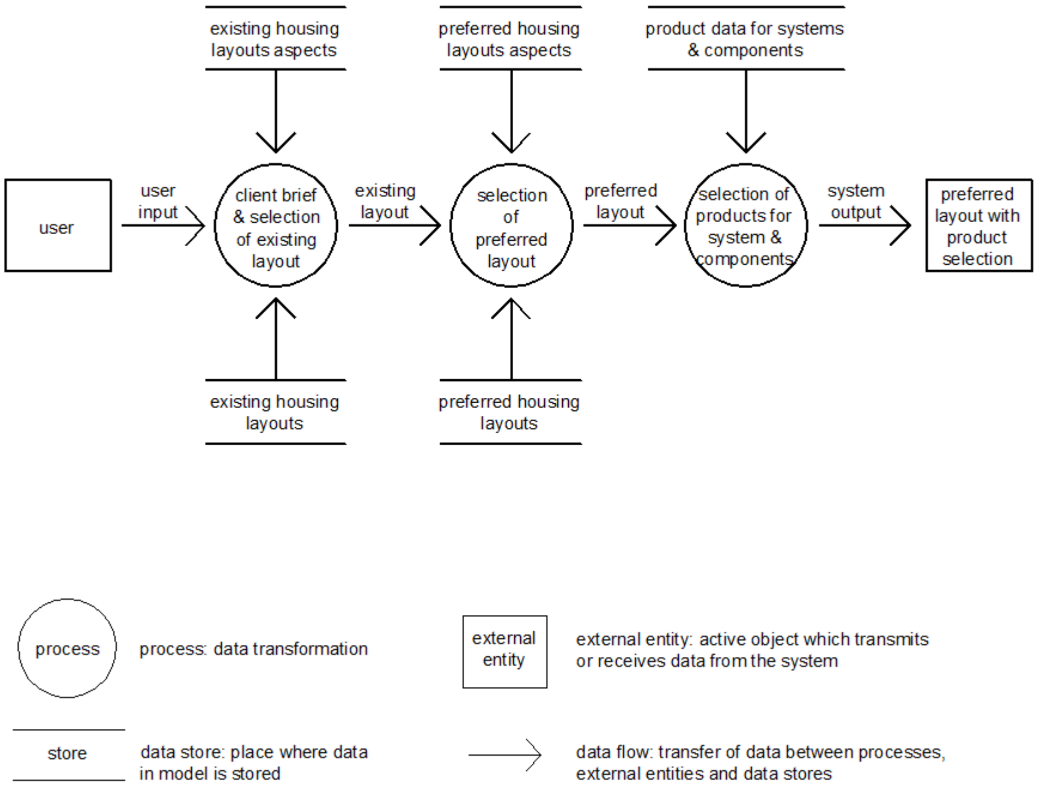


Figure 13 – Decision Support System Process Model (van Leeuwen *et al.*, 2000)

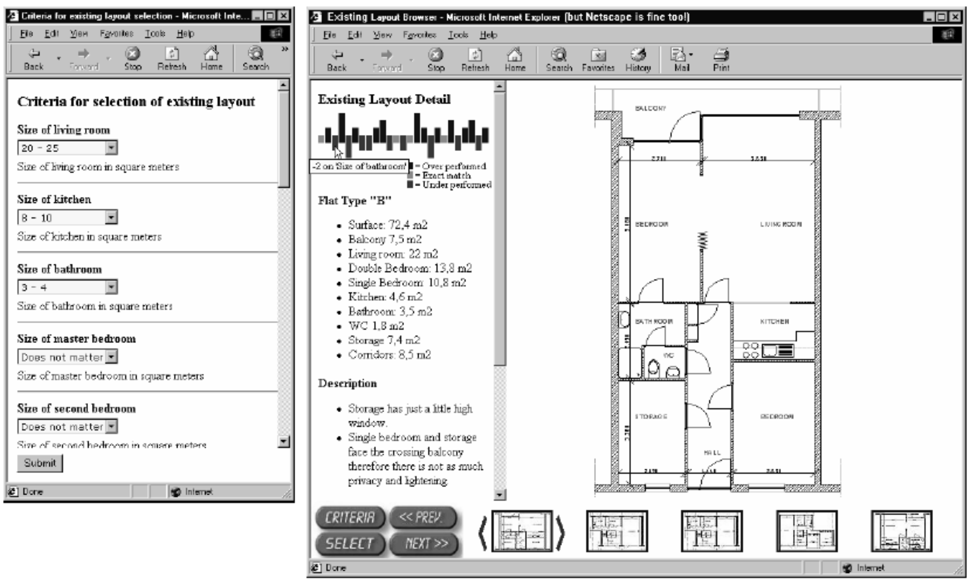


Figure 14 – Querying and browsing the case base of typical existing housing layouts (van Leeuwen *et al.*, 2000)

The proposed process uses a Knowledge Based System (KBS) that includes knowledge of architectural design variants, cost consequences, and building product applications, as well as CBR that supports the reuse of existing design knowledge. This reuse is effected after storage of design problems, design solutions and design outcomes for specific design cases.

The decision support system shown in Figure 13 uses a database of typical existing housing layouts. The process starts by selecting a typical existing housing layout from the database that sufficiently matches the layout of the new refurbishment case (Figure 14). In this first step the owner will query and browse the case database using criteria such as the size of rooms or the desired level of rehabilitation in order to select layouts.

After selecting a sample layout, the system shows several variations on refurbished layouts which will be evaluated to meet the requirements defined by the owner. The user selects the preferred refurbished layout after evaluating the variations. The last step will be the selection of products listed in the system database, for each of the house's systems and components.

This methodology was analyzed for three major reasons: it included the future resident in the conception process, it used the CBR method to solve new rehabilitation problems based on solutions for previous similar rehabilitation interventions, and it enabled several possible design solutions or alternatives to be generated.

HUANG AND SHIH METHODOLOGY, 2005

As previously mentioned, during the planning process communication between expert designers and non-expert users is vital (Huang and Shih, 2005). The Huang and Shih framework helps tenants express refurbishment needs to the designers and bridge the knowledge gap between designers and tenants. The authors state that an inexperienced decision made by untrained tenants could directly affect the final outcome of a refurbishment project. To facilitate communication between both sides and inform tenants, Huang and Shih propose the use of CBR systems which generate suggestions for the tenants based on previous refurbishments.

Huang and Shih's proposed decision support system encompasses a four-step design communication process and a case-based design data model.

The proposed methodology is based on the assertion that a complex refurbishment case is better solved when it is divided into several smaller sub-problems. For each sub-problem a sub-solution can be found and subsequently they can all be integrated into the main solution.

The completeness of the communication process is built on the case-based design data model which consists of two parts: a Case Base, with complete information about successful rehabilitation cases, and a Pattern Base which includes requirements, evaluations and solutions.

The pattern base includes several sets of patterns and becomes an information network for common design requirements, problems and solutions.

The design communication process encompasses four stages: i) Identification of primary refurbishment goals; ii) Selection of preferred case; iii) Adaptation of preferred case; iv) Evaluation of adapted case.

In the first step the designer, together with the tenants, identifies the goals of the refurbishment and assigns priorities and degrees of urgency to the refurbishment goals. The second step involves the selection of cases based on the primary refurbishment goal expressed by the tenant in the first step. The third step uses the Pattern Base and adapts the cases so they can solve the refurbishment problems better. The final step consists of an evaluation of the tenant's level of satisfaction with the planning result.

This methodology was analysed for three major reasons: it includes the future inhabitants together with the designer in the definition of the rehabilitation programme, it uses a CBR method to solve new rehabilitation problems based on the solutions for previous similar rehabilitation interventions, and it defines a method for evaluating the design solution based on the tenant's requirements.

TEIXEIRA AND PÓVOAS METHODOLOGY, 2010

The goal of the rehabilitation methodology proposed by Teixeira and Póvoas (2010) is to minimize the differences between theoretical conception and the act of planning.

The authors consider that there is a great need for guideline methodologies in rehabilitation work and that, in general, this work is carried out on a case-by-case basis wasting the knowledge acquired in similar work. At the same time, the lack of studies characterising the existing stock of buildings in terms of type, style and construction is, according to Teixeira and Póvoa, one of the reasons for the inefficiency of rehabilitation work in Portugal. The proposed methodology covers the planning phases from the characterisation of the building to the intervention proposal and is aimed essentially at the constructional rehabilitation of buildings in terms of correcting anomalies and making them suitable for contemporary performance. Within the context of constructional rehabilitation three levels of intervention are established: i) maintenance and repair of small anomalies; ii) improved performance of existing elements; iii) introduction of new elements, as a response to new programme demands.

This methodology is based on the definition of typical solutions defined for the building type analysed – middle class housing included in the historic building stock in the city of Porto. The intervention methodology is classified in Table 3 and includes two major phases prior to construction: characterization of the existing housing stock, and the design process.

In the characterization of the existing housing stock the authors include a survey phase for alterations currently being introduced into the existing buildings which, like the methodology proposed in this thesis, aims to systematise the needs and objectives of owners.

This intervention methodology is based on the concept that typified solutions can be proposed for particular models. In the case analysed, the authors even succeed in creating an abstract constructional model which represents the main features of the case study and consequently the models for solutions.

Analysis of this methodology has enabled two aspects to be explored which are necessary to the definition of the methodology proposed in this thesis: the characterisation of the existing building and the transformations that have taken place in order to inform the transformation solutions, and the typology of rehabilitation solutions within the specific context of the building.

CHARACTERISATION OF THE EXISTING HOUSING STOCK	Definition of construction model	**HISTORICAL RESEARCH**	Searching local authority archives Investigation of other type of registrations
	Common transformations in existing buildings	**SURVEY**	Geometric Photographic
	Most frequent anomalies and their causes	**DIAGNOSIS**	Preliminary inspection Detailed inspection Definition of state of conservation
INTERVENTION CRITERIA		**DESIGN**	Definition of intervention criteria
TYPICAL CONSTRUCTION SOLUTIONS	Repair and replacement of damaged components Structural reinforcement Improvements in performance		Preliminary design Pre-final design Final design
		CONSTRUCTION	Technical assistance Construction supervision
PROPOSED REGISTRATION FILES		**MONITORING / MAINTENANCE**	

Table 3 – Teixeira and Póvoas rehabilitation methodology for urban buildings (Concept of an intervention methodology for urban buildings: middle-class housing in Porto. From research to practice) (2010: 2)

DURMISEVIC'S METHODOLOGY, 2007

The methodology proposed by Durmisevic (2007) uses an expert system to assess the feasibility of a rehabilitation intervention. According to Durmisevic, even when a building has reached the end of its functional lifetime it does not mean that it cannot be efficiently upgraded to meet new requirements or change its function. The goal of Durmisevic's research is to define the extent to which a building is flexible in terms of future use.

For this purpose a tool was developed to provide an answer to the capacity of the existing building to be transformed for a given new function. The transformation potential of a building is calculated on the basis of a systematised list of aspects that determine its transformation value. These aspects consider spatial transformation (positioning and dimensioning) and technical transformation (disassembly and capacity). Durmisevic proposed a tool based on a fuzzy-neural tree structure for the knowledge representation and modelling that enables the system to assign a transformation value to a given building.

In addition to evaluating the transformation value of a given building for a new given function, this system can also be used to evaluate a large number of buildings in order to choose the one with the best transformation potential for a given function. The latter outcome is the one that is of most interest to this present research.

According to Durmisevic, the main advantage of having such knowledge models is efficient use of time in comparison with the comprehensive studies and months of preparation needed to reach a conclusion regarding the transformation potential of one building only.

An analysis of this methodology allows two aspects required for the definition of the methodology proposed in this thesis to be explored: on the one hand, the definition of a tool that can rapidly assess the transformation potential of a building for a particular use and, on the other hand, the fact the use of this analysis in more than one case enables the building with the best transformation potential to be chosen.

3.3 EXPERT SYSTEMS AND RULE-BASED SYSTEMS

From the outset, this research, investigated the possibility of using expert systems, also known as knowledge-base systems, to solve the problem addressed in this thesis.

In these systems, knowledge, represented within a particular area of application, plays a decisive role in the ability to solve problems (Bento and Côrte-Real, 2000: 32).

When an expert system and an expert are exposed to the same data, the performance of the former should be similar to that of the latter.

This means that the purpose of these systems is to encode, in the form of rules, expert knowledge in a certain field. Expert systems therefore constitute a particular and complex type of rule-based system.

Rule-based systems contain a set of assertions that are combined in a knowledge base and a set of algorithms or rules which determine the actions to be taken on the basis of these facts.

In addition to allowing us to act on the facts, these rules also enable new facts to be inferred from the input knowledge and data (Freeman-Hargis, 2003).

The essential features of a rule-based system are as follows:

1. A rule-based system involves three elements:
    a. A set of facts that represents the initial knowledge base;

   b. A set of rules which must contain all the actions that should be taken within the scope of a problem, but nothing irrelevant. A rule consists of two parts: conditions (IF) and actions (THEN);
   c. An inference engine which executes the rules based on the facts.
2. These systems solve problems by applying rules to facts (i.e. searching for correspondences between facts and IF condition rules);
3. The THEN part of the rule can declare new facts that trigger other rules (Wu, 2004), (Freeman-Hargis, 2003);
4. A rule-based system needs a condition that determines whether a solution has been found or that none exists. This is necessary in order to terminate some rule-based systems that would otherwise be locked into infinite loops (Freeman-Hargis, 2003);

The knowledge base contains facts and assertions as well as rules, both *backward rules* (action IF condition) and *forward rules* (IF condition THEN action). All the rules are usually included in the knowledge base (Camarinha-Matos, s.d.).

The inference engine is responsible for the execution of rules called up by the facts associated with the current problem in order to obtain a solution. This engine helps the user to acquire useful knowledge from the knowledge base.

> *"Inference is a process of constructing new representations of knowledge on the basis of existing representations. This process is accurate when the new representations correspond to facts that are related to those corresponding to the existing representations."* (Bento and Côrte-Real, 2003: 35)

The inference engine consists of an interpreter and a scheduler. The scheduler plans the overall approach to solving the problem on a strategic level. The interpreter is the machine which solves the problem and provides a layer between the user interface and the computer operating system to manage the input and output of data using natural language (MacFarland, 1990: 165).

The knowledge base is separate from the inference engine. This allows the inference engine to filter the knowledge and show only useful knowledge, maintaining the knowledge base in an explicit and declarative way (Camarinha-Matos, s.d.: 4.7) (Figure 15).

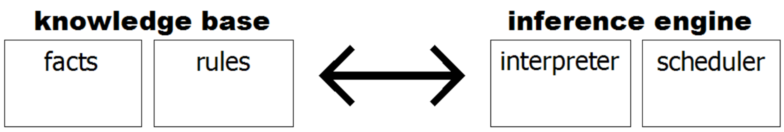


Figure 15 – Expert system. Based on (Camarinha-Matos, s.d.: 4.7)

The solution to a given problem begins with the knowledge base (facts and rules) and the data from the current problem. The system then analyses all the IF condition rules and identifies a set composed of all the rules whose conditions are satisfied on the basis of the problem data. A rule emerges from this set that represents the strategy chosen to resolve the present conflict. When this rule is activated all the THEN actions are carried out.

The system subsequently continues the cycle of choosing rules to act on certain problems. This cycle ends when there are no more rules whose conditions have been met or an ending rule is activated (Freeman-Hargis, 2003).

The order in which the rules operate can be determined by the problem or the user's preferences. The organisation of rules in a certain order (the application of the first rule sets the order) and random selection rules (within a range which is likely to answer the problem) are possible strategies. Nevertheless, if too many rules coexist it will be difficult to operate and maintain the system.

Expert systems can be computerised and therefore became effective tools, designed to enhance the quality and availability of the knowledge required by decision makers.

The computerised automation of architectural design generation may reach solutions faster using a more efficient and accurate process, since the computer can manage massive amounts of data.

To achieve this, instructions have to be prepared and provided for the computer software or a matrix within which a solution to the given problem will be found.

The implementation of a software application that manages information and provides solutions as output would allow for: i) storage of a large amount of information; ii) very rapid provision of the stored information, iii) very rapid selection and isolation of information, iv) high-speed calculations; v) the generation of multiple solutions for a given problem; vi) comparison of solutions and the selection of the most appropriate ones; vii) information that is easily combined, related and organised (Palmer, 1981: 158).

3.4 SHAPE GRAMMAR

Shape grammars were invented by Stiny and Gips (1972) more than thirty years ago. They are "*algorithmic systems for creating and understanding designs directly through computations with shapes, rather than indirectly through computations with text or symbols.*" (Knight, 2000) A shape grammar is a set of rules that apply step-by-step to shapes to generate a language of designs.

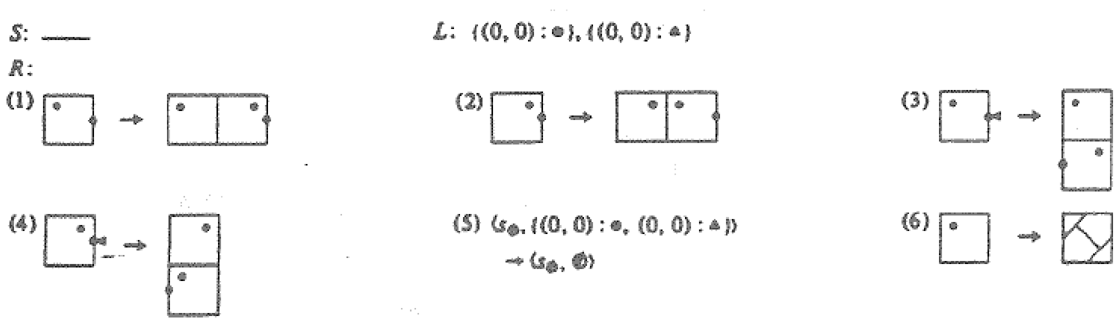
Shape grammars are generative because they can be used to synthesize new designs in the language, descriptive because they provide for ways of explaining the formal structure of the designs that are generated and analytical because they can be used to tell whether a new design is in the same language.

In 1976 Stiny distinguished between original and analytical grammars. Original grammars enable new design languages to be created, whereas analytical grammars make it possible to understand existing languages.

Original grammars enable new designs to be generated, based on a shape vocabulary and the spatial relations between the shapes. In 1980 Stiny (1980b) created kindergarten grammars to exemplify how to create an original grammar using Fröbell's building gifts.

According to Knight (2000), the first research into analytical grammars was carried out by Stiny in 1977, based on an analysis of Chinese designs (Chinese lattice designs, Figure 16). This was the first parametric grammar and contained only 5 rules that enabled all known Chinese patterns to be generated, as well as endless new hypothetical designs.

The second approach to analytical grammar was carried out by Stiny and Mitchell (1978), based on villas by the Italian Renaissance architect Palladio. Since then, numerous analytical grammars have been inferred from the works of various architects. Over the years other grammars, such as parametric grammars and colour grammars, have emerged from research.



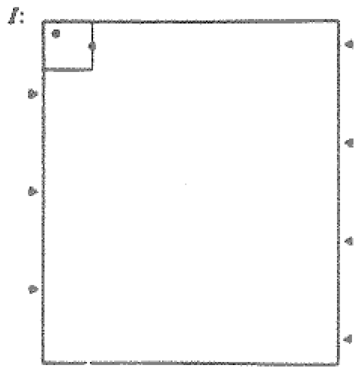
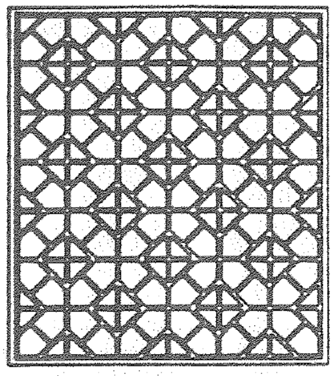


Figure 16 (top and left) – Shape Grammar used to generated the lattice design showns in Figure 17. Ice-Ray Lattice grammar, (Stiny, 1977: 90)

Figure 17 (right) – Original Chinese Lattice Design, (Stiny, 1977: 90)



Design languages can be defined by means of a shape grammar considering some important aspects defined by Stiny for the Kindergarten grammar (1980b):

- Definition of a shape vocabulary which consists of a limited number of different shapes;
- Definition of the spatial relations between the shapes in the vocabulary. Designs are generated according to these spatial relations;
- Definition of shape rules in terms of the spatial relations. Shape rules are construction mechanisms for spatial relations;
- Definition of the initial shape (within the shape vocabulary) which is the first step of a design and is the shape to which the first rule is applied;

Shape grammars are defined in terms of shape rules and initial shapes. Each shape grammar defines a language of design.

Shape grammar is not a deterministic process since it enables multiple designs to be generated, based on a single language but determined by different choices (Figure 18 and Figure 19).

Shape grammar languages do not look for one solution to a given problem but for multiple solutions based on the same set of rules or criteria.

Shape rules are used as mechanisms for generating designs. In shape grammars, rules to add and remove shapes can be used to transform spatial compositions. The euclidean transformations provide for new shapes to be produced by changing the location (translation), orientation (rotation), reflection, or size (scale) of a given shape (Stiny, 1980a).Two shapes are geometrically similar when one can be changed into the other by an euclidean transformation or a finite composition of them.

In addition to shapes, labels can be added to shape rules to guide (and constrain) symmetry operations. Labels supply additional information about shapes, such as ”how”, “where” or “when” a shape rule may be applied (Knight, 1983) (Figure 20 shows examples of these types of labels):

_ "How" labels specify how a rule can be applied to a subshape in each Euclidean transformation. Rules with "how" labels are applied under restricted Euclidean transformations;

_ "Where" labels specify to which subshape or subshapes the rule may be applied. They do not restrict the Euclidean transformations under which the rule can be applied because they do not alter shape symmetry;

_ "When" labels specify that a rule may be applied to a subshape simply by being associated with the same point or points relative to the shape and the subshape. These labels do not need to be associated with any particular point or points in both shape and design as long as the preceding criterion is satisfied (Knight, 1983: 131). "When" labels do not restrict the subshapes to which the rule can be applied or the Euclidean transformations under which it can be applied. If "when" labels are removed from the left and right part of the rule, the rule would be applied in exactly the same way. Examples of this type of labels may be seen in the Palladian Grammar (Stiny and Mitchell, 1978) among others.

"How" and "where" labels are spatial because their location is important to shapes. The location is not important to the "when" labels and they are therefore not spatial.

In the shape rules illustrated in Figure 19 and Figure 20: design*a,* labels were not used and the final designs were selected from a large range of possible choices. The shapes rules shown in Figure 20: design*b*, design*c* and design*d* have labels that restricts the final solution.

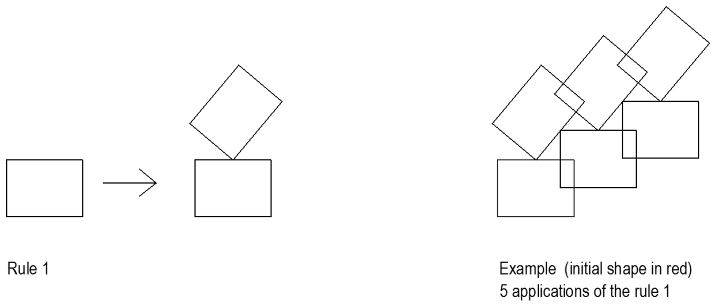
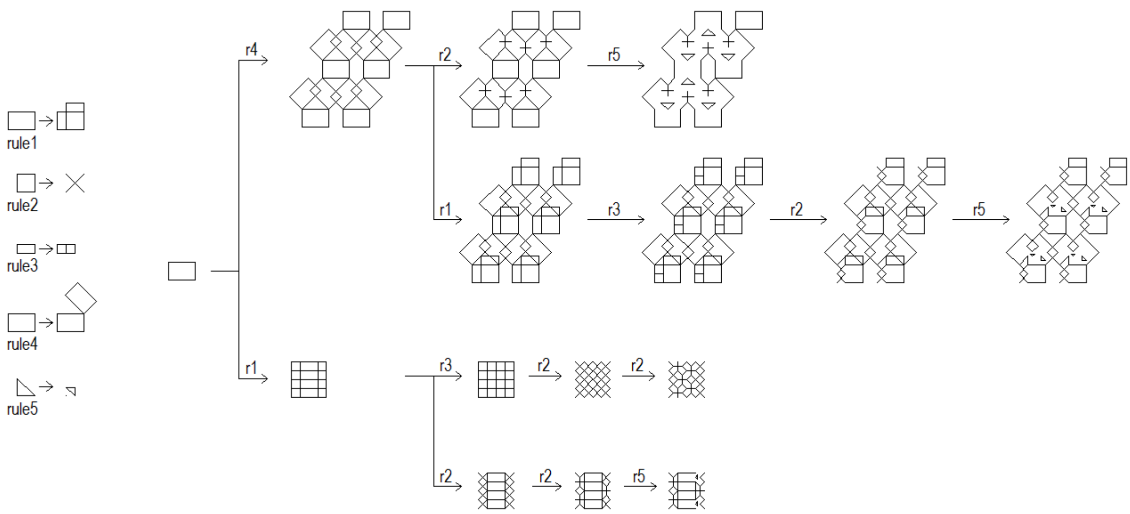


Figure 18 (left) – Example of an original grammar using only one rule.

Figure 19 (bottom) – Example of an original grammar using five rules and the possible ways of generating shapes that can be followed and lead to different designs.



Shape grammars are used to define several kinds of design languages, by specifying new rules, and to describe the properties of designs, through analysis of the rules that generated them. At later stages and in more complex grammars, the computerised implementation of a shape grammar is beneficial as it allows a greater amount and variation of designs that will be generated in less time.

Duarte's work on the Malagueira grammar was implemented in the computer. Experimental subjects who manually applied Duarte's shape rules to develop a design solution revealed that a grammar written for the computer is difficult and slow for a human designer to understand and apply (Duarte, 2007: 275). This indicates that, in an earlier phase a shape grammar should be written that can be easily understood and applied by human designers. This will allow the grammar to be validated and possibly implemented on the computer afterwards.

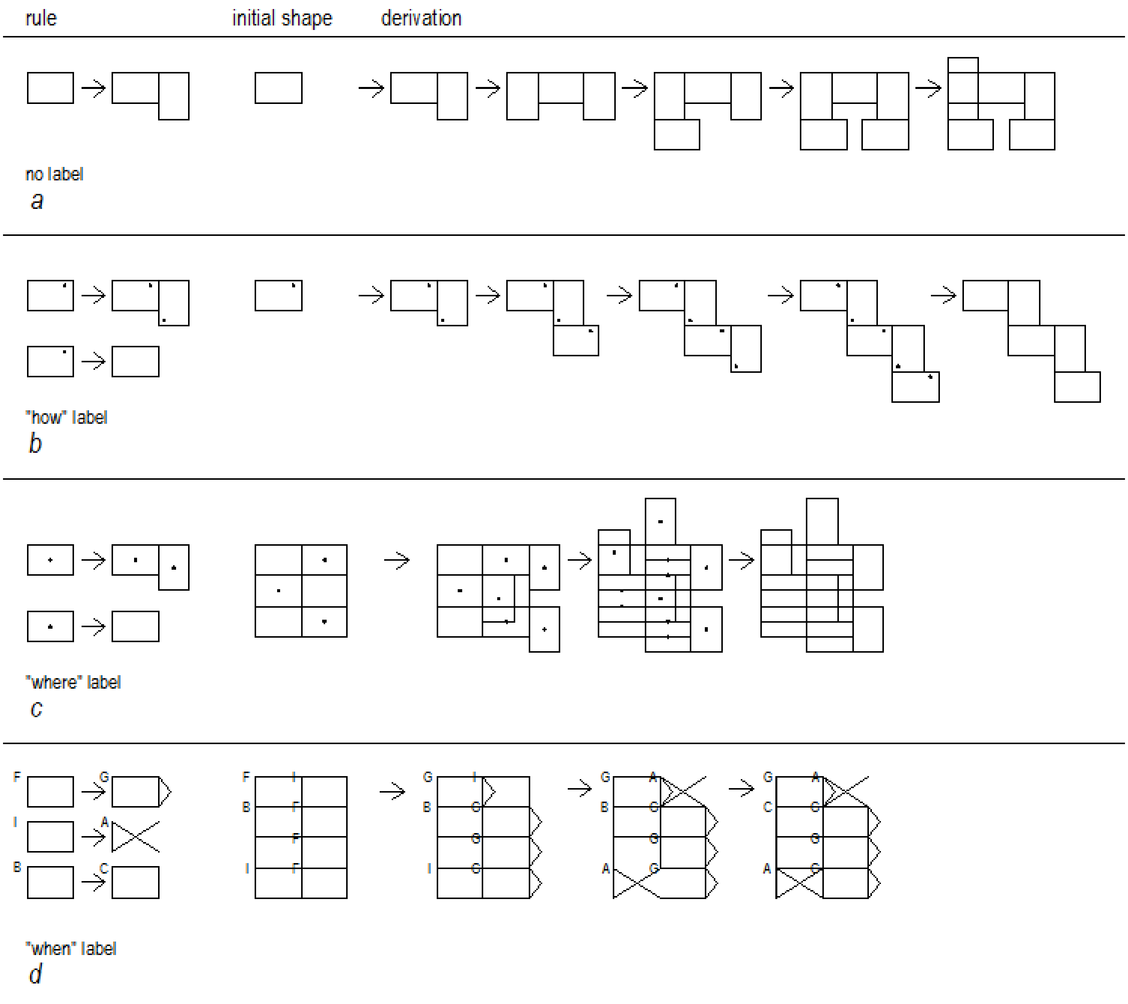


Figure 20 – Designs obtained by applying a rule to an initial shape. Four examples are shown, involving similar shapes but different types of labels, each of which creates a different design.

DESCRIPTIVE GRAMMARS

Shape grammars explain the composition of the design and simultaneously provide a basis for the description of designs in other terms (Stiny, 1981).

Stiny (1981) states that the way in which a design language is understood depends on two factors. The first factor is the shape grammar which specifies the set of composition rules. The second factor is the rules themselves, which can describe the design in terms of functionality, use, meaning and type, among other aspects. These aspects are specified by a descriptive function which assigns characteristics to the shapes.

This description involves, firstly, the definition of a shape grammar, then the definition of descriptions of the shape to be manipulated, and finally the definition of descriptions for the initial shape and for each rule. According to Duarte (2007: 53) the relation between shape grammar and descriptive grammar is such that for each shape rule there will be one or more corresponding description rules, besides a initial description that correspond to the initial shape. Shape rules are applied to a design in progress and the corresponding descriptive rules are applied to a description in progress. The description of the evolving design is updated each time its shape changes.

A descriptive grammar consists of a description of shapes using symbols instead of shapes, as in a shape grammar. By using symbols, a descriptive grammar allows for programming.

Stiny's example of a descriptive grammar (1981) is now used to exemplify how descriptive grammars are formalised (Figure 21). The Language L_G defined by a shape grammar G contains designs made up of blocks (oblongs, pillars and squares). Pillars are labelled N, S, E, W and ● in the first stage of the generation and then the ● label is changed to a ▲ label. Labelled shapes have the following descriptions:

$$\#a_1\#a_2\#a_3\#a_4\#a_5\#a_6\#a_7\#a_8\#$$

The sharp sign # is used to distinct components a_n, $1 \leq n \leq 8$ in a description. Our example will only use components a_1 (either a sequence of coordinate pair (x,y) indicating the positions of pillars visited by the symbol ● during the generations, or a single coordinate pair (x,y) indicating the position of the pillar currently visited by the symbol ▲), a_2 (integer ≥1 specifying the number of pillars in a labelled shape), a_3 (integer ≥1 specifying the number of walls in a labelled shape), a_4 (list of enclosed "rooms" not containing other rooms in labelled shape).

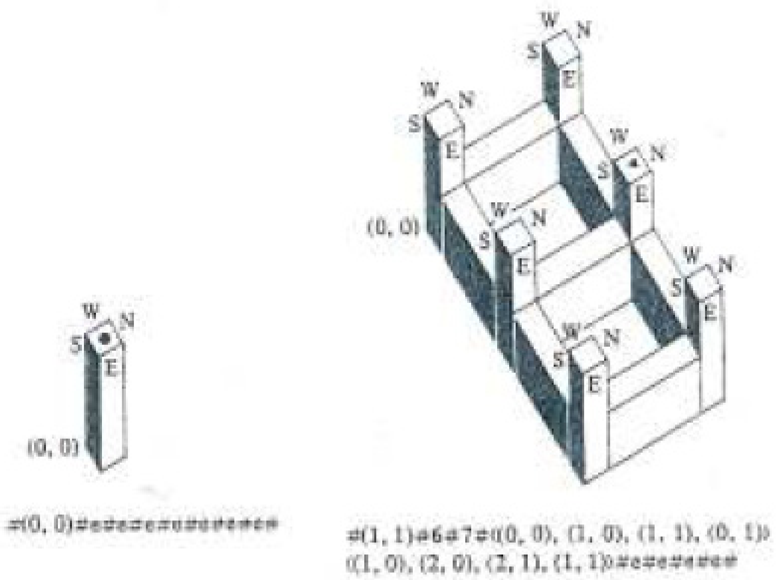


Figure 21 – Shapes and their descriptions (Stiny, 1981)

COMPOUND GRAMMARS

Compound grammars may be implemented when different properties of the shape need to be represented in different computations that interact with each other. The use of different representations (e.g plan, section, elevation, spatial void, solid mass, graph), represented in different algebras, helps to manipulate complex problems within the design (Duarte, 2007: 54). In her paper "Computing with Ambiguity" Knigth (2003) states that different algebras can be combined to form composite algebras. The shapes in composite algebras are compound shapes made up of different elements from different algebras.

Li (2001) in Yingzao Fashi grammar, Duarte (2001) in Malagueira grammar and Colakoglu (2005) in Hayat houses grammar explored the use of compound grammars in their work, not only as a way of generating multiple representations of designs but as a solution to the parameter problem (Knight, 1999).

SHAPE GRAMMARS IN ARCHITECTURE

Shape grammars have been applied to architecture using both analytical and original grammars. Analytical approaches are the most frequently used in the research that has been carried out so far.

Studies of analytical grammars aim to explain design languages (by author or typology) but can also be used as generators of new solutions within the language. Studies of analytical grammars in architecture include those by Stiny and Mitchell on the Palladio villas grammar (1978), Koning and Eizenberg on Frank Lloyd Wright's house grammar (1981) (Figure 22), Downing and Flemming on the Bungalows of Buffalo grammar (1981), Flemming on Queen Anne house grammar (1987), Andrew Li on traditional Chinese architectural grammar (1998) (1999), José Duarte on Alvaro Siza's Malagueira house grammar (2001) (Figure 23), Colakoglu on the Hayat house grammar (2005), Gülen Çağdaş on the traditional Turkish houses grammar (1996) and Kruger and Silva (1998) on the Cistercienses Churches grammar, among many others.

These approaches to analytical grammars have different goals and the grammar is conceived in different algebras. Palladian grammar uses two-dimensional shapes and aims to define the Palladian style and generate existing Palladian villas as well as new villas in the same language. The research into the Frank Lloyd Wright prairie houses uses three-dimensional volumes and aims to analyse the compositional principles as well as generate houses according to the language (Figure 22).

The research into Queen Anne houses has produced two grammars, one for the generation of plans and another for the articulation of plans in three dimensions (Flemming, 1987). Hyata house grammar aims to explore the applicability of shape grammars to a real design setting in order to generate new houses (Colakoglu, 2005).

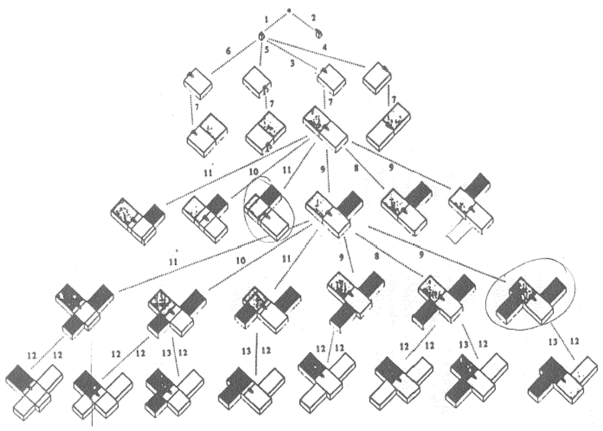


Figure 22 – Frank Lloyd Wright prairie house grammar by Koning and Eizenberg. Part of the derivation tree showing rule applications. (Koning and Eizenberg, 1981: 11)

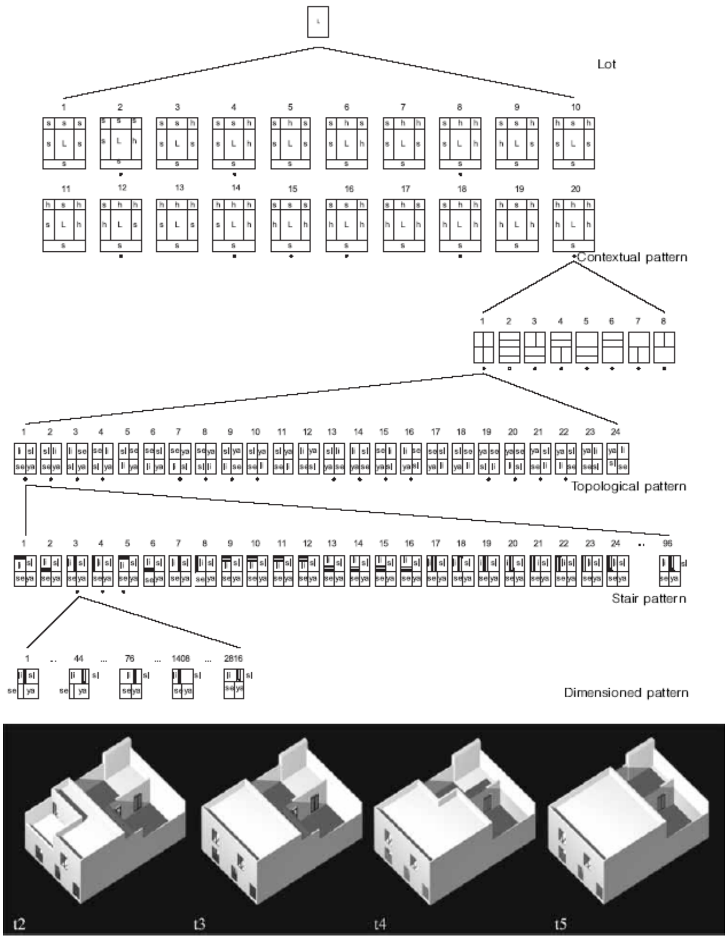


Figure 23 (top and bottom) – Discursive grammar of Siza's houses at Malagueira by José P. Duarte (Duarte, 2005: 361, 377).

Tree illustrating the universe of solutions allowed by the grammar.

3D models of four variations of a new house generated by the grammar.

The Malagueira grammar by Duarte (2007: 329, 330) (Figure 23) is a discursive grammar since it is able to generate syntactic and semantic correct designs that satisfy the *a priori* requirements. This grammar is both a descriptive grammar and a shape grammar (with heuristics to determine which rules apply in each step). The Malagueira grammar has two parts: a grammar to generate the functional housing programme (a descriptive grammar) and a grammar to generate the project (a shape grammar associated with a descriptive grammar).

Research into shape grammars has been introduced into architectural training courses to promote an abstract method of thinking about architecture. In this context, Li (2001) proposed teaching shape grammar to students using analytical grammar in order to understand a specific design language, and used the example of traditional Chinese architecture. This process advocated by Li argues that grammars do not constitute an authoritative definition of style. Analytical shape grammars allow us to understand a given language but also to generate different designs based on their compositional rules.

Original grammars exploit design solutions based on a vocabulary of shapes and spatial relations. These grammars are created from the outset by designers and enable a few or endless design to be generated. As analytical grammars, original grammars are used in architectural training and also by architects in real contexts. Original shape grammars were used to generate new designs such as the "Fallen Tower" in Italy by Rand Brown, an Art Museum in Taiwan by We Cheng Chang and a housing complex in Manhattan by Murat Sanyal (Colakoglu, 2005: 15) (Figure 24).

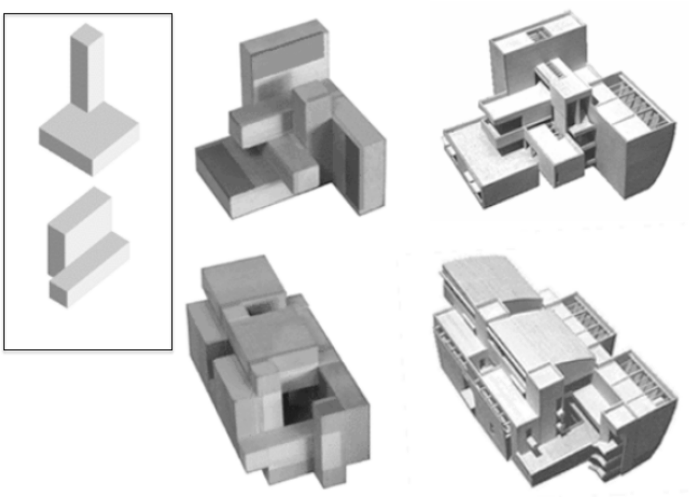


Figure 24 – Examples of original shape grammars used in project classes,. Student: Jin-Ho Park; instructor of the class:Terry Knight (http://www.andrew.cmu.edu/course/48-747/)

3.5 SPACE SYNTAX

Space syntax was conceived by Bill Hillier and Julienne Hanson in the late 1970s as a tool to help architects understand the role of spatial configurations in shaping patterns of human behaviour and to estimate the social effects of their designs. In their theory, space is represented by its parts, which form a network of related components. Using space syntax methodology, space is represented first by maps of convex spaces to describe contiguity, adjacency, and proximity and then by graphs in which spaces become nodes and connections become arcs to describe accessibility and permeability.

This theory allows for the description (representation, characterisation and quantification) of spatial organisation based on existing spatial relations. The spatial organization represents a continuous space network organised and ordered by relative adjacency or physical and visual permeability (Heitor, 2007).

Space syntax was proposed as a model for the analysis of urban form and architecture. This analysis is based on a two-dimensional representation in which reality is represented by symbols and relationships expressed in operational terms. This analysis model enables a particular architectural object's spatial structure and the influence of that structure on its users to be understood.

Space is represented as maps and graphs that describe the relative connectivity and integration of spaces. Space syntax depends on three basic concepts of space:

a) An isovist, viewshed or visibility polygon, which expresses the volume of space visible from a given point in space, together with a specification of the location of that point (Figure 25);
b) Axial space, a straight sight-line and possible path. With an axial map or axial graph, spaces (or rooms) can be represented by dots and the connections between them by arcs. This representation reinforces spaces and the necessary path and movement involved in passing through them and therefore accessibility and permeability relationships.

   The justified graph is a graph in which a particular dot is selected as the root and the other dots in the graph are aligned above it in levels. This graph consists of several levels depending on accessibility from the outside. The shape of the justified graph captures the depth distribution of spaces (Figure 26).

c) Convex space, an occupiable void in which, if imagined as a wireframe diagram, no line between any two of its points extends beyond its perimeter: in other words, all points within the polygon are visible to all other points within the polygon[18]. Convex maps are planar connected configurations obtained by breaking the system down into the set with the fewest convex elements (Heitor *et al.*, 2004). With a convex map, voids or spaces are represented by a convex shape. In this concept of space, if a room shape is not convex, the room may be represented by two or more convex shapes. The resulting convex surfaces reflect relative contiguity and contention (Figure 27);

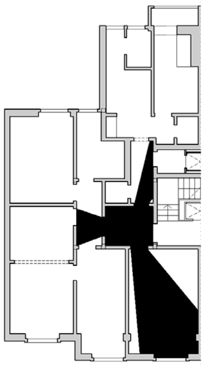


Figure 25 – Isovist polygon, visibility from the lobby (example of a dwelling from the case study)

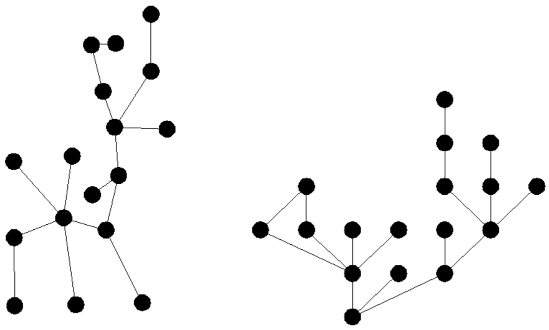


Figure 26 - Axial graph and justified graph (example of a dwelling from the case study)

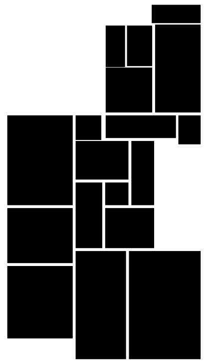
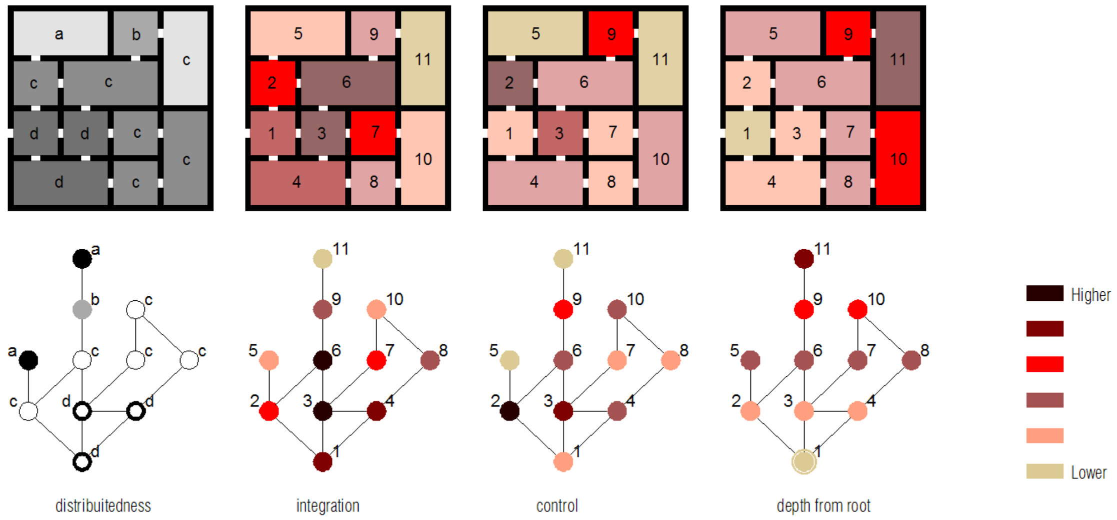


Figure 27 – Convex space (example of a dwelling from the case study)

Space syntax uses syntactic measures which, through an analysis of space, quantify the spatial relationships between cells, defining their degree of integration, depth, choice, control, and distribution, among other elements.

The most popular space syntax analysis method for networks is integration. Integration corresponds to a measure of spatial hierarchy which quantifies the degree of centrality (or accessibility) of the system spaces (Heitor, 2007). This measure is defined by the minimum number of turns required to go from one space to all the others in the network, using the shortest path. The deeper an area is, the less accessible it will be. Low depth values reflect the least amount of turns and therefore spaces that are well-integrated within the system. Integration therefore represents a topological characteristic rather than a geometric one, since the values do not translate into the linear metres of the path that separates the different spaces.

Integration values express in numerical terms a key aspect which is shown visually by justified graphs (Figure 28 and Table 4). In most spatial networks, integration values will differ in different spaces. According to Bellal (2004: 4) such differences are one of the keys to the way in which culture and social relations express themselves through space. Bellal exemplifies this by stating that because functions in a dwelling are usually assigned to spaces they acquire a spatial expression, which can be assigned a numerical value. If these numerical differences in functions are in a consistent order across a sample, it can be said that a cultural pattern exists (Bellal, 2004: 4).



nodes	5	9	11	10	7	6	3	2	1	4	8	TDn	MDn	RA	i	CV
5	0	3	4	5	4	2	3	1	2	3	4	31	3,1	0,46	2,14	0,33
9	3	0	1	4	3	1	2	2	3	3	4	26	2,6	0,35	2,81	1,33
11	4	1	0	5	4	2	3	3	4	4	5	35	3,5	0,55	1,8	0,5
10	5	4	5	0	1	3	2	4	3	2	1	30	3	0,44	2,25	1
7	4	3	4	1	0	2	1	3	2	2	2	24	2,4	0,31	3,21	0,75
6	2	1	2	3	2	0	1	1	2	2	3	19	1,9	0,2	5	1,08
3	3	2	3	2	1	1	0	2	1	1	2	18	1,8	0,17	5,62	1,5
2	1	2	3	4	3	1	2	0	1	2	3	22	2,2	0,26	3,75	1,66
1	2	3	4	3	2	2	1	1	0	1	2	21	2,1	0,24	4,09	0,91
4	3	3	4	2	2	2	1	2	1	0	1	21	2,1	0,24	4,09	1,08
8	4	4	5	1	2	3	2	3	2	1	0	27	2,7	0,37	2,64	0,83
Min												18	1,8	0,17	1,8	0,33
Mean												**24,9**	**2,49**	**0,33**	**3,4**	**1**
Max												35	3,5	0,55	5,62	1,66

TDn : Total Depth (TD) for actual node
MDn : Mean Depth (MD) for actual node — MD=TD/(K-1)
RA : Relative Asymmetry — RA=2*(MD-1)/(K-2)
i : Integration Value — i= 1/RA
K : Number of nodes — i= 1/RA

Calculations done by AGRAPH software

Figure 28 – Example of a spatial configuration showing justified graphs of integration, control, depth from root and distributedness. Adapted from (Hillier, 2007: 249)

Table 4 – Syntactic measures of spatial configuration shown in Figure 28

According to Holanda (1999), several studies have suggested that well-integrated buildings promote more informal and intense use, whereas more segregated buildings correspond to strongly hierarchical relationships amongst the inhabitants. Relative asymmetry (RA) measures the integration of a space by assigning a value between (or equal to) 0 and 1, in which a low value describes high integration.

Depth is a configuration property of a spatial layout. A space is at depth 1 from another if it is directly accessible from it, at depth 2 if it is necessary to go through an intermediate space, and so on. (Bellal, 2004)

Connectivity or contiguity of a space is the number of contiguous spaces, i.e. those which are directly adjacent and have physical and visual permeability. The connectivity of one space in relation to another is equal to 1 if there is a connection between both and equal to 0 if not. In a justified graph, the connectivity value of a space (cell) is the sum of the axial lines that reach it when each of the lines has a value of 1. High connectivity corresponds to a space with good accessibility. Control expresses the proportionate amount of access that a space has in relation to adjacent spaces, i.e. indicates the degree of importance of a space as a point of passage in relation to the surrounding areas. (Heitor, 2007)

Choice is a syntactic measure that suggests the existence of alternative routes from one space to another. The space-link ratio (SLR), according to Bellal (2004: 115) is the number of links plus one over the number of spaces. This gives a value varying between 1 for a tree-like configuration without any alternative routes and above 1 for the degree of ringiness. The possible types of human behavior that happens in buildings are, according to Hillier (2007: 248): occupation and movement. Occupation means the use of space for static activities (reading, sleeping, and eating) or localized movement activities (cooking, working). Movement means movement between spaces of occupation.

Distribuitedness is a syntactic measure used by Hanson (1998) in order to define spaces that are not distributed ("a" and "b") and spaces that are distributed ("c" and "d") (Figure 28). When there are multiple routes leading to a room, a configuration is considered distributed. If only one route exits, it is nondistributed. This measure uses the permeability relationship between different spaces. Hillier (2007: 250) classified spaces in a graph into four topological types "a", "b", "c" and "d". "a" spaces are terminal spaces, reached only by one arc (links=1; dead-ends), and their priority is occupation rather than circulation. "b" spaces are reached by two or more arcs where the number of links is one less than the number of spaces (topological form of a tree); their priority is circulation and they offer controlled access to adjacent spaces (links>1; arranged in a chain or a tree). "c" spaces are reached by two or more arcs and are connected in a ring shape (links>1; arranged in a ring). These spaces induce movement and provide controlled access. "d" spaces are reached by two arcs and are connected by more than two rings (links=2, arranged in at least 2 rings). In addition to inducing movement, these spaces induce relationship and choice. (Heitor *et al.*, 2004)

According to Hillier (2007: 252) "a" and "d" spaces contribute to a more integrated network while "b" and "c" spaces contribute to segregation networks.

Figure 28 shows an example of a spatial network analysed according to several syntactic measures such as integration, control, depth from root and distribuitedness. In this spatial network, nodes 6 and 3 have high integration values, meaning they are the most accessible nodes in the network. The relative asymmetry (RA) describes the integration of a node by a value between (or equal to) 0 and 1, in which a low value describes high integration. The mean RA value for this network is 0.33 which stands for a highly integrated network. In contrast, node number 11 is the least accessible node, as confirmed by the higher value for mean depth (MDn) of 3.5. The choice ratio of the network is 1.18, which means that there are some, but not many, alternative routes from one space to another. The node with the highest control value is number 2, which means that this is the most important point of passage in relation to the surrounding areas. Regarding space distribuitedness, it can be seen that distributed spaces prevail over non-distributed spaces. According to Hanson (1998) the measure of distributedness is given by *(c+d)/(a+b)* which in this case amounts to 2.6. Sociologically, we assume that higher distributedness values occur in a space with no strong barriers between inhabitants and the activities carried out there (Holanda, 1999). Therefore this network has a flexible distribution allowing for different paths to reach a space. Holanda refers to the symmetry measure as the result of the total integrated spaces (a and d) over the segregation spaces (b and c) - *(a+d)/(b+c).* This measure enables the extent to which the building promotes the segregation of the inhabitants and their activities to be evaluated. The symmetry ratio is 0.8 in this case, which means that segregation in high and, according to Holanda (1999), enables higher status differentiation within the dwelling.

[18] Wikipédia. *Space Syntax*. Available at WWW <URL:http://en.wikipedia.org/wiki/Space_syntax> (accessed February 2010)

4 FAMILIES AS RESIDENTS

An architectural design programme is based on various kinds of data, amongst which knowledge of the future occupants is an essential element in conception.

When architects consider a design programme they are faced with a group of future occupants who may either be known (e.g. in the case of a commission for a single family dwelling) or partly unknown (e.g. in the case of a multi-family residence).

In order to address the research aims concerning the definition of the various profiles required for the integration of ICT and for occupancy, it is necessary to begin by defining the potential groups that may share the accommodation.

However, an *a priori* definition of groups of residents may imply that the proposed rehabilitation is intended only to address specific groups, thereby excluding, for example, integrated rehabilitation projects for multi-family residences developed with the aim of eventually placing the dwelling on the housing market for sale or rent. This thesis aims to address both cases – rehabilitation of a single dwelling for a known family and rehabilitation of one or more dwellings for unknown residents – and the chosen methodology therefore responds to both.

In order to address situations in which the future inhabitants are unknown, two types of strategy are proposed: i) through the use of market studies the developer knows which target group the housing is to be designed for and, on this basis, can choose one or more profiles from amongst those defined here; ii) rather than choosing a specific profile, the developer can opt for an undefined group of residents characterised solely on the basis of family size. The strategy for defining the functional programme for the latter group, defined in *Part 1: Chapter 4.2.10*, is explained in *Part 2: Chapter 2* and the ICAT pack is explained in *Part 2: Chapter 3.*

The aim of this chapter is to categorise the different domestic or residential groups so that they can be cross-referenced with the available ICAT solutions (*Part 2: Chapter 3)*, the housing programme (*Part 2: Chapter 2)* and the physical dwelling that is to be rehabilitated (*Part 2: Chapter 4)* by making use of a transformation grammar.

To this end, literature on the subject was studied, with a particular emphasis on the characterisation of the population of Lisbon in terms of the families emerging from the last available Census – in 2001 – and the work of Wall (2003)(2005), Aboim (2003), Vasconcelos (2003) and Morgado (2005). The latest INE (Statistics Portugal) statistics were used for some population indicators.

The classification of households enables certain groups to be established, either on the basis of their shared living structure or the age of their members.

The traditional family structure which includes one man, one woman and their children does not necessarily reflect the family life of many households. In fact, the traditional family structure – the nuclear family consisting of a couple with children – has become less important and the presence of other groups has increased in society (Figure 34).

According to Karin Wall (2005: 553) a group of people who live in the same household, whether they share resources or not, is termed a "domestic group or unit". This definition meets the criteria for co-residence or cohabitation, in which individuals, whether from the same family or not, share accommodation, as opposed to the concept of a family group which implies blood or marital ties (Wall, 2005: 553). In fact, although the family united by blood and marital ties almost always features in cohabiting groups, different situations may sometimes occur.

Examples include groups of young people living in the same house as students, or groups of elderly friends sharing a house.

The concepts used by the INE in the 2001 Census to classify domestic groups and referred to in this work are the classic family and the nuclear family. For the INE, the classic family consists of a group of people who live in the same accommodation, are related (in legal or de facto terms), and may occupy all or part of the dwelling. Any independent person who occupies all or part of a unit of accommodation is also considered a classic family. Domestic staff living in the accommodation where they work are included in the respective family. In addition, according to the INE, the nuclear family consists of a group of people within the classic family, between whom one of the following relationships exist: a couple with or without unmarried children, a father or mother with one or more unmarried children, grandparents with one or more unmarried grandchildren, and a grandfather or grandmother with one or more unmarried grandchildren[19].

The word "family" is used in the context of this research to designate a domestic group or unit residing the same household regardless of whether its members share blood or marital ties and regardless of the number of occupants. This use of the term "family" covers nuclear families, classic families and "complex families" as defined by Wall (2003) (the nuclear family plus other individuals or other nuclei[20]). In the restricted sense of the word, "family" means a group of people linked by blood or marital ties and affinities or residence. According to Wall, in addition to blood or marital ties and affinities, the links between the various members of the group may also be work-related (Wall, 2003: 84). In terms of what has already been stated about the various types of relationship between occupants, the preference here is to use the term "family", since this includes some notion of friendship and identity bonds within the group.

4.1 LISBON STATISTICAL DATA

The resident population of the city of Lisbon has been declining rapidly and nowadays totals 564.000 inhabitants, reflecting a fall of 14.9% in 10 years (INE, 2001). The continuing depopulation of the city has been accompanied by dispersal into the metropolitan area, which has driven the Lisbon population to the borders of the municipality.

The average age of Lisbon city residents is 44.11, as opposed to 39.01 in Portugal as a whole, with the two most representative groups, according to INE data, falling within the age range 20 - 24 and 25 - 29 (Figure 29). There has been a fall in the birth-rate over the last 20 years, with very low figures registered for young people under the age of 19 (i.e. born between 1981 and 2001) which, within a few years, will be reflected in the figures for adults of working age.

Unrestricted developments in border areas of the city have meant that in 2007 the city of Lisbon represented only 17% of the population of the Lisbon Metropolitan Area (LMA) (INE, 2007). Moreover, in 2007, the Greater Lisbon area represented 72% of the population of the LMA, with the remainder resident in the Setúbal Peninsula.

In 2006 there was a 1.95% negative effective growth rate in the city of Lisbon, whilst the Greater Lisbon Area registered a positive value of 0.33% and the LMA 0.54%. Only some border cities had a higher effective growth rate: Mafra in Greater Lisbon, with 3.42% and, in the Setúbal Peninsula, Alcochete, with 4.06% and Sesimbra, with 4.27% (INE, 2007).

Elderly people (aged over 64) represented one quarter of the population (24.18% in 2007), Lisbon being one of the most elderly cities in Europe which, in turn, is the most elderly continent in the world (Figure 30). In the Great Lisbon area the presence of elderly people reduces to 17.33% in 2007 (Figure 31). At 180.8%, the ageing index for the city of Lisbon is the highest in the LMA, compared with 109.3% for the Greater Lisbon area and 98.4% for the Setúbal Peninsula. Lisbon is also the city with the highest old age dependency index in the LMA, at 38.7%. The cities with the lowest old age dependency index are Vila Franca de Xira, at 18.3%, and Seixal, at 16.7% (INE, 2007).

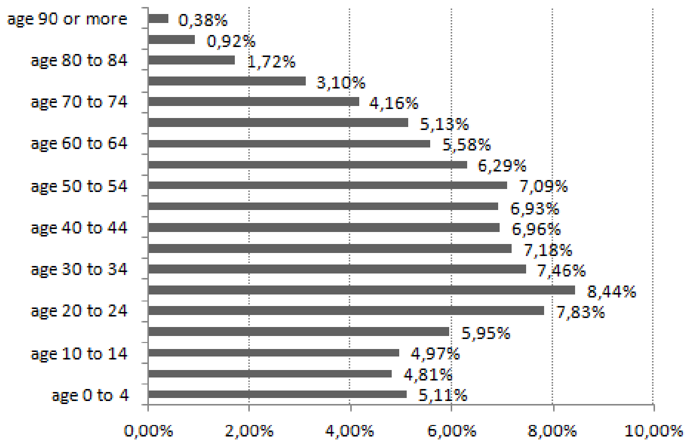
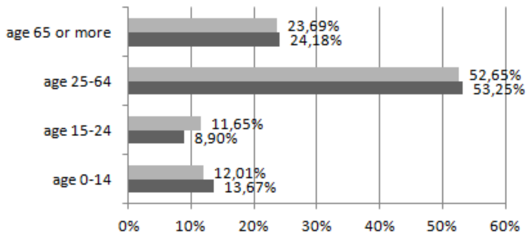
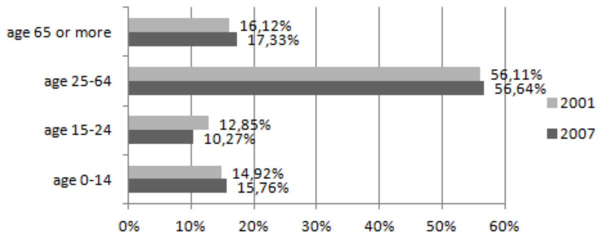


Figure 29 (right) – Lisbon resident population by age group. Source: (INE, 2001)

Figure 30 (bottom left) – City of Lisbon resident population in 2001 and 2007, by age group. Source: (INE, 2007)

Figure 31 (bottom right) – Greater Lisbon Area resident population in 2001 and 2007 by age group. Source: (INE, 2007)





With regard to the elderly population, it should also be stressed that almost half (14.4%) of the classic single-person families (30.5%) are composed of individuals aged over 65.

It has been calculated that by 2050 almost one third of the Portuguese population will be aged over 65. In fact, according to the INE (2003), the resident population projections for Portugal for the period 2000-2050 reveal that the population will continue to age as a result of the estimated increase in life expectancy, as well as the continuation of sub-replacement fertility levels. In the various scenarios defined by the INE for 2050, the percentage of elderly people always remains higher than that of young people and in the most pessimistic ageing scenario may total 395 elderly people per 100 young people (a figure that has quadrupled since 2000).

With regard to living arrangements in the city of Lisbon, nuclear families represent 68% of classic families. The INE classification of classic families according to size reveals that in Lisbon the most representative families consist of two individuals, followed by 1 individual and, in third place, 3 individuals (Figure 32). It is interesting to note that nationwide there are far fewer families consisting of 1 individual, and these are ranked fourth. The size of the average family has fallen over the years. In 2001 the average family size in Portugal was approximately 2.76 people per family, a figure lower than the 3.1 recorded in 1991 and 3.4 in 1981. The average family size is 2.57 in Greater Lisbon area and 2.85 in the Greater Porto area. This does not vary significantly throughout the country: the highest figures are found in Madeira and Tâmega (3.27 people per family) and the lowest in the Baixo Mondego (2.50) and Beira Interior Norte (2.51) regions.

In terms of nuclear families, the couple with children remains the most representative nucleus in Lisbon, at 44% (56.7% in Portugal as a whole), followed by couples without children, at 35.8% (30.9% in Portugal) and single-parent families, at 18% (11.5% in Portugal) (Figure 33

Figure 33). With regard to number of children, in nuclear families with children the most representative figure is 1 child (37.22%) (Figure 35).

The characterisation of families presented in this chapter indicates a series of objective housing needs.

The required housing size and functional needs as well as the possibilities for the use of ICAT can be extrapolated from the statistical data on families resident in the city of Lisbon and their composition (number of people and kinship).

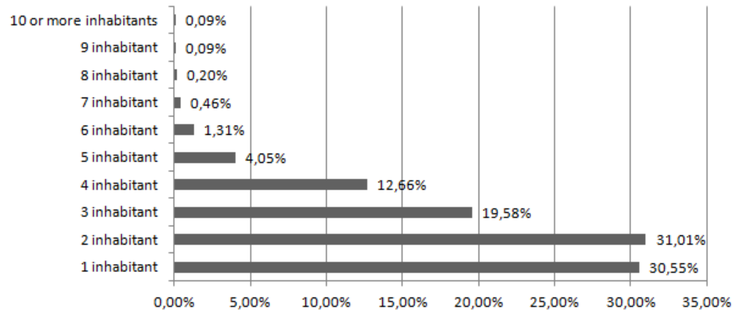


Figure 32 – (right) Classic families in Lisbon, by family size. Source: (INE, 2001)

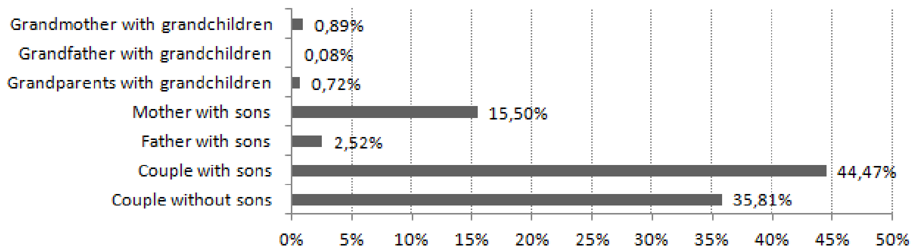


Figure 33 – (bottom) Types of nuclear family in Lisbon (total of 159,666 nuclear families). Source: (INE, 2001)

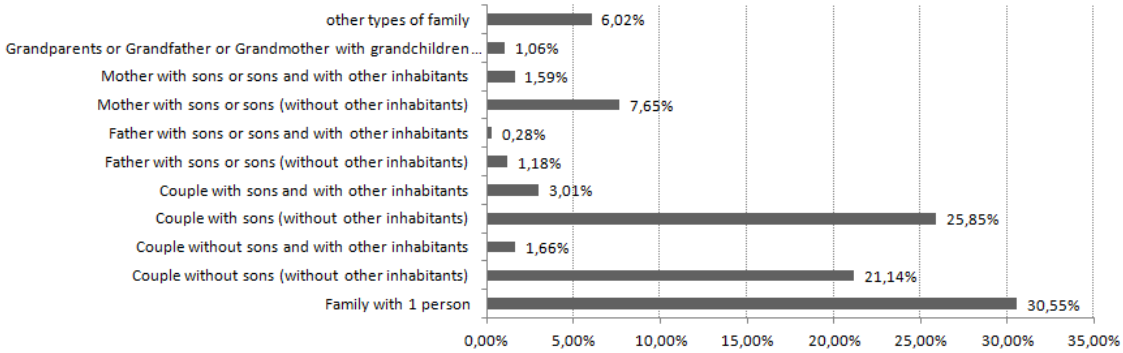


Figure 34 – (top) Types of classic family (based on nuclear families) in Lisbon (total of 234,451 classic families). "Other types of family" includes families with 2 or 3 nuclei, with or without children and with or without other individuals. Source: (INE, 2001)

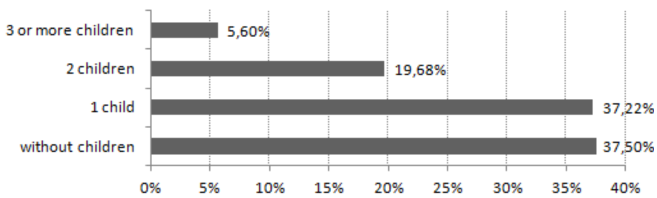


Figure 35 – (right) Nuclear families and children in Lisbon. Source: (INE, 2001)

As Morgado states (2005: 48), family values, lifestyle, attitudes towards work and leisure and types of living arrangements are very subjective variables that are difficult to quantify and will influence the overall characteristics of the desired residence. In addition to these factors, the phase in the life cycle also has a major influence on the choice of housing, since this is established either by the age group to which the family members belong or their socio-economic level.

In conclusion it may be stated, in accordance with Aboim (2003), that the main changes which have taken place in the structure of domestic units over the last 40 years are the reduction in average family size, the increase in the number of single people, the fall in the most typical format for the nuclear family i.e. the couple with children, and the reduction in complex units (containing various nuclear families and non-kinship relations). Parallel to this reduction in the number of families comprising couples with children, the number of couples without children and single-parent families has risen.

The causes of the changes in family life are the decrease in, and postponement of, fertility, the higher divorce rate, the increase in population ageing, the increase in the number of working women and the new, more individualistic, culture amongst the younger sections of the population (Aboim, 2003).

4.2 FAMILY TYPOLOGY

The literature previously cited was used in the family typology and the classification was based on the following criteria:

– Classification according to circumstances: living in a group or living alone;
– Classification according to age or phase of life of residents (e.g. young people, adults, elderly people);
– Classification according to situation regarding children (married with/without children, single-parent families/single adults);
– Classification according to mobility and/or disability (inclusion of those with restricted mobility or disability);

Families resulting from break-ups, divorces and second marriages were not considered separately but included on other groups such as couples with or without children or single adults.

The follow classification was therefore adopted for families, which will be defined in the course of this chapter:

Although it was felt that any form of housing should guarantee access for all residents regardless of their current physical state of health, due to the fact that this work focuses on housing rehabilitation, which frequently involves significant restrictions, it was considered that improved access should only be obligatory for families who, from the outset, included one member with restricted mobility or a disability.

Within this context, to avoid having to include an additional sub-type "with restricted mobility or disability" for each type of family within the family classification system, the choice was made to define specific needs in these cases, which are included in the definition of the ideal functional programme (*Part 2: Chapter 2*) and the ideal ICAT pack (*Part 2: Chapter 3*) for each family type that includes a member with restricted mobility or a disability.

As previously stated, the aim of the family typology was to define the functional programme and ICAT pack, adapted initially to each family profile and subsequently to the existing housing. The definition of family groups was therefore justified solely by the fact that they have different living arrangements and therefore different functional and ICAT needs. The characterisation which follows aims to define these differences.

Co-residence	Couples with children	Couples with dependent children/minors
		Couples with independent children/adults
		Couples with children and other individuals
	Couples without children	Young couples who may eventually have children
		Childfree couples
		Couples whose children have left home
		Couples without children but with other individuals
	Single-parent families	Mother or father with children
		Mother or father with children and other individuals
	Young people	Co-residence with other young people
	Adults	Co-residence with other adults
	Elderly people	Couples
		Couples/single elderly person with grandchild
	Other types of family	2 or 3 nuclei with or without children and with or without other individuals
Single people	Young people	
	Adults	
	The elderly	

Table 5 – Classification of families.

In defining the ideal functional programme and the pack of ICAT functions the family profiles described below were used, with slight adjustments or additions when requirements were similar.

Within the types defined, 3 criteria are essential to the definition of space and ICATs: the possible presence of an elderly person or an individual with restricted mobility or a disability; the possible presence of children from different marriages; the possible presence of residents other than the parent/children nuclear family.

In the event that one of the residents is elderly person and/or has restricted mobility or is disabled, the functional criteria and criteria for the use of ICAT are more demanding and their specifications are described in *Part 2: Chapter 2* and *3.*

In the context of recomposed families with children from different marriages, it is important to consider that the different children belonging to the new couple have a greater need for privacy than would be the case if they were siblings and the children of the same parents.

In families which include one or more other individuals (grandparents, aunts or uncles, cousins, friends, etc) in addition to parents and children, the need to recognise the independence of these individuals and to ensure privacy for the different groups within the family is greater. Wall (2005) has termed these families complex families and defines them as families consisting of a basic nucleus (a couple or couple with children) plus other relations or individuals who are not related to them. Although they do not feature greatly in data on the Portuguese population, they have a certain importance if analysed transversally. According to this author, there are three stages in family life – the start of married life, the birth of the first child and the "current moment" (on average, 17 years after the start of married life) (Wall, 2005: 562). At the start of married life, 30.6% of couples live with other relations, a situation which occurs mainly when a younger couple lives with an already existing family. When the first child is born (on average 2.4 years after the start of married life) this falls to 26.6% of couples (Wall, 2005: 562). At the "current moment", approximately 88.1% of couples live in simple families consisting of parents and children.

The majority of couples – 62.7% – always follow the path of the basic family (couple without children or couple with children). Approximately 37.3% of couples live with other groups of people – in complex families – at some stage in their life.

Although it is rare to spend an entire lifetime in a complex family (only 7% of the population do so), it is common to move from a complex to a simple family (23.8%) or from a simple to a complex family (4.5%) (Wall, 2005: 563). The latter situation basically occurs when other family members move in on a temporary basis.

The family typology relevant to determining the functional programme and pack of ICAT functions should be understood not as an end in itself, but as a beginning. In other words, housing rehabilitation should not only take the present-day occupants into consideration, but also their likely future development. It is therefore necessary to cover the different phases in the life cycle of the occupants as broadly as possible.

4.2.1 Couples with children

Couples with children (living with or without other individuals) comprise 28.86% of the classic families in Lisbon (Figure 34). The term "couple" is used, in the context of this study, to define two people who are either married or in a de facto union, regardless of gender. This group also includes recomposed couples with children from different marriages and therefore complex kinship relations.

The number of children in nuclear families is shown in Figure 34 – (top) Types of classic family (based on nuclear families) in Lisbon (total of 234,451 classic families). "Other types of family" includes families with 2 or 3 nuclei, with or without children and with or without other individuals. Source: (INE, 2001)

Figure 35, and this data does not separate the children of "couples with children" from the children in "single-parent families". In these nuclear families, 37.22% have only 1 child, 19.68% have 2 children and only 5.60% have three or more children. The figures therefore reveal small domestic units.

COUPLE WITH DEPENDENT CHILDREN UP TO ADOLESCENCE

The available statistics do not enable the exact figures for this group to be calculated, but on the basis of the 2001 Census it may be ascertained that 20% of couples with children have at least one unmarried child aged under 25.

According to Morgado (2005: 55), the arrival of children is usually associated with functional reorganisation or even a search for new housing. Couples with dependent children are generally economically weaker due to the fact that they are bringing up children, have housing costs and are still in the early stages of their careers (Morgado, 2005: 55).

COUPLE WITH INDEPENDENT CHILDREN FOLLOWING ADOLESCENCE

The available statistics do not enable the exact figures for this group to be calculated, but on the basis of the 2001 Census it may be ascertained that only in 5.76% of couples with unmarried children is the youngest child aged 25 or more.

In contrast to the previous group, couples with older children who are adolescents or young adults have greater independence and fewer economic restrictions, very often due to the fact that the children are involved in the household economy (Morgado, 2005: 55).

COUPLES WITH CHILDREN AND OTHER INDIVIDUALS

In addition to couples with children, this group also includes other relations or individuals not related to them.

Although it represents only 3.01% of the situation in Lisbon, Wall (2005: 562) considers that this figure should be interpreted more transversally, as previously stated.

In addition to the previous considerations regarding the need for privacy in recomposed families which contain children from different marriages, the inclusion of people within the domestic group other than members of the immediate family is also an important factor when defining living space.

4.2.2 Couples without children

This family type represents 35.81% of the nuclear families in Lisbon (Figure 33).

The group contains very diverse subgroups which essentially depend on the age of their members. According to Morgado (2005: 57), couples without children generally tend to be more open to innovative types of dwellings and solutions than couples who have children. The same author notes that the fact that the family unit does not include children makes it easier to work from home and to create specific office space.

As there are fewer restrictions in terms of compartmentalising living space for this group due to the absence of children or other individuals, configurations of work or leisure areas are possible, assisted to a large extent by ICAT.

COUPLES WHO MAY EVENTUALLY HAVE CHILDREN

In comparison with other couples without children, it is essentially young couples who face the greatest economic constraints.

These couples usually live in small 1 or 2 bedroom accommodation, generally rented, so that they can develop as a family within a small area. The group also includes those who opt for a more definitive situation by anticipating, from the outset, the development of the family cycle.

CHILDFREE COUPLES

As members of this group are no longer young adults, they may be considered to have greater financial resources due to the fact that their careers are more advanced and they have no expenses associated with children.

According to Morgado (2005: 57), advancing age will probably determine certain developments associated with less appreciation of innovation. At the same time, increased financial resources may lead to a greater demand for exploring new places through travel and consequently less interest in the home. This group is more likely to be interested in open-plan urban apartments

(Morgado, 2005: 58), such as lofts, the demand for which has increased markedly in the city of Lisbon in recent years.

COUPLES WHOSE CHILDREN HAVE LEFT HOME

This group has the same characteristics as couples with children but in general has acquired greater financial resources and more free living space, reoccupied, in some cases, by grandchildren after some years have elapsed.

COUPLES WITHOUT CHILDREN BUT WITH OTHER INDIVIDUALS

Any of groups a), b) or c) may feature in this group if accompanied by other relatives or individuals not related to its members. This group comprises only 1.66% of the classic families in Lisbon.

4.2.3 Single-parent households

This domestic group represents 18.03% of the nuclear families in Lisbon, with the total falling to 14.6% in the Greater Lisbon area. It is a very heterogeneous group in terms of the parent living with the children, with the mother and child(ren) group representing 15.5% and the father and child(ren) group only 2.52%. Although this difference is maintained, the number of male single-parent families increases with the age of the children (Wall, 2003: 53). In Portugal, 72% of single-parent families live alone and the remaining 28% live in complex families, leading to the conclusion that these families are economically, socially and/or residentially dependent to a certain extent (Wall, 2003: 54).

SINGLE-PARENT HOUSEHOLDS WITH 1 OR MORE CHILDREN

82.5% of the single-parent family group includes only the mother and children or father and children.

SINGLE-PARENT HOUSEHOLD WITH 1 OR MORE CHILDREN AND OTHER INDIVIDUALS

17.5% of the single-parent family group includes other individuals in addition to the mother and children or father and children group.

4.2.4 Young people (co-residing with others)

Young couples with or without children, young people who live with their parents (couples or single parents) and young people living alone have been excluded from this group and assigned to other groups.

Given this, only young people sharing accommodation with others (essentially other young people) as students or when starting their careers, are included in this category.

This group is included in the institutional families[21] in the 2001 Census and represents less than 1% of the scenario in Lisbon.

According to Morgado (2005: 53) the areas linked to this section of the population are associated with the incorporation of ICAT and with socialising with other young people. However, young people usually have limited financial means and are restricted by a lack of resources (Morgado, 2005: 53).

4.2.5 Adults

Adults who are part of a couple with or without children and adults living alone have been excluded from this group and assigned to other groups.

Given this, only adults co-residing with other individuals are included in this group. As with young people co-residing with other young people, this group is included in the institutional families in the 2001 Census and represents less than 1% of the scenario in Lisbon.

4.2.6 Elderly people

This group consists of people over the age of 65. Two hypothetical living arrangements are considered: the elderly couple and the elderly couple or single person living with grandchild(ren). The hypothesis of co-residence in extended families consisting of grandparents, children and grandchildren is not included, since it is felt that where they exist, the particular needs and requirements for these cases should be added to those of couples with children. Single elderly people are classified separately in a category for single people only (see 4.2.8).

The elderly population in the city of Lisbon has been increasing, totalling 24.2% in 2007 (Figure 30, page 69). The physical and mental capacities of the elderly tend to deteriorate with age, meaning that they become more dependent and less mobile. It is therefore natural that these groups seek stable housing solutions with lasting physical and human references (Morgado, 2005: 58).

According to Morgado, in terms of physical condition and health matters, elderly people experience a higher incidence of sight and hearing problems, neurological disturbances such as Alzheimer's, and dementia. This has very strong implications for living arrangements within the household and it is at this point that universal design and the removal of architectural obstacles become essential to mobility and consequent autonomy. To supplement the removal of architectural obstacles, the use of assistive technologies is a process which helps promote autonomy in the elderly. In spite of this, these are not always accepted by the elderly as they are naturally more conservative with regard to innovation and the adoption of new technological systems.

If still working, their activities tend to centre on the house or a place nearby, as do leisure activities (Morgado, 2005: 58). In general, retirement represents a period of greater financial constraint for elderly people.

Solutions such as sheltered housing exist nowadays for elderly single people or couples, offering small housing units within a building that offers communal areas and central support services. Despite this, the majority of elderly people, whether single or couples, prefer to remain in their own homes.

COUPLES

Elderly couples aged over 65 pass through various phases ranging from the retirement of one or both individuals to the emergence of health problems, namely those associated with reduced or restricted mobility.

THE ELDERLY COUPLE OR SINGLE PERSON WITH GRANDCHILD

This group constitutes a simple family nucleus and represents only 1.69% of nuclear families. The needs of the elderly are added to those of the young person.

4.2.7 Other types of family

This type of household consists of a set of two or three nuclear families with or without children and with or without other individuals and represents approximately 4.3% of the classic families in Lisbon.

The decision was made not to include this group in the study which cross references functional requirements and ICAT needs, since the solutions it requires include the solutions for each of the nuclei it contains.

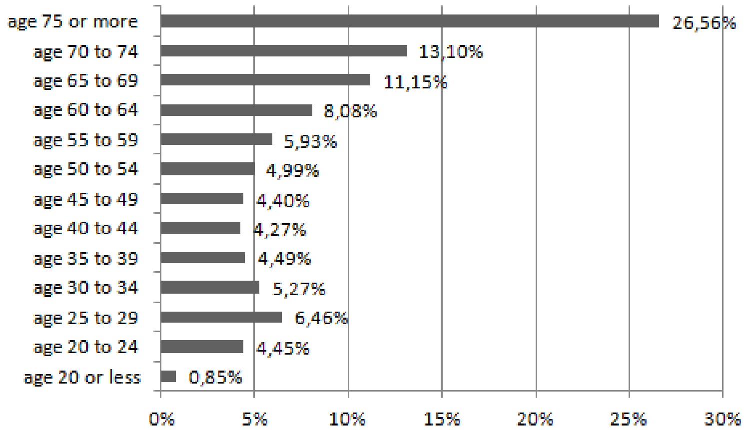


Figure 36 – Classic single-person families in Portugal, by sex and age group. Source: (INE, 2001)

4.2.8 Single people

In the city of Lisbon the group of people living alone represents 30.55% of classic families (INE, 2001). As there is a lack of data for the city of Lisbon, an analysis was undertaken of the whole of Portuguese territory, in which single-person families represent 17.3% of the total, and their distribution by age is shown in the graph in Figure 36.

The variations in the graph clearly indicate the main trends or stages of life for people who live alone: young people who have recently left home and have not yet married or are co-residing with others (aged 25 to 29), and adults and elderly people from the time they are widowed.

This group of people lives in circumstances that frequently lead to loneliness and therefore throughout the research attempts were made to develop rehabilitation solutions that favoured a social mix in which larger families could live alongside smaller ones.

Young people

This group may include young people who are still students living away from their home town and young people starting their careers and beginning to live independently.

Adults

This group includes adults who, by choice or involuntarily, are single. It also includes adults who are living alone without children due to divorce or separation.

According to Morgado (2005: 61) this situation reduces the level of tolerance, increases the level of demand and it becomes more difficult to negotiate relationships, closing the doors to future communal living.

The elderly

Elderly people living alone represent 14.4% of the classic single-person families in the city of Lisbon (but only 9.05% in the Greater Lisbon area).

Elderly people frequently live alone because they have been widowed and this corresponds to the final phase in the family cycle. In addition, an immediate consequence of the reduction in the number of three-generation families has been for elderly individuals (mainly women) to remain alone after being widowed.

These cases are mainly associated with sub-letting (51% of the dwellings in Lisbon are sub-let (CML, 2002b), resulting in a lack of dynamism in the housing market in the city of Lisbon.

In these circumstances, elderly people may be visited by family, friends or a personal carer and will therefore require extra space.

4.2.9 People with restricted mobility and/or disability

People with restricted mobility and/or disability are considered to be those who are disabled to some extent (the proportion of the resident population in the city of Lisbon who have some degree of disability is 7.6% (INE, 2001)), or whose mobility is temporarily or permanently restricted. Elderly people have been excluded from this group, since they are treated as a separate group, as already mentioned – i.e. as single elderly people or elderly couples.

People with restricted mobility and/or disability were not considered as a co-residing group but instead as representatives of a condition in which any individual included in the previous groups may find themselves. This condition may be temporary, as the result of an accident or illness, or definitive and, depending on its nature, should be considered when defining housing requirements. Therefore if a particular family contains an individual with restricted mobility and/or disability, the requirements defined by this condition, which are described in *Part 2: Chapter 2* in terms of functional housing questions and in *Part 2: Chapter 3* in terms of assistive technologies and domotics, should be added to the family requirements

Specific requirements were defined for people with restricted mobility and/or disability, given that their needs in terms of space and housing functions are greater, in addition to the use of technologies. Moreover, technologies offer various specific solutions for these cases and should be dealt with separately.

It was considered that the existence of a member of the domestic group with restricted mobility and/or disability implies adopting the chosen criteria.

4.2.10 Non-defined group

A non-defined co-resident group was considered, purely for the purpose of defining a minimum ICAT pack for the dwelling which assumes compliance with minimum residential criteria.

This group is defined only by the number of occupants and not according to sex, age or relationship factors. The profile of the most representative family for the number of occupants should be used to define the functional programme. The following are therefore available:

- For 1 inhabitant, the profile for the Single Elderly Person (Figure 36);
- For 2 inhabitants, the profile for the Couple without Children (Figure 34);
- For more than 3 inhabitants, the profile for the Couple with Children (Figure 34).

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[19] Concepts used by the INE, available at WWW: <URL:http://metaweb.ine.pt/sim/CONCEITOS/Conceitos.aspx>

[20] Concepts used by the INE, available at WWW: <URL:http://metaweb.ine.pt/sim/CONCEITOS/Conceitos.aspx>

[21] An institutional family contains a group of people living in collective accommodation who, regardless of any family ties between them, abide by common discipline, are beneficiaries of an institutiion and are governed by an entity within or outside the group. Available at WWW: <URL:http://metaweb.ine.pt/sim/CONCEITOS/Conceitos.aspx>

5 HOUSING AND LIFESTYLES

One of the objectives of this thesis is to define the new functions and requirements for housing in the current Information Society (IS) by analysing the impact of the integration of technology, namely ICTs, within living space, both in terms of spatial-functional organisation and construction.

Within the context of this work, given that recommendations are made for housing rehabilitation and the intention is to focus on changes in life styles created by the use of ICTs, basic functions and requirements were defined on the basis of the existing bibliography - *a priori* of ITC considerations – then developed to incorporate needs emerging out of the use of ITCs.

Therefore, use was made predominantly of research studies and a survey carried out during the course of this work. Specifically, this involved studies on the housing programme produced by Pedro (1999a and 1999b), (2002), (2006), the use and computerised implementation of Pedro housing programme in the Malagueira grammar by Duarte (2007), the work of Pereira (2006) on developments in housing over the last 30 years (case studies), the work of Morgado (2005) on emerging types of housing, the work of Oliveira (2000) on new housing models and forms of contemporary housing appropriation, the work of Paiva *et at* (2006) on housing rehabilitation, and the results of the survey applied to the field of study, on the basis of which certain contemporary housing trends were identified (case studies) (*Part 1:Chapter 7.4*).

The analysis in this chapter comprises a synthesis of present day housing requirements which have been substantially developed in the works cited above and serves as an introduction to the concepts used in the chapters which follow. This review does not aim to cover all aspects of contemporary housing requirements, but only those essential to the definition of the rehabilitation principles and which are associated with new experiences of technology.

This chapter summarises the criteria used throughout the thesis, specifically in *Part 2: Chapter 2*, and defines, in general terms, the functions and quality requirements for housing. It also summarises the main social changes that have led to changes in the structure of housing and establishes the relationships between the characteristics of housing structures and those of co-residing groups.

5.1 HOUSING FUNCTIONS, SPACES AND ORGANISATION

Within the context of this thesis, housing is studied in terms of the physical building and individual dwellings, focussing on the dwelling as the residential unit that must respond to contemporary requirements. Therefore the functions that take place in existing housing, the areas within the dwelling in which they take place and the dynamics of relationships between spaces will be covered.

Given this context, the essential focus is on the individual dwelling, although in terms of the building itself the conditions required to validate the integration of ICAT are also taken into consideration.

BUILDINGS

Building			Low rise (up to 4 floors) Min.	Low rise (up to 4 floors) Rec.	Mid rise (4< 9 floors) Min.	Mid rise (4< 9 floors) Rec.
Communal areas						
Areas used communally	Entrance	Exterior	○	●	○	●
		Interior	○	●	○	●
	Vertical communications	Stairs	●	●	●	●
		Lift	○	○	●	●
		Ramps	○	●	○	●
	Horizontal communications		●	●	●	●
	Communal parking area		○	⊗	○	●
	Recreation room		-	⊗	○	●
	Communal outdoor area		○	●	○	●
Communal service areas	Rubbish chutes		○	○	○	●
	Rubbish deposit/storage area		○	○	○	●
	Rubbish bin emptying area		○	○	●	●
	Mailboxes		●	●	●	●
	Storeroom for cleaning materials		●	●	●	●
Technical service areas	Meters (on the communal area)		○	●	○	●
	Space for cables/pipes for various infrastructures		○	●	○	●
	Space for machinery and equipment		○	○	●	●
Private areas						
Dwellings	Condominium or privately rented properties		●	●	●	●
	Caretaker's house		○	○	○	○
Autonomous units	Commercial or service areas		○	○	○	○
Areas annexed to dwellings	Private store rooms		○	⊗	○	⊗
	Private outdoor areas		○	●	○	●
	Individual garages		○	○	○	○
Non-residential areas						

Areas which do not exist, or do not exist in most cases or are undersized in *rabo-de-bacalhau* buildings:	
(light grey)	Creation not a priority
(medium grey)	Creation a medium-term priority
(dark grey)	Creation a priority

Table 6 – Classification of areas in a multi-family residence and their importance in terms of quality levels. ○ Optional, ⊗ Recommended, ● Essential. Adapted from (Pedro, 1999c: 10, 33). Areas shaded grey do not exist in any of the *rabo-de-bacalhau* buildings studied.

According to Coelho and Pedro (1998: 196), the multi-family residence represents, on the one hand, the framework for family residential units according to the various household groupings and including the use of communal areas and, on the other hand, a marker for the outdoor area in the local neighbourhood.

Within the typology of multifamily residences, the building type under consideration consists of individual areas (dwellings and their annexes) and communal spaces and may also include non-residential space such as commercial or service areas.

In terms of communal areas, the buildings analysed in the case study presented in *Part 1: Chapter 7* – *rabo-de-bacalhau* buildings – have a similar arrangement. Given the age of these buildings, some of the areas that nowadays exist in recently constructed buildings and contribute towards quality by providing residents with better living conditions, do not exist in the *rabo-de-bacalhau* buildings, as will be seen in *Part 1: Chapter 7* and *Part 2: Chapter 2.*

Table 6 shows the areas needed in a multi-family building and their importance in terms of quality levels. The building areas are divided into two levels – minimum and recommended – referring to the quality level of the building. On the question of the existence or otherwise of particular areas, integration priorities have been defined, in line with Pedro (1999c), as optional, recommended and essential spaces. Areas shaded grey highlight the priorities for the inclusion of areas in the proposed rehabilitation projects which do not exist or exist in few *rabo-de-bacalhau* buildings. Assuming that Table 6 expresses new constructional requirements for residential buildings, different levels of priorities have been assigned to the rehabilitation processes. These priorities take into account the need to address these requirements and the amount of work needed to satisfy them. It may be concluded that the major problem in "rabo-de-bacalhau" buildings is the lack of communal spaces for new functions and requirements. The need for technical services areas to incorporate infrastructures and devices is one of the most important tasks to be completed.

DWELLINGS

According to Coelho and Pedro (1998: 278), a dwelling is a space consisting of various zones which, in terms of a household, are either more private or more communal, more intimate and reserved or more clearly designated for social occasions and receiving guests, more informal or service-based or more representative, more personal and isolated or more orientated towards gatherings and socialising.

Activities take place in the accommodation which may be grouped according to sets of functions, representing more generalised units of behaviour within the dwelling (e.g. personal hygiene) (Pedro, 1999a: 245). These functions are listed in Table 7, in accordance with Pedro (1999a: 11), and their preferred location in particular rooms or living spaces is defined in Table 8 on three levels: essential, recommended and alternative.

This classification is merely indicative of the possibilities for combining areas/functions and does not claim to be the only hypothesis for the use of space. In fact, the proposed criteria for alterations (*Part 2 – Chapter 2*) do not aim to influence the use of space through an excessively rigid compartmentalisation, but instead allow for fluidity between different rooms to enable the dwelling to evolve and reflect other phases in the life of the co-residing group. However, this aim is affected by the equally important need to provide the living space with the requirements that allow for particular functions e.g. privacy, free space, access to infrastructures and acoustic comfort, amongst others. In addition, the fact that the intervention work is carried out on existing buildings with a construction system that seriously restricts demolition, means that any claims for adaptability and flexibility are affected by constructional constraints from the outset.

Function	activities
Sleep/individual relaxation	Sleeping / relaxing Dressing and undressing Leisure / recreation / study Storage of clothes
Preparation of meals	Storing and preserving food Preparing / cooking meals Washing / storing dishes Storing / getting rid of rubbish
Everyday meals	Setting the table / serving / clearing the table Eating
Formal meals	Setting the table/ serving / clearing the table Eating
Relaxing / socialising	Leisure (recreation / games / reading / talking) Watching / listening to audio-visual content
Visitors	Talking, games Serving / consuming aperitifs / drinks Watching / listening to audio-visual content
Recreational activities – children	Leisure (recreation / games / reading / talking) Taking care of, and supervising, children
Study / recreational activities - young people	Studying using a computer Leisure (socialising with friends / games / reading / listening to music / watching audio-visual content)
Work/ recreational activities – adults	Studying / working using a computer Leisure (socialising with friends /games / reading / listening to music / watching audio-visual content)
Care of clothing	Washing clothes in machine/by hand Drying clothes in machine / open air Ironing Hand or machine sewing Storing clothes
Personal hygiene	Washing Bathing or bathing children Dressing, grooming, shaving Medicines or treatments Excretion
Time spent in private outdoor area	Leisure / relaxation / socialising Caring for plants and/or animals
Circulation	Entering and leaving the dwelling Removing and putting on outdoor clothing Receiving visitors Moving between rooms
Storage	General storage (items used occasionally) Kitchen storage (food, dishes and cleaning products) Indoor clothing
Parking	Parking / entering / leaving vehicle Storage of car maintenance equipment

Table 7 – Residential functions and activities. Main functions are highlighted in bold. Adapted from (Pedro, 1999a: 11)

Functions		Double bedroom (be.d)	Twin bedroom (be.t)	Single bedroom (be.s)	Home office (ho)	Study and recreation room (rr)	Kitchen (ki)	Living and dining room (li/di)	Dining room (di)	Living room (ll)	Bathroom (ba)	Hall (hl)	Corridor (co)	Service room (se)	Laundry (la)	General storage (st)	Pantry (pa)	Balcony or private exterior (bl)	Parking (pk)
Rooms (key) | habitable – H; not habitable - nH		H	H	H	H	H	H	H	H	H	nH	nH	H	H/nH	nH	nH	nH	nH	nH
Sleeping /individual relaxation	Couple	E																	
	Twin		E																
	Individual			E										R					
	Storage	R	R	R									A						
Preparing meals							E												
Everyday meals							R	R	R									A	
Formal meals								E	E										
Relaxing/socialising								E		E									
Visitors					R	A		E	R	E								A	
Recreational activities – children			R	R		E		A	A	A								A	
Study / recreational activities - young people			R	R	R	E		A	A	A									
Work/ recreational activities – adults		A			E			A	A	R									
Ironing /sewing							A							R	E				
Washing clothes	Machine						R				A			R	E				
	By hand						A				A				R			A	
Drying clothes	Machine						R				A			R	E				
	By hand						A								R			A	
Personal hygiene											E								
Tine spent in private outdoor area																		E	
Circulation	Entering / exiting							A		A		E	R						
	Communication / separation							A		A		R	E						
Storage	General						A					A	A	A	A	E	A		A
	Kitchen						R						A	A	A	A	E		
	Indoor clothing	A	A	A							A		A	A	A	A	A		
Parking																		A	E

Key (cell shading): E = Essential; R = Recommended; A = Alternative

Table 8 – Location of functions, by rooms. Adapted from (Pedro, 1999a: 12).

5.2 HOUSING REQUIREMENTS

This chapter discusses the quality requirements for housing that are relevant to housing rehabilitation projects (Table 9). Some of these requirements, which contribute towards meeting the objectives of the research, will be highlighted in *Part 2: Chapter 2.1* and will be examined in greater detail.

CONSTRUCTION QUALITY REQUIREMENTS

According to Paiva *et al.* (2006: 294), construction quality requirements should encompass authenticity, durability and compatibility.

Authenticity refers to the origins of materials, structural solutions and construction processes which must be preserved and respected. Aesthetic authenticity is also ensured by preserving the defining architectural concepts associated with buildings from various periods. In addition to constructional authenticity, this is also reflected in the degree to which the character of the location of buildings, which defines them and is defined by them, is preserved.

Durability requirements may be safeguarded by choosing previously tested materials and technologies which do not compromise or make future maintenance difficult. In addition, compatibility requirements are associated with the use of new materials and technologies, as opposed to those which already exist. In addition to being compatible, new materials must be reversible, so as not to impose what is currently considered necessary and appropriate on future uses.

Construction requirements		Authenticity
		Durability
		Compatibility
Habitability requirements		Acoustic comfort
		Visual comfort
		Tactile comfort*
		Mechanical comfort*
		Air quality
		Hygrothermal comfort
		Waterproofing*
		Hygienicity*
Safety requirements		Structural safety
		Fire safety
		Everyday safety
		Protection against intruders /aggression/robbery
		Road safety *
User requirements	Spatial-functional suitability	Capacity
		Spaciousness
		Functionality
	Connectivity	Privacy
		Socialisation
		Acessibility
		Communicability
	Personalisation	Appropriation
		Adaptability
Aesthetic requirements		Attractiveness
		Domesticity
		Harmonisation
Energy efficiency requirements		Energy efficiency
Economy requirements		Economy

Table 9 – Quality requirements for rehabilitated housing (adapted from Paiva *et al.* (2006), Pedro (2000: 98) and Heitor *et al.* (2004: 513)) * Requirements not within the scope of this thesis and therefore not described

HABITABILITY REQUIREMENTS

Habitability requirements are defined by the need to provide acoustic, visual, tactile and hygrothermal comfort in housing, in addition to air quality, waterproofing and hygenicity.

Acoustic comfort envisages sound insulation for the different areas in the residence and to insulate the residence from the surrounding environment. Hygrothermal comfort involves controlling the air temperature in the different areas in the residence and between the residence and the surrounding environment. In both cases the options chosen for spatial-functional organisation and the installation of acoustic and thermal insulation are decisive in promoting housing comfort. Natural ventilation and, if necessary, mechanical ventilation must ensure air quality. Visual comfort presupposes sufficient, controllable natural light which, in terms of rehabilitation work, can only be provided in on an individual case basis.

SAFETY REQUIREMENTS

The safety of residents is an essential factor in any project, and it is therefore important to take into account structural safety, fire safety, protection against intruders/aggression/robbery and everyday safety.

Great care must be paid to structural safety in any rehabilitation project, given that proposed changes may threaten the stability of the building and all related issues. It is essential to assess the structural safety conditions of the building during the analysis and diagnosis phase.

Buildings must offer satisfactory fire safety conditions, which should take the form of requirements with the following objectives: reducing the likelihood of fire; limiting the spread of fire; facilitating the evacuation of the building; enabling fire fighters to intervene; defining development conditions for buildings from the perspective of fire safety.

Residential buildings and their individual dwellings must be provided with mechanical devices and detection systems that can prevent intruders from entering.

Promoting everyday safety presupposes careful design of the construction elements most likely to lead to accidents in the home and in buildings. These include, in particular, stairways and individual steps, flooring, raised surfaces without guardrails, electrical equipment in poor condition and narrow circulation areas (Paiva *et al.*, 2006: 385)

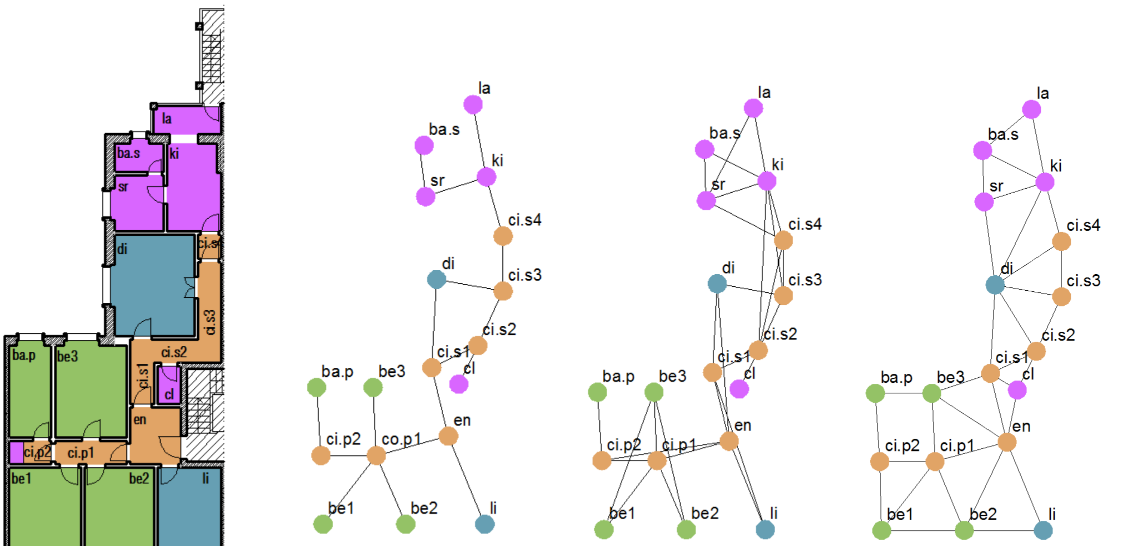
USER REQUIREMENTS

The spatial-functional suitability of a building refers to the features which a dwelling must have in order to create a "*set of functional areas able to accommodate the equipment, furniture and circulation areas necessary for its appropriate use by the number of residents determined by its capacity*" (Paiva *et al.*, 2006: 350). The capacity of the housing represents the set of areas and rooms included in the residence. The spaciousness of a dwelling enables residents to make use of the equipment, furniture, circulation areas and space to exercise their activities within the rooms and is therefore related to the size, shape and way in which space is enclosed. The functionality of a residence refers to the efficiency with which residential functions and activities are carried out.

Connectivity defines the links between the different areas and/or rooms and is related to the functions carried out within them. The links between different areas and rooms refers to the way in which one space is connected to other spaces. Spaces may have the following characteristics in relation to the functions carried out within them: inclusive, when various functions are accommodated within the same room; isolated, when the function carried out is the main or only one within the space in question; demarcated, when there is no clear physical separation between two spaces in which separate functions are carried out.

In order to complement connectivity, a topological definition is used to classify relationships between spaces and rooms and the nature of the links between them. This concept is associated with notions of accessibility, privacy, communicability, socialising and visibility in different areas in a dwelling which will, in turn, affect the syntactic measures of living space, such as depth and integration. Relationships between spaces may be direct (door to, passage to, window to) or indirect (next to, close to, far from, inside, adjacent to, merged with, depth, integration, distributedness).

The way in which relationships between rooms in a dwelling are established must, on the one hand, offer individual and family privacy and, on the other hand, provide easy physical links between functional spaces that are closely connected.



Accessibility graph

Shows "door to" and "passage to" relationships

Visibility graph

Shows "door to" and "passage to" relationships plus the axis view

Adjacency graph

Shows "adjacent to" relationships (in which at least part of a wall is shared)

Figure 37 – Example of original dwelling and accessibility, visibility and adjacency graphs

Dwellings may be analysed on the basis of all these topological concepts and with the aid of tools such as space syntax, which will be explored in *Part 2* and is illustrated in Figure 37.

The appropriation of living space presupposes that it is designed in order to promote the involvement and identity of the users. With regard to adaptability, it is important that the dwelling allows for different uses of the various areas, in the sense that they can be adapted both to changes within the resident group and to different co-residing groups and, consequently, different life styles. This capacity to adapt provides dwellings with a longer life span, since it enables them to respond to different life styles without the need for change.

AESTHETIC REQUIREMENTS

Aesthetic requirements aim to ensure that all the features in a living space contribute towards creating an overall image that triggers pleasant memories, is culturally enriching and naturally appealing (Pedro, 2000: 33).

ENERGY EFFICIENY REQUIREMENTS

Energy efficiency requirements are concerned with the current need to introduce economy measures and rational use of energy into buildings. Measures include reinforcing thermal insulation, controlling air infiltration, using (passive and active) solar technology and improving the efficiency of energy systems and equipment (Paiva *et al.*, 2006: 427).

ECONOMY REQUIREMENTS

Economy requirements refer to the need to ensure that living spaces meet all other requirements at an overall minimum cost (the cost of building, developing and maintenance) (Pedro, 2000: 34) during the expected useful life of the dwelling.

5.3 SOCIAL CHANGES INFLUENCING HOUSING STRUCTURE

The changes that have taken place in society have had a significant effect on life styles and the structure of family housing. In fact, in recent years countless changes have taken place in the structure of society that have had an impact on residential patterns, the most influential of which, according to various authors (Eleb, 1989) (Oliveira, 2000) (Guerra, 2000) (Aboim, 2003) (Morgado, 2005) (Paiva *et al.*, 2006) (Pereira, 2006), will be highlighted.

As previously stated, according to Aboim (2003), the main changes that have taken place in the structure of domestic units over the last 40 years are the reduction in average family size, the increase in the number of single people, the fall in the most typical format for the nuclear family i.e. the couple with children, and the reduction in complex units (containing various nuclear families and non-kinship relations).

The consequences of the mass entry of women into the employment market are the higher age at which the first marriage takes place, the higher age at which the first child is born, reduced fertility rates and therefore smaller families. In addition, this situation has led to a greater role sharing within the family, together with a more equal use of domestic areas. The fact that both partners work, combined with longer periods of time spent outside the home (working, travelling, other activities) are the consequences of a reduced or less continuous use of the dwelling by the family.

The increase in the divorce rate and average life expectancy, together with the mobility of young people for the purposes of studying outside their usual place of residence, have led to a rise in the number of people living alone.

In addition to these changes, the emergence of new types of personal relationships between household members is also an important factor and includes recomposed families with children from different marriages, whose length of residence varies. Parallel to this, relationships between adults and young people within households has also changed, both in terms of autonomy and in the different ways in which parental authority is expressed. This change in basic family values has influenced the use of space, which is now used more informally and shared more amongst the different family members.

The economic changes that have been experienced in recent decades have led to a society orientated towards consumerism, in which goods have become easily available. This has been felt in terms of the ease with which new domestic appliances and games equipment can be acquired, in addition to the amount and volume of objects that are stored.

Parallel to the spread of ICTs and mobile equipment, new habits associated with individual privacy and, within households, the need for autonomy amongst family members have emerged (Pereira, 2006). In this context, the functions carried out in dwellings are changing, e.g. the inclusion of recreational activities and communications with the outside world in bedrooms, in addition to relaxing/sleeping.

In another context, it can be seen that standards for health, hygiene and environmental comfort requirements are much higher nowadays, with obvious consequences for the structure of housing, both in terms of planning buildings and housing infrastructures.

These and other social changes have had impacts on housing requirements that have been cited by various researchers, including those previously mentioned, namely:

- Larger spaces;
- Fully installed sanitation facilities;
- Specific areas for the care of clothes;
- A private area for each adult in the household;
- A large living room offering facilities for new kinds of recreational equipment, in addition to serving as a reception room;
- A kitchen large enough to eat everyday meals in and for the family to gather in whilst meals are being prepared;
- Rooms allocated no specific function, reserved for future use (e.g. as an office), for occasional use (e.g. as a guest room), or as a support zone for the rest of the house;
- Areas for working from home, specifically for e-work;
- Extra storage space;
- Greater flexibility in functional organisation to allow for multiple uses of the same space.

In this context, the organisation of living space must be considered in terms of improving the way in which areas are adapted to contemporary life styles. In addition to specifically social matters such as families with smaller numbers of children, other issues have led to changes in the structure of housing. Within the context of this thesis, the most important are the impact of ICT, domotics and other technologies that have invaded our homes and are responsible for many of the changes in organisation, use and ways of living in these spaces. The existence of technological items in the home aims to establish interactivity between the space, the equipment and the user through intelligent performance involving regulation, monitoring and surveillance, amongst other facilities, in addition to establishing a link between physical and digital space. The diffusion of technological equipment across all the rooms in the household, often creating functional redundancies, provides areas with greater autonomy and personalisation, encouraging alternative uses of areas previously dedicated to one single function. For this reason, the traditional spatial hierarchies within housing are compromised and the nerve centres of the traditional household are changing.

Once we are aware of this new situation, the great question we face is that of being able to envisage a habitat, as a quality residence that is durable, will evolve slowly and can adapt to technologies or ephemeral elements and sees obsolescence as a major factor in its existence (Eleb *et al.*, 1989: 97).

In addition, it is important to investigate the role of technologies in changing residential behaviour and, consequently, transforming domestic space. Will the use of ICT, automation technologies, mobile technologies and other technologies mean that the spaces we live in will be different? What is it that changes in living space: shape, size, the relationship between them, functionality, construction or the equipment that is installed?

5.4 HOUSING CHARACTERISTICS IN RELATION TO CO-RESIDENT GROUPS

In addition to the need to characterise existing co-residence profiles (described in *Part 1 – Chapter 4*) according to size, age, family relationships or affinities and mobility, it is also necessary to characterise the relationship between these groups and particular types of housing from various perspectives, including typology, appeal and capacity.

With regard to the quantitative characterisation of co-resident groups, the most likely, hypotheses for group size are shown below.

		Type of accommodation		
		No. residents	Size	Classification**
Couples with children	Couples with dependent children/minors	3, 4	Medium	T2, T3
	Couples with independent children/adults	3, 4	Medium	T2, T3
	Couples with a large number of children (≥3)	5, 6, 7*	Large	T3, T4, T5
	Couples with children and other individuals	4, 5, 6, 7*	Large	T3, T4, T5
Couples without children	Young couples who may eventually have children	2	Small	T1, T2
	Childfree couples	2	Medium	T2
	Couples whose children have left home	2	Medium	T2
	Couples without children but with other individuals	3, 4, 5	Medium	T3
Single-parent families	Mother or father with children	2, 3, 4, 5, 6, 7*	Medium	T2, T3, T4
	Mother or father with children and other individuals	3, 4, 5, 6, 7*	Large	T3, T4, T5
Young people	Co-residence with other young people	2, 3, 4, 5, 6, 7*	Medium / Large	T2, T3, T4, T5
Adults	Co-residence with other adults	2, 3, 4, 5, 6, 7*	Medium/Large	T2, T3, T4, T5
Elderly people	Couples	2	Medium	T2
	Couples/single elderly person with grandchild	3, 4	Medium	T2, T3
Single people	Young people	1	Small	T1
	Adults	1	Small	T1
	The elderly	1	Small	T1

Table 10 – Classification of co-resident groups by number of residents and type of accommodation envisaged. Adapted from (Morgado, 2005: 68). *The percentage of classic families in the city of Lisbon comprising 7 individuals (e.g. a couple with five children) is very small, and larger groups were therefore not considered. ** "T1" refers to the number of bedrooms in a dwelling. "T" stands for "type" and the number which appears after it refers to the number of bedrooms.

Group size was cross-referenced with housing typology in order to calculate the range of bedrooms needed by each group (Table 10). On this basis, within the scope of this study it is possible to:

- Verify the feasibility of a particular dwelling for occupation by a particular household, in the case of those intending to rehabilitate their housing;
- Envisage the appropriate typology for a particular co-resident group, in the case of those looking for new accommodation.

The typologies for couples with children differ according to the number of children, their sex and level of dependency, varying from a T2 to a T4, or larger in the case of several children. However, certain basic principles should be observed in all cases (Pedro, 1999a: 16) (Morgado, 2005: 53):

- There should be an area for the couple, an area for the children and a communal area for the couple/parents and children;
- The area for the couple should be provided with sound and visual insulation;
- The area for the couple should have a lavatory nearby;
- Sound insulation should be installed in areas adjacent to the children's area, in which quieter activities take place;
- The children's area should allow for control and supervision of children (when very young) without restricting emerging needs for autonomy and privacy in young people;
- The need for autonomy and privacy is greater in the case of children who are young adults (working or unemployed) and may be formalised through private areas (bedroom and bathroom) accessed independently from the rest of the private area.

In the case of recomposed families, particularly when they involve children from both previous marriages, it is necessary to ensure autonomous spaces for both original groups in order to prevent invasion of privacy.

Single-parent family typologies should have the same characteristics as those for couples with children, with a slight reduction in area as only one member of the couple is resident

In general, the typologies for couples without children vary from a T1 to a T2. These dwellings should make provision for the following (Pedro, 1999a: 16) (Morgado, 2005: 58):

- There should be a communal area for the couple;
- Ideally here should also be a specific area for each partner;
- Flexibility of use should be established through connections between rooms;
- Service areas may be reduced to a minimum;
- The preparation of meals is usually an activity of socio-cultural value for this group and a large space should be considered for this purpose.

Young people or adults living alone usually seek smaller dwellings close to urban centres, the workplace or place of study, or even the transport interfaces.

Regardless of age, the typologies for individuals co-residing with others (not the nuclear family) vary according to sex, age, number of residents and the relationship between them, and it is therefore unfeasible to predict the typology for this group. With regard to characteristics other than the size of the housing, these dwellings should make provision for:

- Separate private areas for each resident;
- Shared social areas for the various residents, including areas for preparing meals and for relaxing/socialising;

– Lavatories may be shared or private according to the size of the accommodation.

Households consisting of an elderly couple or single elderly person should feature large, demarcated areas adapted for people who have difficulties with mobility and who tend to remain in them for long periods of time during the day.

In addition to the characteristics previously cited for housing for the elderly, households which include individuals with restricted mobility should also take the following into consideration (Pedro, 1999a: 16):

– The space required for the use of facilities (e.g. the user area in bathroom facilities);
– The size of spaces and passageways (e.g. width of doors, width and angles in corridors);
– Equipment for residents' special needs (e.g. mobility aids in bathrooms);
– Access conditions (e.g. no steps or raised floors).

6 INFORMATION, COMMUNICATION AND AUTOMATION TECHNOLOGIES IN HOUSING

This chapter discusses the concepts underpinning the use of Information, Communication and Automation Technologies (ICAT) in housing, emphasising the possibilities for correct energy management, improved communications and information, efficient support for the elderly and those with restricted mobility and, consequently, greater comfort and better quality of life.

The aim of domotics applications and of integrating their various functions is to create a perfect balance between residents and the home, helping to improve the level of environmental comfort and offering a series of services that include adequate functions for the various activities that might take place within them, whether associated with work or private life.

In technological and social terms, current trends mean that it is necessary to reassess the concept of residence and the role of technology in housing. Consequently information, knowledge and communications networks have become requirements to be implemented in all residential buildings and, if possible, in all their individual units.

The domotics application installed in a dwelling should, firstly, be completely reliable. Equally importantly, it should be easy to understand and adaptable to the needs of users, whilst also allowing for the possibility of expansion to meet future requirements.

Moreover, in applications of a certain size for which future extensions are envisaged, options which dictate the use of one particular brand or supplier should be avoided.

In addition to requirements associated with comfort, it is essential to pay attention to reducing energy consumption, both in new buildings and rehabilitation projects for existing buildings. This objective can be achieved by supplementing passive technologies with intelligent control technologies and monitoring. However, greater control and monitoring mean more devices and, above all, larger and more extensive cable networks to link them all together. The density of these electrical and communications infrastructures, in turn, means they occupy more wall, floor and/or ceiling space, and present higher costs.

In this chapter the domotics operating principles which provide a response to these problems will be explored and the domotics systems and functions available on the market described.

The introduction to the technical subjects developed in the first two sections of this chapter is designed for those who are unfamiliar with domotics. For those familiar with the subject, it will be sufficient to discuss only sustainability, which is addressed in the third section.

6.1 ICAT: TECHNICAL EXAMINATION

The final consumer or developer should take several key factors into consideration when choosing a domotics system.

Reliability is one factor that should be emphasised. Part of the reliability of a system is based on the fact that intelligence is distributed over several devices so that if any component fails the others will continue to function.

In addition, the choice of a system should be based on its capacity to satisfy not only current requirements but, principally, future needs. From this perspective, the system should allow for long-term maintenance, extension and restructuring.

The expectations and financial resources of the customer should also be taken into account, together with the actual user needs and building infrastructure available.

Finally, the system must not dictate the use of one particular brand or supplier, since this would mean that the user would have fewer choices and face the risk of either the brand or product or the supplier disappearing.

6.1.1 Communication protocols

In order for a system to function in an integrated manner all the components must be able to communicate in the same language, using the various forms of transmission available. Another, more complex possibility involves using specific equipment to convert the language of one piece of equipment to that of another.

The language used between domotics systems is called a communication protocol and currently numerous and rival protocols exist.

Since the 1980s, systems that had formerly been independent began to communicate with each other. This led to many manufacturers to create various communication protocols to respond to their specific areas and concrete needs. This profusion of protocols made it difficult to incorporate different brands in the same installation, and for fitters, engineers and users to acquire experience. For reasons of business competitiveness, protocols were not shared between brands but were developed independently without any attempts being made to standardise them.

Even though modern houses are equipped with smart technological appliances, very few of these appliances can be seamlessly connected to each other. According to Miori *et al.* (2010), domotic technology vendors are currently concentrating on building up closed relationships with their customers, and leveraging their economic investments by establishing barriers to new manufacturers entering the market.

In effect, domotics users were barred from being able to freely choose the equipment they wanted on the market, since their choice was restricted to items which communicated in the same language. Common protocols therefore began to emerge, such as KONNEX (KNX), a communication language adapted by a wide range of manufacturers and open to any manufacturer who wished to make use of it. The standard KNX system, which is a protocol compatible to over 100 manufacturers, is based on decentralised bus technology and can provide an integrated solution for control systems in buildings.

Nevertheless Miori *et al.* (2010) believe that no domotic technology currently has the potential to actually play a leading role. The authors claim that the market logic is to tie consumers to a particular domotic protocol, which then forces them to only purchase compatible devices in order to maintain a consistent level of interoperability.

In Portugal and in Europe, the most widely-used protocols in building automation are X-10, LonWorks (from the Echelon Company), KNX (KONNEX), SIMON, Vivimat, Cardio and Ermax.

Closed Proprietary protocols

Domotics systems which are based on closed proprietary communication protocols are characterised by the fact that services and components are sold exclusively by one single company.

The choice of a proprietary system makes it impossible to use other components that are not part of the same brand and, consequently, makes it impossible to make integrated use of services or functions that are not used or developed by this brand. The evolution of these systems therefore depends on the brand and how successful it is on the market.

Although certain manufacturers of these systems are respected on the market and their systems have interesting potential, often at attractive prices, opting for these systems represents a risk that should be avoided.

In certain cases the systems started out as applications for small automated devoices designed to provide solutions for managing air conditioning or lighting (Domo@energia, 2007). These are partial solutions, since each system only resolves one problem and is usually incompatible with others. In terms of cabling, the systems are usually centralised and have an enormous impact as they require a star topology in which each piece of equipment must be directly linked to the switchboard. Nowadays someproprietary protocols use decentralised technologies that are able to incorporate components for specific functions within a building.

The most widely-used proprietary protocols in Portugal include SIMON, Vivimat, Cardio, ComuniTEC and Ermax.

OPEN PROPRIETARY PROTOCOLS

Open proprietary protocols emerged via groups or associations of companies involved in developing compatible products. These systems favour the interests of the owner of the system, the companies that use the system as a work tool and therefore require quality and continuity, and those who acquire the system and require quality guarantees for the product and services. (Alves and Mota, 2003: 108). Although the protocols support innovation and the development of robust products, the owners of open proprietary systems are heavily restricted in their choice of supplier, which creates limitations in terms of alternative choices.

The CAN protocol, initially developed for the car industry by Bosch, is an example of this type of system. This communication protocol was used in the Ericeira Kasa do Futuro to ensure a high level of flexibility and a wide range of components.

STANDARD PROTOCOLS

Examples of protocols used in open, non-proprietary systems include the X-10, KNX (EIB, EHS and Batibus) and LonWorks (from the Echelon Company) which allow for a wider range of products, manufacturers and suppliers.

The technical characteristics of these open or standard systems are defined by international standardisation bodies and any company may develop work compatible with the protocol and submit it for certification.

Open systems are gaining increasing acceptance, both amongst manufacturers and suppliers and final users. The products and services they offer are therefore expected to gradually increase, together with new quality guarantees.

Open systems are undoubtedly the best choice and from amongst them KNX is the best developed system in Europe. It can be adapted for use in domotics systems in industrial, services or medium and large-sized residential buildings.

6.1.2 Centralised or decentralised systems

Domotics systems can be subdivided into two groups according to whether the intelligence of the system is housed in centralised or decentralised systems.

In centralised systems only one component manages the intelligence and signals from the sensors are sent to the central component, which decides what actions have to be taken by a certain actuator. The major disadvantage of centralised systems is that if the master fails, the entire system does not work. The greatest advantage is the lower price.

In decentralised systems every component has intelligence. In this type of system the sensors put commands directly on the bus and actuators "listen" for the commands intended for them so that they can execute them independently (Kaiser, 2008d: 5). The major disadvantage of decentralised systems is the higher cost of expansion and the need for specific components. The major advantage in comparison to centralised systems is that when a component fails, in principle it will not affect the operations of the other components.

6.1.3 Integration

The main gap in existing domotics solutions lies in the integration of the systems and services provided. An integrated system is characterised by the existence of a single access point for all systems and for sharing resources in order to make better use of them and prevent duplication. The possibility of accessing a system via a single point offers other advantages for integration such as greater uniformity and an easier learning process for residents. The operations of the domotics system are therefore more secure and less susceptible to error, allow for more coordinated and quicker reactions and facilitate the execution of complex tasks. In terms of maintenance, integrated systems also offer greater advantages with regard to controlling devices and providing for more efficient maintenance and, consequently, lower costs. In addition, by making the best use of resources, integrated systems allow for solutions that have a better functionality/cost relationship.

However, there are also disadvantages to integrated systems, such as the possibility of inadequate use of the specific characteristics of certain systems/brands and certain legal obstacles (e.g. fire regulations).

The majority of present-day centralised domotics systems are composed of conventional mechanisms or automatisms (e.g. switches, push buttons, dimmers, movement detectors, telephone remote control modules, timers and twilight sensors). This type of automatism may be sufficient for some small isolated monitoring applications such as centralised control of the blinds in a dwelling. In this case, it is sufficient to install a controller with an auxiliary input for the central circuit in each motor and cable all the motors in the dwelling together then install a central controller that can be fitted either with a timer or simply a central switch to raise or lower the blinds. In this context, dwellings may contain certain independent automated applications that respond only to isolated control requirements. However, this solution makes it impossible to integrate systems and is unable to take advantage of the different devices and control systems in the dwelling, meaning that certain types of equipment will be duplicated (e.g. some presence detectors will be used for lighting and others to detect intruders) or others will be under-used.

An integrated system presupposes the use of a control system with a communication protocol that enables messages to be exchanged between a series of devices, functions and systems (e.g. heating, security and lighting). This system incorporates various functions, all connected by common transmission media and all sharing the same philosophy.

In terms of cabling, there is a great difference between a traditional and an integrated system, since in the latter functional associations can be established between actuators and sensors, which can be modified at any time and adapted to different situations.

In order to integrate any system, Renato Nunes (Nunes, s.d.: 3.28) states that the following requirements must be ensured: the physical interconnection of systems; a common language for communication between systems; the capacity for functions carried out by one system to envisage and take advantage of the functions carried out by others (interaction and cooperation).

One example of an integrated system is the KNX/EIB system, based on a decentralised topology in which the sensors and actuators communicate with each other. Using the KNX protocol, each component in the system is provided with a bus coupling unit (BCU). When any of the buttons are activated, a message is sent to the bus with a particular coding basically consisting of the data to be transmitted and the route for the recipient. This message will be received by all the actuators in the system, but only the one that has the correct route will execute the prescribed command. Therefore it is not necessary to install any central element as communication takes place between the sensors and the actuator. In its basic format the system can direct over 11,500 components and can be expanded to four times this number. Each of the components can make use of various channels, meaning that this is a very powerful modular system.

Given the lack of domotics solutions that allow for broad integration, various different solutions with a reasonable level of scalability and dependability, providing interoperability among heterogeneous home systems have been investigated in recent years. These systems use a protocol conversion manager whose task is to convert the different middleware protocols into the specific internal protocol used by the main gateway Miori *et al.* (2010). One example of this is the Pellegrino *et al.* (2006) Domotic House Gateway which is capable of seamlessly interacting with different devices from heterogeneous domotics systems and appliances.

6.1.4 Integrated home system components

In order to create a domotics system sensors, actuators, interfaces, controllers and consumers will be required, in addition to a means of communication that interlinks the various elements. These items of equipment must be able to communicate with each other by one or more means of communication.

The components required to operate the system, such as modems or routers which allow information to be sent between the various transmission media along which the message travels, are also part of the domotics system.

SENSORS

Sensors, which are the "eyes" of the system, gather information from the places where they are installed by monitoring. These devices detect the status, characteristics and quality of movement, temperature, power failures, water or gas leaks, fire, light, wind and damp, amongst other information. The data they gather may be in the form of direct commands for actuators or may first go to a control centre and, according to programming, issue a command for the corresponding actuator(s).

Sensors can, and should, serve as the "eyes" of more than one actuator to prevent redundancy. In order to accomplish this, the various systems and functions that have been installed must be integrated.

Various types of sensors can be used in housing, and the following are the most common:

- Thermostats _ units which measure temperature and compare it to a set temperature. The thermostat will open or close an output contact depending on whether the temperature is above or below the set value.

_ Temperature sensors _ theses devices measure room temperature and send the data to a central controller which decides how to act on the information. They may be used to regulate the air conditioning system, in kitchens, or connected to the fire detection system. The sensors should preferably be located near the ceiling;

_ Smoke detectors _ detect the presence of toxic fumes. These sensors are placed in circulation areas, in particular in the entrance hall. They should not be fitted in kitchens, especially near ovens and hotplates.

_ Gas detectors _ detect the presence of gases such as propane or natural gas and should be located near areas where leaks may occur. They are usually fitted in kitchens next to the oven and hotplates and next to the boiler or gas heater

_ Water leak detector _ detects the presence of water above a defined floor level. These sensors are placed near the floor in kitchens, bathrooms and other areas such as the laundry area, where flooding may occur.

_ Level sensors _ measure the level of a liquid in a tank. In a rainwater tank, for example, a level sensor can detect when the level is too low and pass this information on to the integrated home system (Kaiser, 2008b: 28).

_ Light sensors _ when fitted indoors these devices are generally used to control lighting. They allow for continuous regulation of lighting, compensating for any lack of natural light, in addition to raising/lowering blinds. They can be configured to regulate the desire lighting level.

_ Humidity detectors _ used to regulate the air conditioning system;

_ Motion detectors _ one of the current applications of these detectors is to detect breaches of the security system. Other uses are related to their interaction with the automatic command system for the lighting circuits in areas used infrequently, such as corridors.

_ Presence detectors _ detect the presence of people in rooms where there is little movement. The technique used is similar to a motion detector, but the detection sectors are more sensitive, so that somebody working at a desk can be detected. The system then knows that it must keep the lighting and heating on, if necessary (Kaiser, 2008b: 24).

_ Magnetic contacts _ these detectors are mainly used for doors and windows. When the magnet is not in the contact vicinity (i.e. the window is open) the contact is passed on to the integrated home system. When the window is open the heating can be switched off, or when a person leaves the home a signal can be sent to the occupier if a window or door is still open (Kaiser, 2008b: 26).

_ Wind sensors _ placed on the exterior of the dwelling to activate sun blinds and windows in the event of strong winds;

_ Rain sensors _ if these sensors detect any rainfall they can send a signal to automatically close the windows and retract the sunblind, for example.

_ Weather station _ this device, which is composed of one or more sensors, can measure physical properties such as wind speed, indoor and outdoor temperatures, light and rain. If programmed, it can automatically control lighting circuits, heating and watering systems and automated blinds according to the meteorological information gathered. As an example of one application, if rain is detected, the watering system is suspended.

These devices send alerts via the bus that activate various procedures such as the automatic closure of an electrically operated water valve, activation of an alarm, automatic transmission of a voice message to a predefined phone number, etc. All the sensors can transmit the information they have to actuators which execute the pre-programmed tasks.

Numerous types of detectors exist which can be mounted externally on ceilings or walls, or inside walls in casing.

ACTUATORS

Actuators are the components within the integrated home system that receive data signals and take action on this basis to control one or more connected consumers (Kaiser, 2008d: 18). Actuators, also called output components, are the "hands" of the system and consist of mechanisms which either switch off automated procedures activated by other mechanisms, thus regulating and/or making the necessary changes to provide the best conditions for the system to function under, or only followed predefined procedures for particular situations.

Actuators include relay modules, remote controlled switches, motor modules, dimmers and other output interfaces.

Actuators are usually divided into three main groups: lighting, blinds/shades and heating. (KNXportugal, s.d.) In terms of lighting, regulators allow for variations in intensity and actuators control motorised blinds, shades and sunshades. Electrically operated valves may be used to control heating systems or may be associated with specific sensors (for smoke, gas or water), acting as safety mechanisms which interrupt the supply of water or gas in the event of a leak. (KNXportugal, s.d.)

CONTROLLERS AND INTERFACES

Interfaces or controllers supply and receive information from the user. The function of the interface between the human being and machine is to supply the user with information in a format that is comprehensible to them and to send information to the machine in its own language. If the interaction is efficient, it allows for dialogue between the two with maximum understanding and minimum effort.

The interface constitutes the face of the machine the user is operating. It should be user-friendly and intuitive and should not require any specific training in order to manipulate its main functions. There should be as little need as possible for intervention in the equipment but when this is necessary it should be carried out using very simple mechanisms. In fact, this interface must take into account the fact that ordinary residents are not professional technological operatives and therefore do not have any knowledge of computer configuration.

Domotics applications always include an interface that enables residents to alter the comfort and safety parameters, amongst other functions. This interface may be fixed (a touch screen on a wall, fixed computer, on/off/slider switch, keyboard, telephone or computer), or mobile (a remote control, PDA, mobile phone or laptop) and a combination of various different types may be used (Figure 38 to Figure 43). These interfaces issue commands via a cabled or wireless transmission system.

It is possible to manage and control all the domotics applications from inside the home, or from outside, using GSM or Internet communications. In particular systems it is possible to access visualisation programs that enable the installation to be monitored and controlled via a computer located inside or outside the home.





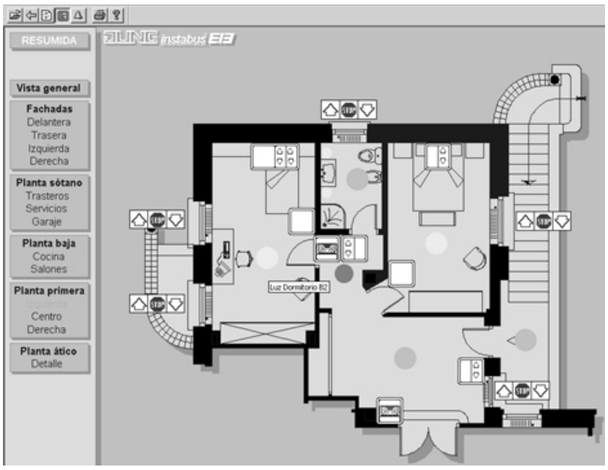



Figure 38 – Operating panels (source: http://hiddenwires.co.uk/)

Figure 39 – Remote control with large buttons for the visually impaired (source: http://vidaportatil.com.br/)

Figure 40 – PDA for domotic control (source: http://domoenergia.no. sapo.pt/KNX_EIB.htm)

Figure 41 – Telephone with large buttons for individuals with motor and visual difficulties. (Source: http://www.l ojaviva.com.pt/)

Figure 42 – Touch screen (source: www.jungiberica.es/)

Figure 43 – Domotic control software used on a computer. (source: http://domoenergia.no.sapo.pt/KNX_EIB.htm)

If one or more items of equipment are set to interact with the system management it is convenient to use software that is the same or very similar in order to facilitate the learning process for residents and avoid creating difficulties in interacting with the interfaces.

The various types of interface mechanisms include the following (Kaiser, 2008d: 20):

- Switches and push buttons _ panels with one or more on/off/slider switches or push buttons to activate the domotics functions in the home (lighting, blinds, air conditioning);
- Alarm wristband or medallion _ band worn on the wrist or medallion hung around the neck with a push button designed to activate a personal alarm. These systems are generally used by elderly people or individuals with restricted mobility or other conditions that make them dependent on the help of others.
- Operating panels _ operating elements that have one or more push buttons. Operating panels vary with regard to construction and design, according to different manufacturers. Generally they are aesthetic and functional panels with a varying number of push buttons (Figure 38);
- Touch screen _ this equipment can be installed on or in the walls of the home in strategic positions. By touching the icons or text on the screen, residents can navigate a menu structure and all operations can be executed via the integrated home system (Figure 42);
- Touch window _ similar to the touch screen but without an active screen, as the screen shows a printout on a film. It is also operated by touch;
- RF transmitters _ hand-held (battery operated) or wall transmitters (supplied by the 230V network or voltage-free, operated by a piezoelectric element) that convey radio frequency signals to RF receivers;

- Infrared remote controls _ multifunctional hand-held transmitters which can operate not only the lighting, but also the television, audio system, roll-down shutters, etc (Figure 39).
- Telephone (fixed and mobile) _ domotics home systems can be operated by telephone. Voice or text messages can be sent to activate domotics operations;
- PDA _ can operate domotics home systems using wireless communication (Figure 40);
- Computer _ using a direct link between the home system and the computer or via an internet connection (with the help of a graphic user interface[22], Figure 43);
- Card readers and proximity readers _ used to control access to the home;
- Code panels _ used to control access to the home;
- Biometric detectors _ although not widely used in homes, fingerprint and iris scanners are also sensors that can be used in an integrated home system when extra protection is required for the building.
- Modem _ provides access to the installation via a telephone line. A simple push button or visualisation software allows for remote control of electrical circuits. (KNXportugal, s.d.).
- Gateway Internet _ enables the system to be accessed via a PC, PDA or even a mobile phone Internet connection. Some gateways provide links to video cameras, allowing images to be collected in real time from the installation (KNXportugal, s.d.).

CONSUMERS

Items of equipment that can be operated by a domotics system are called consumers. This equipment is the same as the equipment used in traditional electrical installations. Consumers are connected to an integrated home system via actuators. Examples of consumers include: lights and light fittings; motors (used for garage doors, gates, roll-down shutters, awnings, curtains, etc.); ventilators; electrical or central heating and air conditioning equipment; electrical domestic appliances (such as washing machines, dishwashers, driers, coffee makers, etc.); power points; electrical valves; door locks; audio and video equipment; telephones.

TRANSMISSION MEDIA

Communication between sensors, actuators and equipment can only take place if transmission media exist. These may be grouped into two main categories: physical (metal and optical fibre) transmission media and wireless transmission media.

Metal conductors are the simplest example and the most widely used physical communication media for the transmission of electrical signals. Despite the many advances and innovations in wireless transmission systems, physical cabling still offers a number of advantages that makes it the most widely-used system in domotics. In fact, data transmission by cable remains more reliable, more secure and cheaper than wireless transmission.

Laying cable infrastructures represents a small part of the total amount invested in the construction/rehabilitation of a building[23] and means that the best use can be made of both cable and wireless technologies.

Physical transmission media are one of the components of a communications system. They may be grouped into two main categories: metallic transmission media and optical fibre transmission media.

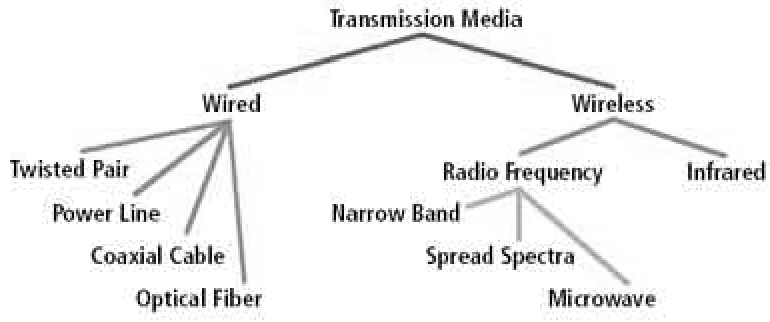


Figure 44 – Transmission media. (source: http://www.tiresias.org/cost219ter/inclusive_future/inclusive_future_ch3.htm)

Nowadays the most simple and commonly used communication medium is metallic conductors. These have been adapted to meet the growing needs of communications systems, responding to the emergence of new wireless and optical fibre communication technologies with continually increasing capacity.

Optical fibre networks have begun to replace metallic cables in telecommunications infrastructures with the aim of increasing capacity and reliability.

From amongst the transmission media, optical fibre offers the greatest reliability and capacity to transmit data, despite the high cost of installation. Optical fibre has become increasingly accepted in the field of communications, above all in the service sector, which has led to a relative reduction in installation costs. In domestic terms, cost still remains its greatest disadvantage, although there are many examples of the use of optical fibre. However, twisted pair and coaxial cable are the most widely-used media of this kind.

The twisted pair (TP) is used, for example, in most copper cabling in telephone systems. This type of transmission media is also used for small-scale home automation applications when there is an average requirement for data quality and high speed transmission. The advantages of this physical communication medium are its low cost, easy installation (it is flexible, light and easily connected) and much higher guarantee of protection against interference in comparison with simple cabling. The disadvantages are low speed transmission, the fact that it is liable to produce noise, and its great sensitivity to electromagnetic interference, meaning that this medium cannot be coupled to electricity lines.

Coax is a transmission medium widely used in domotics installations. The cable, which is normally used for cable TV connections, is particularly suitable for audio and video signals, networks with high transmission capacity allied to speed and quality, and LAN networks. The cables can carry much higher frequency electrical signals than simple metallic cables, which gives them a much greater transmission capacity than the twisted pair. Another advantage is that they are not susceptible to interference and are cheaper than optical fibre.

The power line (PL) is only used in home automation applications when there is a low requirement for data quality and high speed transmission. The electricity network is the transmission line used in X10, HomePlug, PCLbus and Universal powerline bus (or UPB) technology. The main disadvantages of this transmission medium are, on the one hand, the fact that it is liable to produce noise and is very sensitive to interference and, on the other hand, its low speed transmission.

Optical fibre is used essentially in office buildings where the preference is for high speed, quality data transmission. There are many advantages to this transmission medium, namely high transmission speed, lack of sensitivity to electromagnetic interference (it can share ducts with other cables) and damp, reliable transmission which is not interrupted as the fibres do not lose power, the small diameter of the cabling, despite its capacity to transport a large number of signals, its ability to cover great distances without the need for repeaters, compatibility with digital technology, easy installation (although more difficult than the twisted pair), and the fact that it is the only medium that can transmit voice, data and video simultaneously. Yet although there are many advantages to this transmission medium, optical fibre also has various disadvantages, beginning with its very high cost. Other disadvantages should also be emphasised, such as the fragility of the fibres, the need for converters (most equipment functions via electrical connections rather than light signals and it is therefore necessary to purchase expensive converters for each optical cable termination), the difficulty in obtaining good connections between cables and the difficulty in repairing cables.

Mobile networks offer users the full or partial option of mobility since they use electromagnetic waves which multiply in space rather than physical communication media.

In domotics systems, radio frequency (RF) and infrared (IR) networks are used. Bluetooth and Wi-Fi technologies are used widely in RF networks. Bluetooth technology is associated with WPANs (wireless personal area networks) and therefore has low coverage. Wi-Fi (Wireless Fidelity) networks are WLANs (wireless local area networks) with greater coverage than those using Bluetooth.

As it requires an unrestricted line of vision in order to function, infrared transmission technology is used mainly in small or indoor environments and is commonly found in domestic remote control devices.

The advantage of RF communication is that it can operate over greater distances than infrared and the signals can also pass through obstacles and walls.

As converters RF signals are obstructed by metal, distances will be shorter in buildings with reinforced concrete than in brick or wood-framed buildings. The receivers also have to be installed in a non-metal box, or have an external antenna. (Kaiser, 2008d: 14) In this study, as one of the techniques used for the structural reinforcement of the buildings consists of installing distended steel mesh in walls, this problem has a major impact and will be analysed in *Part 2: Chapter 3.2.2*.

ITED AND NATIONAL LEGISLATION

The current regulations for the installation of telecommunications infrastructures in buildings and their connection to public telecommunications networks take the form of the ITED (*Infra-estruturas de Telecomunicações em Edifícios* - Telecommunications Infrastructures in Buildings). This legislation emerged out of Decree-Law no. 59/2000 of 19 April and applies to all buildings constructed since 1 January 2005. The regulations specify the (minimum and recommended) areas, pipe networks, cable networks, equipment, materials and cabling quality standards for buildings.

The aim of the ITED is to ensure simple and efficient access to current and future telecommunications services by creating new regulations for the planning, installation and management of telecommunications infrastructures in buildings. The intention of the ITED is to ensure access to fixed current and future (telephone and data) telecommunications services provided by public networks via cable or radio, sound or television broadcasting, distribution by cable or hertz waves and private video and telesurveillance systems for buildings. In this way, any building is connected to all the public telecommunications networks it wishes to access, which makes it easier for new operators to access the residences of final consumers, thus increasing market competition and extending liberalisation (ANACOM, 2004).

The ITED also covers the computer network for housing. The physical transmission media envisaged by the ITED are the twisted pair, coaxial cable and optical fibre.

National regulations for new or rehabilitated buildings do not include installation requirements for any home automation devices. The existing regulations and legislation only cover the requirements for access to telecommunications networks and the installation of electrical networks.

TOPOLOGY

The search for flexible and efficient solutions for communications inside buildings has given rise to structured cabling systems. These systems provide buildings with a very flexible and efficient cabling infrastructure which can be used to support one or more communication networks covering a wide range of applications involving voice, data or images. (Nunes, s.d.)

The structured cabling system includes:

- For each dwelling, multiple cables which connect the various plugs in the areas where domotics equipment is installed to the communications cabinet in the dwelling. Each zone of around $10m^2$ is served by 2 to 3 cables, normally under a raised floor or in a false ceiling. Additional cables are also installed in the false ceiling to link sensors and control units, alarms, speakers, etc.;
- In addition, if there are domotics applications in the building that can be integrated into the functions within individual dwelling:
    - On each floor the communications cabinets for the dwellings are connected to the communications cabinet for the floor;
    - The communications cabinets for each floor are connected to the central communications cabinet (Nunes, s.d.).

Moreover, as previously mentioned, the electrical and communication connections may be installed using different transmission media and may support various types of networks.

As Renato Nunes states (Nunes, s.d.), the use of structured cabling must take particular concerns during the design phase into consideration, such as:

- Suitable, correctly located areas for the installation of communications cabinets;
- The means of laying cables (horizontally) to reach the required areas, ensuring adequate distribution for the requirements envisaged (it is always worth considering the possibility of laying additional cables later);
- Adequate space for laying cables vertically.

The physical configuration which defines the geometry of the computer network and the way in which the individual items of equipment are arranged in relation to each other and/or a central computer is called the network topology. The producer generally stipulates one of the following Bus, Star or (hierarchical) Tree topologies, which are the ones generally used in domotics:

i) **BUS** topology uses a common transmission medium to which multiple devices are linked. This requires a protocol to define the use of the transmission medium for all the devices in the network. As there is one single transmission medium, each device must be clearly identified. This is accomplished by allocating unique addresses to each element in the network. As all the devices are linked to the network, the information transmitted to one device is detected by all the others but only the one it is destined for receives it from the network. Although this technology places restrictions on the number of devices and the distance between them, it provides great reliability for high loads. The failure of one node in the network does not affect its performance in general unless the bus fails completely. Rosseti and Tosi (1991: 139) call this topology "distributed intelligence", characterising it as flexible and easy to extend. Its greatest disadvantage is the dependence of all modules on the sturdiness of the cabling. In fact, a break in the cable will cause a substantial part of the installation to fail. The advantages are related to the smaller amount of cables and connections required (Kaiser, 2008d: 9).

ii) **Star** topology simply consists of a central hub to which all the devices in the network are linked via point-to-point or multipoint connections. There is no limit to the number of devices that may be added to the star network, or to the size of the physical transmission medium, which makes it easy to expand the network. Unlike bus topology, the access protocol for the network is relatively simple, since the central hub directs and manages all the network traffic. The main disadvantages of this topology are the large amount of cables and connections to the central controller that it requires. The major advantages are related to the guarantee of continuity for the installation if a certain cable is broken (that module will not work but the others will). Rosseti and Tosi (1991: 139) call this topology "centralised intelligence". In this case, the higher control level is represented by the central computer which manages and controls the system via data sent to it directly by the sensors.

iii) **Tree** topology is structured on different levels and combines the characteristics of star and bus topologies. The only restriction is that closed loops cannot be created. Unlike star topology, the higher level is not the only one which directs and manages the flow of information in the network. Information transmitted by a device on a lower level need only travel back enough to cross the network segment in order to reach its destination, and may not need to pass through the root node. This access protocol means that if the network fails in a section of a star, the network itself will continue to function, whereas if there is a failure in the bus cabling, transmission will be interrupted. The advantages of this topology are related to its flexible installation and the possibility of creating branches anywhere.

6.2 DOMOTICS SYSTEMS AND FUNCTIONS

The various domotics systems (or services) are divided in very diverse ways by different authors. Regardless of how their functions are separated and grouped, most authors define at least three major groups: security/safety, energy management and communications.

The categories of domotics systems shown in Table 11 are used throughout this study. These systems contain a wide variety of functions, which may be interrelated and share information across different systems. This means that it is difficult to establish limits for each function, due to the fact that they are normally incorporated into various systems, as described in the chapters which follow.

System	Subsystem	Function
Security/Safety	Security	Detection of intruders
		Control of access
	Safety	Detection of fire and flooding
		Detection of gas leaks
		Detection of flooding
		Detection of power failures
		Medical emergencies / Personal support
Energy management	Control and distribution of energy	
	Management of renewable energy sources	
	Management of electrical domestic appliances	
	Management of air conditioning/ventilation	
	Management of lighting	
Comfort	Control of air conditioning	
	Control of ventilation	
	Control of lighting	
	Control of motors (blinds and curtains)	
	Control of motors (doors and windows)	
	Control of watering	
	Control of electrical domestic appliances	
Communications and Information	Communications between the system and the exterior	
	Local networks and Internet	
	Telecare	
	e-health	
Leisure & Entertainment	Control of audio distribution	
	Control of video distribution	
Home management		Management and administration of system
		Diagnosis of faults
		Monitoring of consumption
		Preventive maintenance

Table 11 – Domotics systems and functions.

6.2.1 Safety & security

Safety and security is, according to most authors, the priority function for those who acquire a domotics system. A safety and security system must be reliable in order to ensure that it can function under any conditions without setting off false alarms and must it be appropriate for the property it is protecting.

Safety and security cover two separate areas: safety, associated with safeguarding property and preventing accidents, and security, which concerns systems to protect against intruders and control access.

Security may include functions such as the following: control of access, detection of intruders, definition of procedures to be executed in the event of intrusion; control of alarms (sirens, flashing lights, etc.); visualisation and remote registration of presence.

The following functions may be included under safety: detection of fire, gas leaks and flooding; detection of power failures; SOS / Panic function; activation of signals and warnings; medical emergencies.

6.2.2 Comfort

Environmental comfort is a subjective condition to the extent that it assumes different characteristics from one person to another, given that optimum levels for temperature, humidity, ventilation, lighting or sunlight vary according to users. Other factors such as psychological and cultural aspects also influence environmental comfort.

To ensure comfort it is essential that individuals know how to operate the system and can decide independently how to make the best of a "made-to-measure" environment. The regulation of comfort levels should therefore be designed to allow for great diversity and personalisation.

Thermal and air conditioning control ensures the comfort of occupants by making the most rational use of the energy provided. This system enables temperatures to be controlled and heating and cooling equipment to be managed. Temperature may be regulated by the user or automatically by the system on the basis of readings taken throughout the dwelling by temperature sensors or thermostats.

Lighting is a very important factor in defining environmental comfort. The aim of the lighting system is to control and manage lighting within the dwelling and its operations are based on data gathered from the environment and stored in the memory of the control-programming unit. The data for the environment comes from presence sensors (which detect the presence of someone inside a room and consequently enable the lights to be switched on or off) and light intensity sensors (which detect the intensity of light in a room, with the controller adjusting the level of lighting in accordance with the established parameters). These sensors may be used near windows, in order to assess the need for artificial lighting. Other relevant data for efficient lighting include the contents of the control unit memory, such as hourly and/or daily schedules, individualisation of areas and power circuits, the spatial distribution of lights, any other type of activity carried out and the consequent lighting requirements, the power to be used and the power available.

Functions to control and regulate curtains, awnings and blinds can also be added to this group. Control can be regulated by factors as diverse as the daily/weekly cycle, intrusion, maximum lighting, constant lighting, general controls (local and remote) and presence simulators.

A domotics system also allows for the possibility of programming and controlling automatic watering, for which the system offers the following functions: timing of watering, activation of remote watering, and activation of watering on the basis of readings from sensors which detect soil humidity and assess the actual need to activate the system.

Certain scenarios that incorporate various systems with a specific objective can also be defined, such as the possibility of disconnecting all the electrical equipment associated with the system (lights, automatic watering, sound system, electric motors, etc.) by a simple touch of a button or by mobile phone / Internet, to allow for safe secure exit of the home.

In addition, at the entrance, controlling access by identifying individuals entering the home (e.g. using fingerprint identification) can activate predefined and programmed profiles that will initiate automatic sequences, such as switching off an alarm, opening a door, selecting a lighting scenario, activating the sound system from a predefined playlist, selecting a scenario for blinds, and switching the plasma screen on to a predefined channel.

LIGHTING

The most common lighting control functions are control of on/off lighting switches from one or more points using a centralised command, remote control of activation and regulation, automatic switching on of lights when movement is detected in corridors, vestibules, stairs and passageways, control of environment scenarios and automatic control using twilight and light sensors.

Functions associated with lighting may also include various actions such as management of various zones and control of different levels of intensity, control of blinds and shade mechanisms, timing and scheduling (and additional manual methods), activation controlled by the alarm system, energy management to provide significant savings, memorisation and repetition of daily routines and remote connection via mobile phone / Internet;

AIR CONDITIONING

Control of air conditioning acts on the heating and cooling systems and is extremely important, given that heating and air conditioning are the main consumers of energy in a building as well as being those most responsible for comfort. Some of the most common air conditioning control functions are temperature, humidity and air quality control, either locally or remotely via a mobile phone, the creation of customised scenarios, adjustments to air conditioning according to outdoor conditions and season, the creation of schedules, and actions in emergency situations (e.g. switching off heating in the event of fire).

Controlling the opening of windows, shutters and awnings is another function that contributes towards both natural ventilation and lighting inside the dwelling and, consequently, to adjustments to indoor thermal conditions.

BLINDS AND AWNINGS

Controlling blinds and awnings in residential buildings is becoming increasingly common. To accomplish this, these components have to be fitted with motors. Controlling awnings enables the natural lighting in rooms to be controlled and prevents the awning from being destroyed in the event of strong wind. In addition to these possibilities, the system contributes towards more efficient use of the energy needed to obtain a suitable level of comfort within buildings, by controlling sunlight.

The most common blind and awning control functions are centralised control of blinds from one or more points, remote control, inclusion in environmental scenarios, automatic control by twilight, light and wind sensors and/or scheduler, and remote control.

The possibilities for darkening or altering the transparency of door or window openings also include smart glass. This type of glazing cannot be controlled manually. Instead, all smart windows with electrical switches can be made to automatically adapt their light transmission properties in response to temperature or brightness by working together with a thermometer or photo sensor, respectively. In addition to smart glass there are other possibilities, such as the use of self-cleaning glass and the automatic opening or closing of windows for ventilation purposes, according to a timer or in response to a rain sensor, for example.

HEALTH

The growing concern with physical condition, hygiene and health has led to the appearance of new services and products on the market. In fact, countless services such as gyms, dental and beauty clinics have emerged, in addition to domestic equipment such as gymnastics equipment, dental kits, devices for measuring blood pressure and intelligent toilets, amongst others.

The appearance of ICT-based home services, known as e-health services, will prove very useful for those with permanent health problems, the elderly and the disabled, as well as ordinary residents, as a form of preventive medicine. Telehealth provides remote healthcare services through the use of ICT and the possibility of a home support service provided by a medical team. This system is directed towards the use of duly monitored networked systems that act as an intermediary between the individual being medically supervised and the group of people who ensure their everyday safety and comfort (social and medical staff, the family doctor, emergency services, family, friends, etc.). The areas in question include detection of falls, illness, voice calls, weight loss, symptoms of respiratory problems, or even monitoring the taking of medicines. To enable these systems to function, residents must be supplied with various sensors that send information to the support service. By means of a simple impulse from a medallion worn around the neck, an elderly person can connect directly to a listening station that will ensure the call is processed and will call for appropriate assistance, if necessary. In the near future, we may see sensors installed in certain places in the home and/or on clothing which monitor aspects associated with our physical well-being, namely cardiac rhythm and blood sugar levels.

Telemedicine services, which may range from remote medical diagnosis based on a description of symptoms to the transmission of X rays or photographic images, already exist in some health centres and hospitals in the country, although they have not yet been implemented in housing in Portugal. In other countries such as Japan these services are already operational. In these cases the hospital equipment consists of a PC and monitor to capture patient information and a videophone which allows the patient and doctor to have face-to-face meetings during which the doctor can carry out a consultation. The equipment in each patient’s home consists of a videophone and a vital signs monitor which takes physiological measurements of the patient and records these in the patient’s diary.

6.2.3 Energy management

The subsystems that interact with the various energy management functions are: distribution and control of electricity; control of equipment and electrical domestic appliances; control of sources of energy; control and regulation of lighting and temperature; control of air conditioning.

A home automation system must be able to efficiently manage the power supply to the dwelling in a way that is compatible with the terms of the contract agreed with the electricity supplier. In fact, the system must manage the use of electrical energy, equipment and power supplies whilst preventing them from using too much power (for example in the case of washing machines and dishwashers, electric heating or electric ovens) during “peak hours” and switching them on, if possible, during the economy hours or distributing their operations to optimise consumption in accordance with the functional needs of each occupant and the dwelling itself.

Management of the use of electrical domestic appliances allows for various forms of interaction between the new generations of electrical domestic appliances with devices that allow their functions to be managed, in particular from outside the home via telephone, Internet or remote control, by making use of their high programming capacity, which may be temporal (defining when they should function) and functional (how they should function). "Intelligent" electrical domestic appliances can reduce maintenance costs, as they can recognise their own anomalies using a process of self-diagnosis that reduces maintenance time (the technician will know which part of the machine to examine).

The use of a day/night electricity tariff, combined with using washing machines and dishwashers during the economy period by programming the machine timer or using controlled sockets are common energy saving strategies.

Control of lighting must comply with energy management principles that may be related to the functions previously described, such as the use of movement sensors to switch on lights when it has been detected that a room is occupied.

In terms of controlling air conditioning equipment, energy management is a priority. This function enhances the possibility of using other sources of energy, in particular renewable sources such as solar power. The domotics system may also be able to manage a multiple energy system, automatically switching from one source to another (fuel, solar, wind, etc.) according to environmental conditions, optimising the operations and performance of each and ensuring continuity.

The energy management system may also include the following functions: monitoring consumption, gathering statistics and controlling use during peak hours.

The potential of domotics systems to promote energy efficiency in buildings and dwellings is discussed in further detail in *Part 1 – Chapter 6.3.1*.

6.2.4 Communication and information

The communication system is the base of the entire home automation system and it is due to its evolution that different types of equipment are able to interact. An automated dwelling must firstly be a communications centre in which the act of sending and receiving information to exterior is a priority. In this context, it should be possible to send alarm messages, receive remote instructions, and carry out videoconferencing, tele-maintenance, remote control via mobile phone or Internet and intercommunication, all within the home.

An automated home can be managed from the exterior by ICTs, namely via the Internet. It is through these technologies that we receive, for example, SMSs, technical, personal and intruder alarms and are able, for example, to programme the air conditioning to switch on one hour before we arrive home.

The tele-alarm is a typical, but not the only, example of the services ICATs can provide for more vulnerable groups such as elderly people and/or those living alone, in terms of safeguarding their autonomy, quality of life and security and preventing isolation, through non-intrusive, automatic and intelligent assistance that can correctly interpret each situation in order to ensure the most appropriate decisions are taken.

With regard to communications and access to information, it is considered essential to provide dwellings with the following equipment and functions: broadband access to the Internet, access to cable or optical fibre television, a telephone network and the Ethernet[24] in all habitable rooms; a domotics system which uses Bus as its main means of communication; a connection to the video caretaker system; transmission of SMS messages or telephone calls when intruder, fire, gas or water leak, power failure and personal alarms are activated; the possibility of receiving remote instructions.

6.2.5 Leisure & Entertainment

The widest applications of this system are found in video and audio systems, which nowadays use a very high level of technology. The combined aspects of sound and image may be distributed to rooms within a dwelling to provide greater comfort.

An entertainment system may include the following options:

- The installation of a centralised sound system with the highest hi-fi standards. The interaction of this system with other systems or domotics functions; control of the system via remote and fixed controls distributed around the home; the possibility of using interior and exterior speakers in various places in the home.
- The installation of home cinema and the linking of home cinema functions with other domotics functions;
- The use of games consoles;
- The use of computers for entertainment (including music, Internet and games)

6.2.6 Assistive technologies

It is recognised that the elderly population in Europe has increased and there is now a growing awareness of the need to intervene and invest in improving living conditions for this social group. This has helped draw attention to the need to provide housing and other buildings with universal features. With regard to the use of domotics to support individuals with special needs, various methods have been studied and solutions implemented in different countries, as discussed in *Chapter 6.3.2*.

The installation of digital controls and communications systems represents a step towards the changes that have to be made to the domestic environment. The proposal to provide housing with assistive technologies will enable individuals to receive help in carrying out daily tasks, supplemented by personal health care.

In addition, ICT provides those with restricted mobility (whether for physical, geographical or economic reasons) with the possibility of access to service centres services without the need to leave the home. In this context, we have seen a considerable improvement in communications options and access to information through countless products and systems adapted for the disabled to enable them to communicate from a distance.

Home automation offers the prospect of significant improvements in quality of life for the elderly and the disabled who are dependent on home care.

However, the benefits of home automation for these social groups will only be realised when the market for intelligent equipment has expanded enough to allow for a wide variety of products at accessible prices.

6.3 ICAT IN REHABILITATION AS A SUSTAINABILITY STRATEGY

This chapter analyses the potential performance of ICAT as technologies that promote both environmental and social sustainability.

On the one hand it is acknowledged that the environmental impact created by humans is increasing, resulting in resources running out, a scarcity of energy, excessive emissions and the creation of waste, amongst other factors. It is therefore imperative that new solutions are found that have a lower impact on the environment.

The construction sector is one of the human activities most responsible for consuming resources and energy and for generating waste[25]. The construction process has a huge negative impact on the environment, since it consumes and wastes resources. On the one hand, building work leads to the release of pollutants and, in addition, it creates waste which, in order to be processed, also consumes resources. This cycle of consumption continues whilst a building is in use and becomes worse towards the end of its life, affecting dwellings, buildings and entire cities.

According to Valério (2007), in buildings designed for residential use, the largest amount of energy is consumed in air conditioning (heating and cooling) and domestic hot water, representing approximately 60% of total housing consumption. According to the same author, the remaining 40% is divided between lighting (5%), preparing meals (6%), conserving food (fridges - 13%), and other electrical domestic appliances (16%).

The use of intelligent equipment to manage energy consumption throughout the life cycle of the home is extremely important in terms of achieving the energy efficiency expected nowadays.

Within the context of rehabilitation, ICAT emerges as a complement to the passive solutions that can be implemented. From the point of view of thermal and acoustic comfort, redefining the outer shell is a priority (including better levels of thermal insulation and low emission double glazing), whilst intelligent energy management and air conditioning systems play a complementary role.

In social terms, ICAT represents autonomy for the elderly and the disabled and/or those with restricted mobility and promotes social inclusion by bringing those who are physically separated closer together.

This chapter refers to various examples of domotics functions which can only be understood with previous knowledge of the complexity of domotics systems.

6.3.1 Ecological and economic sustainability

> *"Information technology promises to expand communications horizons" and, "at the same time, ecological responsibility imposes new limits on individualism. How can architecture do justice to these two trends? How can architecture advance in the information age without failing to take into account the fact it is an age in which we also want to achieve long-lasting architecture through sustainability?" (Daniels, 2000: 76)*

Economic and ecological sustainability is seen nowadays as adding economic value to buildings and is associated with social and environmental awareness. On this level, ICAT allows for optimisation of this economic and environmental dualism.

In fact, the use of ICAT, both in the design/construction and the use/ maintenance phase of buildings (in this case, residential buildings), can contribute towards reducing the environmental impact of buildings. Domotics allows for efficient management of the natural resources required for the safe and comfortable use of buildings, preventing unjustifiable waste (Alves and Mota, 2003: 113).

Home automation can protect the environment to the extent that it manages routines for optimising procedures that provide for a more rational use of natural resources (such as energy and water) and a more rational arrangement of living space.

According to Cantos and Vidal (2002), projects designed to incorporate only bioclimatic issues prove inadequate and incomplete, since the results depend only on the residents' actions and there are no *"measurable or quantifiable results and it is not possible to obtain a good analysis of the improvements"*. On the other hand, an architecture project that aims to achieve environmental sustainability solely through domotic processes is also inadequate since consumption is optimised in terms of comfort and energy performance but it does not prevent energy waste caused by defects in the design of the building (Cantos and Vidal, 2002). A project that contains both aspects allows for two-way communication between the bioclimatic concerns incorporated into the architecture and the automated features of domotics. In this cooperative context, bioclimatic performance is optimum and the results are quantifiable and more objective, resulting in greater sustainability.

Figures 45 (left and right) – Use of motors to open and close windows to ensure ventilation. Opening and closing actions are activated by readings of wind and humidity sensors, amongst other factors. Millennium House, an Integer project, Watford (photo: SE 2004)

One example of actions that combine automated features and bioclimatic principles is the control of blinds/awnings and windows throughout the year during the daytime. This domotic function provides automatic control of blinds/awnings to allow sunlight to enter during the daytime in winter and for them to be closed at night or, in summertime, to allow shade during the day and the opening of windows at night for ventilation (Figures 45). This can be achieved by an analysis of weather conditions using light or other types of sensors, or predefined hourly or seasonal scheduling. The systems enable both the interior environment and temperature to be controlled and the state and intensity of lighting, therefore leading to energy savings in lighting and air conditioning.

However, it is important to stress that in addition to this system, the more common domotics applications that support energy performance in buildings are energy management, control of lighting (artificial and natural light), management of air conditioning systems, management of ventilation routines, changes in the surface temperature of the building by opening and closing windows, remote access and management of consumption.

In terms of energy criteria, lighting cannot be adequately controlled by the use of conventional installations. The introduction of elements such as ballast in fluorescent lights has allowed for greater energy efficiency in artificial lighting, but the best results are only achieved by using additional control solutions. Artificial lighting can be controlled by activation on detection of occupation of particular areas, pre-programmed timers or light sensors. Any of these control systems will not only switch lighting on/off but can also increase or reduce its intensity and allow for energy savings.

Air conditioning, together with lighting, is responsible for 80% of energy consumption in buildings (Domo@energia, 2007). With regard to the management of air conditioning systems, optimum control of best temperatures, setting functions according to schedules and the presence of individuals in a particular area and adequate central control can provide a high level of comfort and energy saving. The use of thermostats activated by temperature, humidity and light sensors is another mechanism that reduces energy consumption. Specifying acceptable maximum and minimum temperatures and raising the levels only slightly also allows for better management of energy consumption and this may be directed by a domotics system. The use of systems that allow for remote control, together with hourly programming of applications in the dwelling, can minimise consumption, distribute the load and take advantage of lower tariffs.

In addition to automated control, it is important to ensure that thermal comfort and lighting options can be customised.

The adoption of passive strategies to provide comfort in dwellings, which is always a priority, does not always succeed in fully meeting the hygrotheric and lighting requirements of dwellings that are to be rehabilitated since these measures were often not planned or could not be optimised at the time of building. It is therefore necessary to use additional low consumption and maximum efficiency active heating and cooling systems that should be managed by domotics systems (Figures 47).

Figure 46 – Use of photovoltaic solar panels to heat domestic water and generate electricity (to supplement energy from the concessionary). Millennium House, Integer project, Watford (photo: SE 2004)

Figures 47 (middle and right) – Use of heat pump to extract cold water for heating from 50m below ground, where it warmer (by around 2ºC). Heating is delivered by under-floor trench heaters through which water is pumped at 50ºC. The temperature is controlled by a domotics system whose interface is located on the walls of rooms and by remote control. Millennium House, Integer project, Watford (photo: SE 2004)

Another present-day concern relates to the generation of energy to heat the environment and domestic water supply and to operate equipment. Systems which heat domestic water and/or generate electricity using renewable energies are usually powered by solar generators (photovoltaic and solar panels) or wind generators and vary according to installation conditions, climatic features and energy needs (Figure 46). Collective awareness of the need to reduce and rationalise energy consumption has led to an increase in the autonomy of alternative electricity generation systems. In addition, the implementation of efficient intelligent systems for the use of non-renewable energies can minimise the impact of consumption by measures such as using day/night tariffs, scaling operations and integrated systems to reduce and control energy consumption

In terms of energy, sustainable management of the dwelling/building aims to rationalise consumption and therefore may also use meters, more economical task management and control of peak consumption by prioritising. Examples include a controller to manage the schedules for equipment (such as washing machines, dishwashers, swimming pool pumps, etc.), in order to take advantage of lower tariffs (night-time schedules) and prevent different appliances from operating at the same time.

The current worldwide scarcity of water is an urgent problem and technology can also play an important role in the efficient management of water resources within the domestic environment. According to Edwards and Hyett (2001: 44), technology provides certain measures to conserve water resources that can be applied to buildings, which include automatic taps with flow limiters, thermostatic taps, low-volume flushes, composting or suction toilets /waterless urinals or urinals with flushes activated by sensors, the replacement of baths with showers, low water consumption electrical domestic appliances, regulated watering, controlled consumption and leak detection (Figure 48 and Figure 49). Some of these systems can be controlled by domotics systems, which can also ensure that they are integrated and operate under a common logic. The operations of a rainwater treatment centre can be managed by a domotics system which links functions and maintenance to the actual need for water at a given time. In terms of management of consumption, losses can be detected and the water consumed in watering reduced according to weather conditions.

Figure 48 (left) – A bathwater temperature and level control allows water to be saved. Millennium House, Integer project, Watford (photo: SE 2004)

Figure 49 (right) – Using humidity sensors to control watering by calculating the actual need for irrigation allows water to be saved. Millennium House, Integer project, Watford (photo: SE 2004)

Solutions which save energy and water not only benefit from these functions but also, if integrated into other domotics systems in the dwelling, can increase comfort and safety in the home.

It is by automating tasks at the level of the building – building automation – and, in the case of this thesis, residential buildings, that greater energy savings can be made, thus achieving better integration of the costs and benefits associated with automation.

Communal systems for controlling lighting and rationalising energy consumption (in the case of central heating and swimming pools, for instance) are examples of systems that reduce consumption by introducing building automation features. Control of the lighting on stairs and communal landings through the use of presence sensors to prevent lights from remaining on unnecessarily and switching off automatically (e.g. using a timer) causing discomfort to residents (e.g. when the lights go off whilst they are going down the stairs) is one example which combines environmental and economic concerns with a concern for the comfort of residents.

6.3.2 Social inclusion

Nowadays ICT is a permanent feature in the everyday lives of most citizens. The systems, which take the form of fixed and mobile video and voice communications to access information via the Internet and instantly transfer information between distant locations, amongst other functions, are indispensable tools today.

ICTs have invaded the home, the workplace and leisure facilities and are useful tools in personal and work-related communications for processing texts and systematised information, and accessing databases and information distributed in electronic digital networks, in addition to being incorporated into countless everyday items of equipment used in homes, offices, factories, transport, education and health care (MSI, 1997). Computers are part of our individual and collective lives and the Internet and multimedia are becoming omnipresent. These systems are not expected to replace traditional options, but rather to add their additional capacities to the range of options currently available.

If, on the one hand, ICT promotes info-inclusion in the sense that it promotes the acquisition and exchange of information, research and the involvement of citizens in a global "forum" through access to communications channels, it also promotes social inclusion for disabled citizens and those with restricted mobility, as previously mentioned. It is perhaps this perspective of inclusion and the fact that it increases autonomy for more vulnerable groups that may ensure ICAT will have a more inclusive nature in terms of current and future housing.

ICT also plays a very important role in housing in promoting the option of telework. The great availability of ICT, the increasing speed at which information can be transmitted and all the social and environmental advantages that will be discussed later have meant that telework has acquired many supporters in recent years.

INDEPENDENT LIVING: THE ELDERLY, INDIVIDUALS WITH RESTRICTED MOBILITY AND THE DISABLED

It is a fact that the majority of people do not have a pressing need for home automation systems, since they can carry out tasks without difficulty. Some even prefer to use traditional systems, ranging from switches to more advanced systems such as remote controls. However, new ICT have enabled people to overcome disabilities, isolated individuals to find friends, those with speech impairments to talk, etc. Appropriate use of technology can ensure that quality of life is improved for everyone by enabling those with physical or cognitive disabilities to integrate into society as much as possible.

The disabled and handicapped represent approximately 8.2% of the Portuguese population (Sousa, 2007: 21), with a marked increase from the very young to the elderly. At some stage, each one of us may experience permanent or temporary difficulties in our activities or mobility due to age, illness or accident. In addition, the Portuguese and European population is ageing, a factor that has drawn attention to the need to provide housing and buildings in general with features designed for universal use. According the INE (National Statistical Institute), this marked ageing of the population is one of the most striking aspects of recent demographics trends. In 2001, for the first time the proportion of elderly people – aged 65 or over – in the census (16.4%) exceeded that of young people – aged 0 to 14 – (16.0%) (INE, 2001). It has been calculated that in 2050 almost one third of the Portuguese population will be aged over 65. According to the INE (INE, 2003), the Resident Population Estimates for Portugal for 2000-2050 reveal the continuing ageing of the population, as a result of the expected rise in life expectancy combined with fertility levels that remain below the threshold limit.

Factors such as smaller-sized families and higher life expectancy[26] indicate that in future many more elderly people will live alone. They will not have the traditional family support and will need to make use of external structures to obtain health care and other forms of assistance, which will have implications for the structure of the health care system. These changes are already being felt, for example in government projects to extend the social network of health care for the elderly and the appearance of new support structures for the elderly in the private sector (see *Residential structures*).

Globally, a pressing need is being felt for more universal use products, environments and services. The concept of Design for All encompasses the idea that human beings are both similar and diverse, rather than special. There is a current concern that universal design should seek to ensure that all products and environments are designed for use by all individuals, in the broadest sense possible, regardless of age, capacity or circumstances. These products and environments should cater for all people, whether children, adults or the elderly, and whether they enjoy full or restricted mobility. Designs which are adapted to a wide variety of people take inter and intra individual differences into account and, within the design phase, increase the life of buildings and reduce the need for adaptation and modification. In future, all dwellings must be prepared for residents with all levels of mobility.

Dewsburry and Edge (2000) consider that adding solutions and technical services to housing will facilitate the removal of obstacles and increase independence, decision-making powers and the autonomy of residents. The creation of dwellings which include universal design, the removal of obstacles, adaptability and assistive technology, will enable residents to remain longer in their homes and contribute towards greater stability in neighbourhoods and society in general.

The possibilities for communications and access to information have improved exponentially in recent years. Countless products and systems adapted for the disabled are now available to enable them to use distance communication. Examples include videoconferencing systems or telephones with images for individuals with hearing difficulties, telehealth, entertainment systems, orientation and navigation systems for wheelchair users, etc., which enable disabled people to enjoy very high levels of autonomy.

The installation of digital controls and communications systems represents the next step in terms of alterations to the domestic environment. The proposal to provide dwellings with Electronic Assistive Technology (EAT)[27] will provide support for individuals when carrying out daily tasks, supplemented by personal health care, thus adapting dwellings to the needs expressed by the concept of universal design. Technology should become part of universal design and should be integrated into it from the outset rather than in its later stages. Dewsburry (2001) warns that the introduction of the great potential offered by technology must be carefully considered and assessed "*so that human beings do not become slaves to technology*".

According to Gann, Barlow and Venables (1999), appropriate assistive technology solutions should contemplate the following factors: affordability, ease of use, flexibility and adaptability, functionality, interactivity, reliability and maintainability, replicability and ease of installation, upgradeability.

For Dewsburry, Taylor and Edge (2001), inclusive, empowering and augmentative assistive technologies can be divided into two groups: "*active mechanisms*" such as control panels and switches which residents interact with, and "*passive mechanisms*" such as sensors and receptors, which residents do not interact with and which allow various features of the dwelling to be altered imperceptibly. Suitable technologies from within these two groups should be chosen, according to the level of dependency of the user.

Various experiments involving the application of assistive technologies in housing for the elderly and the disabled demonstrate the effectiveness of using intelligent houses for this group of people (the Custodian project[28], Aware Home Research Initiative[29], NJORD – TIDE[30], Gloucester Smart House Project[31], SmartBo project[32], Smart Home Project of the Joseph Rowntree Foundation[33], Smart thinking projects[34]). During the development of these projects it was frequently affirmed that it is still difficult to customise technology for specific cases due to numerous problems such as the lack of common protocols and qualified professionals and the high price of equipment.

TELECARE

One solution that is frequently used for these more vulnerable groups is the telecare system. The implementation of systems of this type offers many advantages, both for the elderly who can live independently in their own homes for a longer period of time, and for the state since it avoids the high costs of health care units and also prevents overcrowding in hospitals. The elderly and those suffering from chronic illness or disability require a significant level of support from family and friends and if this is lacking they are may resort to health care units and hospitals unnecessarily.

Telecare systems are based on a series of sensors and electronic aids installed in the user's home which automatically inform the health centre when there is an alarm and initiate a response to the problem that has been detected. The sensors enable the system to function but are not an actual response and cannot function in isolation from the rest of the system. The response lies in the monitoring and response from the healthcare workers via the health centre or alongside the user, as appropriate (Figure 50).

Telecare systems have been widely adopted in countries such as the United Kingdom and, according to James Barlow[35], have been helping to change the structure of health care in cities. In fact, these systems can reduce recourse to hospitals for health care and internment, thus reducing the number of beds occupied.

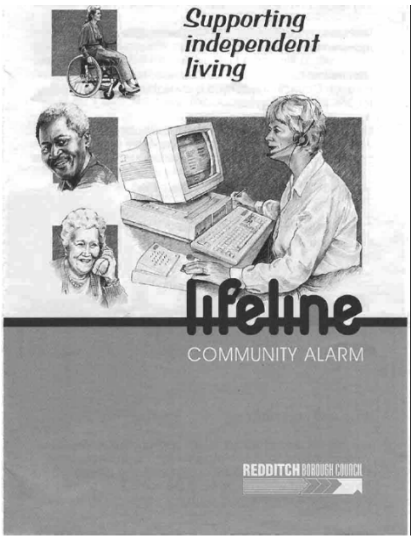


Figure 50 – Advertisement for a telecare line (Lifeline) in Redditch, England. (Source: http://redditch.whub.org.uk/home/rbcindex/rbc-community-services/rbc-comm-services-cr-agency.htm?hilightTerm=telecare)

According to Barlow, Bayer and Curry (2003: 1), the services supplied by telecare fall into four groups: information and communications (medical advice, classification, access to self-help groups); monitoring of safety and protection (floods, gas leaks, open doors, environmental control, protection against intruders); monitoring of health and activities (control of heartbeat, respiration, blood pressure, etc; detection of falls, occupation of rooms, identification and location of individuals, occupation of beds); assistive technology (control of surrounding areas, automatic control of doors and windows, control of automatic movement of chairs and wheelchairs).

A telecare system, if properly implemented, should firstly take into account an assessment of the actual needs of residents, ensuring that they have access to services that meet their actual individual needs rather than making use of a standard "kit" that is the same for everyone. Secondly, it is vital that the installation and programming is carried out correctly. After this, it is necessary to teach the users how to operate the equipment and to ensure that the functions are demonstrated in the home with a link to the care centre that will be monitoring the dwelling. Thirdly, it is important to ensure that the telecare answering centre has the relevant information on each of the users, namely personal information on their state of health and main contacts in the event of an emergency. These centres operate 24 hours a day, 7 days a week and provide a human, rather than a technological response. Finally, it is also important to ensure that the response from the care centre is effective and immediate and conforms to what has been agreed in advance with users of the service.

Basic telecare services may be supplemented with the introduction of electronic assistive technology. As these technologies represent a considerable financial investment, they are normally only used in cases of chronic illness or when funds are available. In fact, introducing ICT into the home through telecare has countless advantages and is not expensive, in comparison with installing automated mechanisms and motors.

TELEHEALTH

Telehealth systems are more specialised than telecare applications and are only justified in cases of chronic illness. These systems are based on tele-monitoring, which enables the patient's state of health to be monitored within the home, thus preventing visits to hospital. This investment in technologies for the home is justified to the extent that it is an investment in preventive rather than curative medicine which ensures that the patient is more efficiently and accountably involved.

Intelligent houses and telecare and/or telehealth systems are natural companions, given that the product (the intelligent house) and the applications (telecare and telehealth) use similar technology. In fact, the sensors and other monitoring equipment used in an intelligent house are also essential in a dwelling with telecare or tele-health facilities.

TELE-ALARM SERVICES AND OTHER INCLUSIVE TECHNOLOGIES IN PORTUGAL

In Portugal the tele-alarm service was created as part of the *Programa de apoio integrado a idosos* (PAII – Integrated Support Programme for the Elderly) with the aim of ensuring urgent and permanent care, principally to maintain the autonomy of the elderly in the home and in their usual environment. The programme is supervised by the Ministry of Labour and Social Security[36]. The users of the service are mainly the elderly, but it can be provided for anyone who needs home care, namely when they are in a situation of dependence.

The system consists of a permanent listening centre, a special telephone installed in the home and a medallion with alarm buttons. This equipment, as well as the care provided, is costly but is partly or totally paid for by the local authorities and subsidised by the PAII. It is expected that by installing this equipment many elderly people will be able to postpone the need to live in care homes or use other health care facilities.

Parallel to this service, PT Comunicações[37] has been developing a range of products and services – Soluções Especiais PT – designed for the disabled, children with serious illnesses and elderly people who are at risk, which offer the best communications facilities. These solutions include packages for PT systems, telecommunications services and equipment with specific features and an implicit social or humanitarian character, to make communications accessible to all, without exception. Some examples include: PT Voz Activa Zoom, PT Voz Activa Mais (allowing access to the Internet for the blind); PT Minha Voz (an enhanced communications product for those who are mute or have difficulties in structuring communication); the Portugal Telecom 112 (emergency number) for the deaf; the Q90 Text Telephone (which enables those with hearing impairments to communicate); PT Emergência 2 (hands-free telephone for rapid assistance calls); PT 118 Braille (for the blind and visually impaired); TeleAula (providing access to classrooms for children who are bedridden or confined to the home or hospital).

ASSISTIVE TECHNOLOGY FUNCTIONS AND COMPONENTS

A home that is technologically prepared to accommodate elderly people and individuals with restricted mobility does not differ very greatly from a dwelling that has been domotised for other social groups. In fact, systems which provide temperature and lighting management, monitoring of the indoor home environment, management of security and other operations, are extremely important for more vulnerable groups.

An intelligent house adapted to accommodate elderly people, those with restricted mobility or the disabled may include the following key functions:

- Providing an environment that is constantly monitored in order to ensure the safety of residents (Figure 51 to Figure 54);
- Ensuring that the tasks the individual is unable to undertake are carried out;
- Ensuring a safe, protected environment;
- Providing autonomy and empowering residents.

Figure 51 (left) – Sensor to detect occupation of bed/wheelchair. (Source: http://www.dudley. nhs.uk/)

Figure 52 (right, top left) – Fall detector. (Source: http://www.dudley. nhs.uk/)

Figure 53 (right, top right) – Movement detector. (Source: http://www.dudley. nhs.uk/)

Figure 54 (bottom right) – Personal alarm. (Source: http://www.dudley. nhs.uk/)

A basic telecare system consist of a telephone line and sensors, which are usually wireless, fitted to walls using Velcro tape or attached to the body (as a wristband) which send signals to the telephone and from there to the exterior (the health centre, family, friends, fire service, specialist support service).

If installed without construction work, the system can function without a cable infrastructure, since information is transmitted to the equipment by using radio frequency.

Interfaces also play an important role in domotics applications for the elderly and the disabled, since they represent the face of the system. Research into "universal design" products has been developing alterations to conventional interfaces in order to adapt them to restricted mobility, visual impairment or other conditions affecting this group of people. This has resulted in equipment such as telephones with large buttons for people with visual or motor difficulties, visual alarms using lights for the deaf and telephone systems with text for the speech-impaired, amongst others.

The use of the same software in the various domotics systems in housing facilitates learning and makes it easier for all residents to understand. In addition the use of a language that is closer to the everyday language of users also makes it easier to use e.g. "I'm hot /I'm cold, rather than "25º/15º".

Reaction to technologies

The process by which elderly people adapt to technology is sometimes complex and lengthy. A study carried out by Maria Sourbati (2002) at Goldsmith's College with the aim of investigating residents and health care assistants in old people's homes concluded that access to the Internet and use of the computer presented various problems.

The most common problems, and the only ones associated with matters relating to physiological changes, were technical problems involving the use of the equipment and software (visual impairment, problems involving movement). Other problems included lack of skills, lack of understanding of the importance of the Internet, and lack of understanding of the link between use of the Internet and the daily routines of the residents and the health care team.

Firstly, these technologies were not of great interest to the residents and in the majority of cases their use required the presence of more experienced users. The Internet was seen by most of the residents only as a leisure and entertainment tool. Despite this, the Internet and the telehealth services were seen by some residents as useful tools in promoting independence. In fact, these dwellers cited on-line shopping, remote access to health care services and on-line prescriptions for medicines as the most useful services.

One of the conclusions of the study was that the elderly have a tendency to ignore and distance themselves from technologies, since they fear that they will replace personal care and lead to isolation (Sourbati, 2002).

The following were identified as obstacles to the use of technologies by health care assistants and the elderly (Sourbati, 2002): a lack of suitable equipment and software or certain conditions (visual impairment, problems involving movement, etc.); a lack of technical knowledge on the part of users; a lack of understanding of the benefits of the system; a lack of adequate training for different needs; problems with system capacity and the need for upgrades; the high cost of access; the short time available for the required training (care assistants); cultural attitudes that were against the use of on-line services.

With regard to the impact of the technology on the elderly and the disabled, Dewsburry and Edge (2000) state that the technology has been well-received in terms of the fact that it makes tasks easier and offers greater social integration. These authors consider that it is essential to involve residents in selecting the technologies that will help them and in analysing their actual needs. In their study they concluded that technologies involving complex use that were not fully understood by residents are useless and harmful.

Concerning the acceptance of technology by this group of residents, Gann, Barlow and Venables (1999) affirm that there has been little research into this area, but state that the advantages in terms of autonomy and independence encourage elderly people to make concessions regarding technology, seeking to understand it and experiment with it. Curiously, this study by Gann also shows that young disabled people are very resistant to technologies that can improve the quality of their home life, since they make them feel inferior. In the majority of experiments carried out as part of the study, residents emphasised a desire for technology to be invisible or at least not obtrusive, so that it did not impose itself on the domestic environment.

Residential structures

The lack of available family members, home care structures and space in the home has meant that many elderly people have to resort to care institutions such as old people's homes despite the desire to remain in their own home as long as possible and enjoy unrestricted use of their time and space.

Figure 55 (top left) – Motor to open and close bedroom door. (photo: AC 2008)

Figure 56 (top right) – Control of access to bedrooms via keyboard and code, magnetic card or key. Presence sensor installed in door frame to prevent closing. (photo: AC 2008)

Figure 57 (bottom left) – Control system via personal computer installed in each resident's bedroom to manage all domotics applications in bedroom. (photo: AC 2008)

Figure 58 (bottom right) – LCD panel to control domotics applications. (photo: AC 2008)

ASURA studios – domotised dwellings for the disabled, Madrid

One solution that has already been tested is to create communities of elderly people who make use of shared services which, on the one hand allows them to be supervised by qualified staff and, on the other hand, provides a certain level of autonomy and involvement. In Portugal some residential structures for elderly people have already been created by Grupo Mello[38], Montepio[39] and Espírito Santo[40], which include residential condominiums and sheltered accommodation for different levels of dependency.

These structures are tending to incorporate electronic assistive technologies to supplement human supervision and monitoring of elderly people, thus helping them to achieve greater autonomy and independence.

One example of the incorporation of this type of technology into the daily life of the community can be found in the Centro Dato in Madrid, which is a residential complex for individuals with severe physical disabilities. The specific nature of this facility lies in the fact that the dwellings are totally accessible and domotised, enabling residents to lead a virtually independent life (Figure 55 to Figure 58). The facility is housed in a building with independent bedrooms and some communal services which residents may choose to use, according to their level of dependence (including meals, medical care and laundry). The domotics system that has been installed is based on EIB technology and operates the systems for the lighting, blinds, air conditioning, access, security, non-intrusive monitoring of activity in bedrooms and overall control of systems via a centre or locally (Juez, 2007).

Another strategy used to make assistive technologies available to vulnerable social groups is to rehabilitate residential structures mainly inhabited by elderly people in order to provide them with technologies that will assist them. One example of this is the strategy used by Westminster City Council in London which, in 2001, commissioned the INTEGER project to investigate the rehabilitation hypotheses for residential buildings, especially tower blocks, in accordance with "green" and "intelligent" principles. The INTEGER Intelligent & Green project emerged in England in 1996 as a partnership dedicated to research, development, assessment and communication of sustainable and intelligent technologies for buildings.

Figure 59 (left) – Exterior of tower block. Glastonbury House in Westminster, an INTEGER project (photo: SE 2004)

Figure 60 (right) – Interior of dwelling after rehabilitation. Glastonbury House in Westminster, an INTEGER project (photo: SE 2004)

Figure 61 (left) – Newcastle, New Cruddas Park, 2005. A Cole Thompson and INTEGER project. (Source: http://www.colethompson.co.uk/)

Figure 62 (right) – Newcastle, New Cruddas Park, 2005. A Cole Thompson and INTEGER project. (Source: http://www.colethompson.co.uk/)

The primary practical objective of the research that was commissioned was the rehabilitation of a council building – Glastonbury House – which was constructed in the 1960s, has 22 floors, 162 flats and approximately 200 elderly residents, and is owned by CityWest Homes (Thompson, s.d.) (Figure 59 and Figure 60). The building in question had never been subjected to any interventions on its infrastructures, which had many problems and were inadequate for current needs and requirements. The INTEGER intervention strategy for the Glastonbury House project focussed on seven main areas: administration, social, design, construction, technology, environment and finances and ICAT was considered crucial to promoting the social inclusion of residents.

In 2005 the INTEGER project was also commissioned to rehabilitate Cruddas Park a group of 11 tower blocks in Newcastle with a capacity to accommodate approximately one thousand residents[41] with the same principles (Figure 61 and Figure 62).

6.3.3 Telework as a factor in social and environmental sustainability

> "*In pre-industrial agglomerations, residential space and working space were closely integrated. (…)*
>
> *(…) the first Modernist planners sought out strategies for industrial zoning and the segregation of incompatible activities. Housing, commerce and industrial activities gave rise to different zones. Leafy suburbs and huge urban housing developments grew up around city centres, leading to satellite cities, forcing workers to travel large distances to get to work.*
>
> *(...) Nowadays, it can be seen that work in the field of information technology – using computers and supported by communications networks – is not incompatible with residential environments. It does not cause pollution, noise or heavy traffic. (...) Combined housing estates and workplaces have once again become possible and attractive (…)."* (Mitchell, 1999a: 23)

The widespread use of new information and communications technologies is driving workers from factories and offices, creating a new polarisation around the home and transforming it into the centre of society (Faria, 2003: 226). Rousseaux (1989) sees telework as a return to "family industry", in which the home is the centre of society and the "family industry" generated there is based on electronics and is more skilled than previous forms of home working.

The migration of the PC from the workplace to the home and the spread of the Internet into residences has proved very significant in terms of the changes experienced in housing. Telework reduces the distance between the workplace and the home and, in allowing for links to the outside world via the Internet, connects the home to new, constantly evolving services. The Internet or other virtual forms of communication are only possible due to the exponential evolution of communications networks which, in turn, are the physical support for SI.

Two basic concepts are essential to an understanding of current telework. Firstly it is distance work, and secondly it implies using ICT.

The concept of distance work first emerged in the 1950s with Norbert Wiener's Cybernetics (Serra, 1996). In his book, Wiener describes telework using the example of an "*architect living in Europe who can supervise, from a distance, the construction of a building in the USA, communicating by a facsimile device*."

Working from home reappeared in European society in the 1960s and began to include the manufacture of clothing, textiles and footwear. It was extended during the 1970s to include sectors such as packaging and the assembly of electrical and electronic items, the food industry, drinks, detergents, plastics and cosmetics (Serra, 1996). The emergence of telework and the study of these problems from the 1970s onwards was due to various factors including the energy crisis (specifically, petrol), "localist" ideas resulting from May '68, lower ICT prices (in particular, for computers) and the emergence of "telematics".

In the 1990s telework re-emerged in a different context and became seen as a source of added value of economic interest to companies. Thus telework began to be considered as a tele-service for various activities such as management, translation, training, secretarial work, accountancy, consultancy work, research, journalism, etc.

In fact, adopting a telework system enables company employers to reduce their investments in physical space, since employees work from home or other places and keep in constant contact with the head office via ICTs such as videoconferencing, the Internet, phone with images, etc.

It is undeniable that telework has provided a better quality of life for families as a more motivating, convenient and efficient form of work that enables private/family life to be reconciled with professional life and also as a better means of managing work and leisure time. Since it allows for less travelling, telework is a more ecological and non-polluting form of work, promotes urban dispersal and, according to Rousseaux (1989), from a physical and physiological point of view, leads to less fatigue and stress.

Other advantages of telework are related to the reduction or even elimination of the time, energy and other expenses associated on a daily basis with journeys to and from work, the solution for problems such as urban traffic congestion, atmospheric pollution, geographic and urban concentration, imbalances in the economic and social development of underprivileged and suburban areas, the reduction in travelling, installations and labour costs, the reduction in company costs, flexible working hours and greater professional autonomy. Moreover, telework is also a means of encouraging elderly people, the handicapped, housewives and the disabled to lead a working life, thus fostering social inclusion.

However, telework also has certain disadvantages in the sense that it replaces personal and direct human relationships with relationships based on distance, putting an end to the notion of society as a series of real and direct interactions between human beings. In addition, on a social level, telework may lead to the disappearance of collective forms of work, the dispersal of the labour force and the exploitation of more vulnerable workers. The disadvantages that telework may bring to workers are isolation, more precarious forms of employment and the possibility of less favourable working conditions. For companies which allow telework, it may lead to difficulties in ensuring control over the presence of workers, poor integration into the company and increased telecommunications costs. In domestic terms, telework creates difficulties in managing space and time (Serra, 1996).

Amoêda (2003: 257) states that studies on telework also show that the idealism of working from home at one's own pace has negative aspects. On the one hand, people tend to move far away from major city centres, mainly to small towns, creating new local traffic flows. Moreover, the energy savings on travel are lost in increased home energy costs. Finally, according to the same author, relieving the congestion in access to cities on working days is offset by the increase in traffic associated with visits to leisure and recreation centres in large cities.

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[22] Using computer programs it is possible to create images of the building (plans with or without additional graphic elements) that enable the current status of the system to be monitored and can act on this information. Visualisation can take place through interaction based on the actual house or remotely via a PC. This option is usually very expensive, since it needs to be customised (KNXportugal, s.d.).

[23] Moya and Tejedor (2004: 21) state that domotising a new dwelling increases the overall price by an average of 1% to 2%.

[24] Ethernet is a family of frame-based computer networking technologies for local area networks (LAN). The most common are Ethernet over twisted pairs to connect end systems, and optical fibre versions for site backbones. It is standardized as IEEE 802.3. (source: http://en.wikipedia.org/wiki/Ethernet). Ethernet, in its most basic form, is the technology used in interconnections between computers and various technological devices. Through signals transmissions, these devices are able to exchange data and important information. When cabling is used to link a distinct family of computers and devices to each other, they form a network. This web of connections is called a Local Area Network or LAN. (source: http://www.worldnet-long-distance.com/ethernet-network/).

[25] According to Edwards (2001: 11), 50% of the world's material resources are destined for construction, 45% of the energy generated is used in buildings (for heating, lighting and ventilation) and 5% in their construction, 40% of the water used in the world is destined to supply buildings, and 60% of the best agricultural land and 70% of wood is used to construct buildings.

The *Direcção Geral de Energia e Geologia* (Directorate-General for Energy and Geology) (2006) states that in 2006 buildings (services and residential buildings and building operations) were responsible for over 32% of final energy consumption in Portugal. According to Valério (2007), energy consumption in buildings in the European Union represents approximately 41% of the total energy used in the Member States. Between 1990 and 2005 these sectors witnessed the greatest increases in final energy consumption (in comparison with other business sectors), registering rises in the order of 23.6% (residential sector), 222.1% (service sector) and 118.3% (construction sector) (Dias, 2007).

[26] The INE estimates that in 2050 the increased life expectancy be will be 79.0 for men (72.9 in 2000), and 84.7 for women (79.9 in 2000) (INE 2003)

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[27] Electronic Assistive Technology (EAT) is opposed to assistive technology solutions (AT) achieved by means of mechanical adaptations such as the removal of architectural obstacles – improvements to access, removal of steps, sizing of divisions, etc. There is a large amount of information available on this subject on Guy Dewsbury's site at URL: http://www.smartthinking.ukideas.com/

[28] Information on the Custodian project available at WWW: <URL: http://www2.rgu.ac.uk/subj/search/research/sustainablehousing/custodian/home.html ?CFID=16502507&CFTOKEN=29780670&jsessionid=503146c3fe209e151a0543e286a755c4b1e2TR> (accessed on 2008-10-12).

[29] Information on the Aware Home Research Initiative project available at WWW: <URL: http://awarehome.imtc.gatech.edu/> (accessed on 2008-10-12)

[30] Information on the NJORD – TIDE project available at WWW: <URL http://njord-tide.arch.kth.se> (accessed on 2004-07-13)

[31] Information on the Gloucester Smart House project available at WWW: <URL http://www.fastuk.org/research/projview.php?id=407> (accessed on 2008-10-13).

[32] Information on the SmartBo project available at WWW: <URL: http://www.dinf.ne.jp/doc/english/Us_Eu/conf/tide98/66/elger_furgren.html>

[33] Information on the Joseph Rowntree Foundation Making Homes Smarter project available at WWW: <URL: http://www.jrf.org.uk/publications/digital-futures-making-homes-smarter-report>

[34] Information on the Guy Dewsburry's Smart Thinking projects available at WWW: <URL http://www.smartthinking.ukideas.com/> (accessed on 2008-10-13)

[35] James Barlow, who holded the Chair in Technology and Innovation Management at Imperial College, London and is the author of several studies on intelligent houses, was interviewed by the author as part of the "Housing for the Future" research project in 2004.

[36] Information on the Telealarm service available at WWW: <URL: http://www.portaldocidadao.pt/PORTAL/entidades/MTSS/DGSS/pt/SER_accao+social+para+pessoas+idosas.htm> (accessed on 2011-04-18)

[37] Information on PT products available at WWW: <URL: http://loja.ptcom.pt/loja/Produtos/Casa/Necessidades_especiais/> (accessed on 2008-10-11)

[38] José de Mello Group sheltered housing, available at WWW: <URL:http://www.jmellors.pt/JMRS/Default.aspx> (accessed on 2008-10-10)

[39] Montepio Serviços de Saúde Group, SA, residential centres, available at WWW: <URL: http://www.montepio.pt/ePortal/v10/PT/jsp/montepio/ServicosSaude/QuemSomos.jsp> (accessed on 2008-10-10)

[40] Espírito Santo Group residences for the elderly. Available at WWW: <URL: http://www.essaude.pt/#> (accessed on 2008-10-10)

[41] *Bringing new life to 1960s tower blocks*. May 2007. Available at WWW: <URL: http://www.modbs.co.uk/news/fullstory.php/aid/3328/Bringing_new_life_to_1960s_tower_blocks.html>

7 CASE STUDY

The housing stock built between the 1950s and 1970s was chosen as the case study for this research on account of what it represents (approximately 36% of Lisbon's buildings were constructed between 1946 and 1970) (Table 1, page 40) and the likelihood of its rehabilitation in the near future. Although the existing housing stock in Lisbon has the potential to attract more people to the city, the fact is that 55% of the dwellings built during the period under study require rehabilitation (INE, 2002) and 24% were considered to be in a state of average to severe deterioration.

The large number of buildings constructed during this period enabled a case study to be selected that would allow for a more specific and objective analysis and (functional, constructional and social) characterisation.

The building type chosen is commonly labelled a "tenement building" and from amongst these buildings the "rabo-de-bacalhau" type was selected, mainly because the topology is very representative of the period and it has a significant presence in the city.

The typology known in professional jargon as "rabo-de-bacalhau" first appeared in the 1930s (Nereu, 2001) and became common in the 1940s and 50s (Rodrigues, 2001). By around 1960 new "rabo-de-bacalhau" buildings had practically ceased to exist and were replaced by buildings with rectangular and square plans (Nereu, 2001).

The buildings have a "right and left" arrangement, a predominance of reticulate concrete structures filled with masonry walls and vary in height with six floors being the average. In the two decades covered by this study, a gradual increase in the height of buildings can be observed, as well as the use of new construction techniques and the increasing use of concrete. Amongst the universe of Lisbon residential buildings included in the 2001 Census, 46% of those built between 1946 and 1960 have a reinforced concrete structure and this figure rises to 63.1% for the period between 1961 and 1970 (INE, 2002). The buildings started to appear in Lisbon at the time when the 1951 *Regulamento Geral de Edificações Urbanas* (RGEU - General Regulations for Urban Buildings) came into force.

In general the dwellings are essentially very similar and usually have a two or three bedroom layout and relatively small and very divided areas.

The need to rehabilitate these dwellings is also vital from a functional perspective, but perhaps not as easy to quantify as it is to understand. In fact, the existing housing stock does not meet present lifestyle needs, both functionally and in terms of standards of comfort. The selected housing stock, now a few decades old, presents several problems that compromise its functional and constructive performance, particularly with regard to comfort. This is the result of a series of factors, of which the following should be emphasised: lifestyle changes leading to new needs and requirements and a lack of regular repair work, which has led to the deterioration of materials, components and utilities.

In this chapter, the characterisation of the "rabo-de-bacalhau" typology is undertaken in accordance with the scheme proposed by Habraken (1988). This characterisation aims to understand the underlying design principles for this building type in order to determine how they can be used today (Habraken, 1988: 3).

The type of dwelling which this study proposes to examine cannot be analysed from a functional and technical/constructional viewpoint alone. In the analysis presented here the three methods proposed by Habraken (1988) are used, namely:

- Analysis according to spatial organisation, studying the different spaces which the dwelling offers and the relationships between them;
- Analysis according to the physical/constructional system, focussing on questions such as the structure of the building and the constitution of walls, floors, coverings, etc.
- Analysis according to stylistic features, studying questions such as the positioning of windows on façades, decorative work on façades, and types of doors and windows.

In addition to these three forms of analysis, since dwellings are cultural artefacts: a collective product that portrays a population (Habraken, 1988), it is also necessary to understand the cultural context, social patterns and lifestyles of the period in which they were built.

These systems of analysis are relatively independent of each other and it is through this independence that it is possible to analyse the various aspects of how the dwelling can be adapted to current lifestyles.

Space syntax theories are also used in the analysis of the dwellings in order to understand their spatial structure and the influence of this structure on residents.

Following this characterisation of the dwellings, Section 7.3 presents a typification of this dwelling typology that will inform the transformation grammar developed in *Part 2: Chapter 4*. Finally, the current situation of the dwellings is diagnosed, in order to identify patterns of use, their potential and their constraints on use.

7.1 SAMPLE SELECTION AND METHODOLOGY FOR GATHERING INFORMATION: THE ORIGINAL CASES AND THE CURRENT SITUATION

The method used to gather individual examples for the study consisted of analysing the plans for the various areas in Lisbon and, in the initial phase, selecting buildings at random with a typology similar to the one chosen. The main source of information used for this analysis was the Lisboa Interactiva site (http://lisboainteractiva.cm-lisboa.pt/), due to the wide range of scales and accuracy of the information presented, even on a scale of 1:500, which enabled the shape of the building to be understood, as well as its urban context and even the street numbers which are essential when consulting the building project records held in the Lisbon City Council (CML) archives. ICTs, studied in this thesis as an inseparable feature of the dwelling, also proved indispensible to the research and greatly facilitated the task of selection.

This preliminary choice was validated after analysis of the building project records at the CML, which allowed for verification that the building belonged to the intended typology.

The typologies studied are located in the areas of the city which expanded most during the period in question and include the Avenidas Novas (where older buildings with central inner yards predominate), Av. Guerra Junqueiro, Av. Almirante Reis, Bairro dos Actores, and Areeiro.

The sample selected consists of 25 buildings (Figure 63), most of which are situated in the aforementioned areas (in 19 cases, corresponding to 76% of the sample). However, the aim was also to include cases in other areas that were more peripheral at the time, such as Benfica, Anjos, Ajuda, Restelo and Campo de Ourique (6 cases, corresponding to 24% of the sample).

Numerous possible examples emerged during the initial search for "rabo-de-bacalhau" buildings using online maps of Lisbon. In order to ensure that the analysis was viable, it was decided to analyse a more restricted group of buildings – 25 in all – so that it would be possible to carry out a detailed analysis of each example, including a survey of all the dwellings in the buildings in the study (approximately 215 dwellings). After analysing the sample, certain cases that had not been considered were subsequently reviewed and found to fall within the type description previously presented. The sample is therefore considered representative of the universe of cases.

The methodology used to gather information for the case study was based in three types of data: original and alteration building project records, bibliography and a survey (Table 12). The analysis of the building project records for the original buildings and for alterations provided an overview of the evolution of the dwellings over the approximately fifty-year period during which they have been occupied. The information gathered for the case study was also supplemented by a survey of the dwellings, the results of which are analysed in *Part 2: Chapter 7.4.*

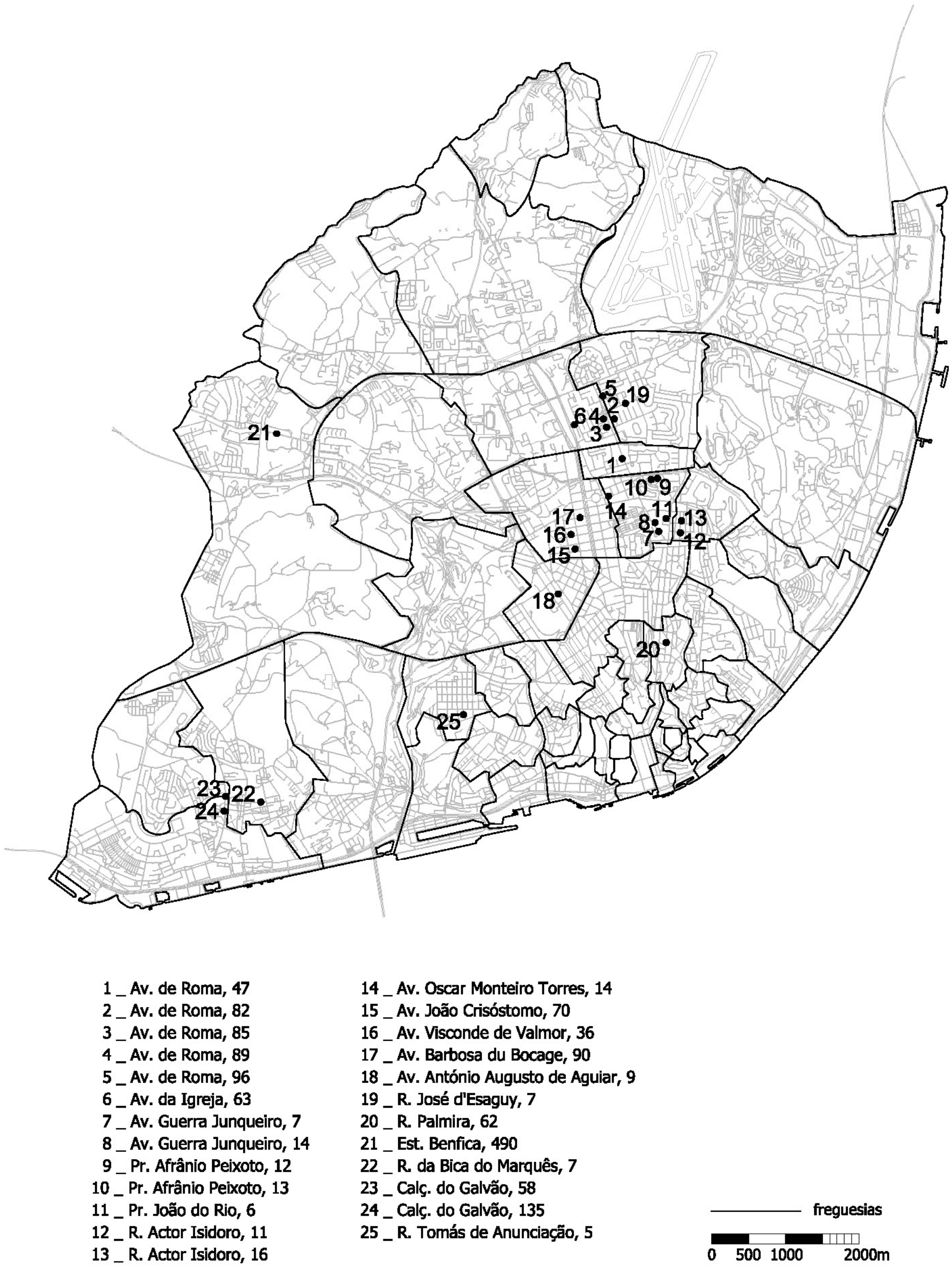


Figure 63 – Location of cases analysed.

	Objective	Methodology		Results
EXISTING DWELLINGS	Description of original buildings	Research	Consultation of building project records (CML) Consultation of bibliography	Functional characterisation Constructional characterisation Stylistic characterisation Characterisation of social and cultural context Typification
	Description of alterations to dwellings	Survey and diagnosis	Consultation of alteration records (CML) Survey of dwellings	Functional characterisation Characterisation of ICT in dwellings Characterisation of space use conflicts Characterisation of use of ICT

Table 12 – Methodology used to gather information for the case study

7.2 CHARACTERISATION OF THE ORIGINAL BUILDINGS

This chapter presents a characterisation of the typology under study from a functional, constructional and socio-cultural point of view. It also includes a brief stylistic characterisation of the model and an analysis of the urban setting for this building type.

"Rabo-de-bacalhau" buildings are found in various urban contexts. In some cases, such as Areeiro, Av. João XXI, Pr. Afrânio Peixoto, Av. de Roma and Benfica, they were designed for areas that were being developed on the basis of a careful urban plan with properly established street hierarchies, accesses and facilities. In these cases they were built in open blocks that contained plenty of green spaces. This typology can also be found in other recent areas of expansion, in geometrically designed closed blocks, as in Bairro dos Actores or Campo Pequeno.

In these contexts urban development projects were undertaken by the local council (e.g. Alvalade) or were awarded to private developers and the building work on the sites was also undertaken by private developers (e.g. Bairro dos Actores) (Salgado and Lourenço, 2007: 62, 72).

In other cases, "rabo-de-bacalhau" buildings appeared in isolation as part of an urban fabric that existed prior to their construction, with less rigid and rationalised planning adapted to the more irregular topology of the area (e.g. Arroios, Restelo, Ajuda). These buildings were developed in closed blocks defined by the outlines of the traditional streets (Salgado and Lourenço, 2007: 80). In general, they are more modest and of a smaller typology than those in the Avenidas Novas and Alvalade.

7.2.1 Characterisation of the social and cultural context

In order to understand the functional organisation of the dwellings in the study it was considered necessary to briefly analyse the population, families, social changes and, in particular, lifestyles in the 1940s, 50s and 60s.

The period under study began immediately after the end of the Second World War and corresponds to an easing of the economic and social crisis due to the war.

Throughout this period, from 1945 to 1960, the Estado Novo regime governed in Portugal. This nationalist regime sought to create a hierarchical and cohesive nation around a strong leadership whose mottos "God, Fatherland and Family" and "Everything for the Nation, nothing against the Nation" were key values for the regeneration of the nation.

Figure 64 – Central poster in the series "Salazar's Lesson". Source: (Tostões, 2004: 119).

The society of the time was marked by tradition which, in terms of state propaganda, was associated with the authentic, nationalism, unity and regeneration (Cunha, 1994: 177) (Figure 64). Portuguese society was traditional, a concept opposed to the modernity with which the expression Estado Novo was associated, and exaggerated the expressions and dangers of degeneration, the unnatural, dissolution and foreign influences (Cunha, 1994: 177).

The subject of the research underpinning this analysis of types of planning and housing in the 1940s to 1960s is family organisation and its changing structure during the second half of the 20th century, specifically the extent of its influence on the morphology of "rabo-de-bacalhau" dwellings.

The state only began to build housing for the population in the 1930s. According to Pereira (2006: 8) state intervention in this sector can be divided into three areas: the programme of neighbourhoods of prefabricated houses for the neediest section of the population, *Casas Económicas* (affordable housing) for those "protected by the state" and quality dwellings for the elites and wealthier classes.

The *Casas Económicas* neighbourhoods (Encarnação, Alto da Ajuda, Alto da Serafina, Alvito, Madre Deus), built from 1933 onwards, were characterised by small single-family residences with a garden at the front and an open space at the back, served by a network of very small roads. The aim of these neighbourhoods was to provide modest dwellings with good, healthy living conditions for the poorest section of the population. As Tostões states (2004: 289), these neighbourhoods combined the *"spirit of the "Portuguese house" with the theory of the "minimal house" and the rural image of the "village" with the Garden City".*

The better quality dwellings for the wealthier classes of the time, which are the subject of this study, aimed to replace the earlier "gaioleiro" ("birdcage") model – with its functional and social mix within the dwellings – and to reflect, both in morphological and aesthetic terms, the superiority of the Estado Novo (Pereira, 2006: 8). These dwellings, in the form of multifamily residences, were developed by the private sector but regulated by the public sector.

In the years following the Second World War the consequences of various changes in family life were felt in urban concentrations. The agents of change are associated with a complex set of causes. In a basic analysis, the following may be highlighted: the economic revival and reduced unemployment; improved living standards and increased consumption of new technology for the home, such as electrical domestic appliances, audio and TV equipment and non-essential goods; the new status of working women who no longer stayed at home during the day; the renting or buying of homes by the majority of young couples; falling birth-rates and the creation of pre-school facilities.

Housing construction boomed during the post-war period and, within this context, the high price of building materials meant that the state promoted collective accommodation in preference to single-family residences.

7.2.2 Functional characterisation

The functional characterisation presented in this chapter considers, principally with regard to individual dwellings, the use of spaces planned in the design phase and defined in the building project records. This is relevant to the analysis of the dwelling in terms of its functional sectors – private, social, service and circulation.

URBAN STRUCTURE

In the majority of cases, "rabo-de-bacalhau" buildings are located in built-up areas of the city which expanded in the 1940s, 50s and 60s.

The Alvalade and Avenidas Novas areas, which represent an urban fabric planned from scratch combining various urban models in a rich typological and functional blend, contain the largest number of examples. Other cases were studied in Benfica, Anjos, Ajuda, Restelo and Campo de Ourique.

Rabo-de-bacalhau buildings are built in an urban front to form blocks which were very often combined with other types of buildings. It should be emphasised that none of the buildings studied were end buildings (Figure 65).

The urban areas in the study have a high level of collective facilities and great functional diversity, with residences coexisting with shops, services and schools and other facilities.

In all the cases analysed, the main urban problems are the deterioration of public communal areas and areas inside the blocks, the need for public parking space, the falling number of residents and increased occupation of housing by the service sector.

Figure 65 – Aerial photograph of the S. João de Deus area in Lisbon showing the "rabo-de-bacalhau" buildings (source: Google maps)

THE BUILDINGS

The configuration of the "rabo-de-bacalhau" buildings is characterised by a symmetrical plan consisting of a sequence of two or more rectangles, the smallest of which overlooks the open space in the rear.

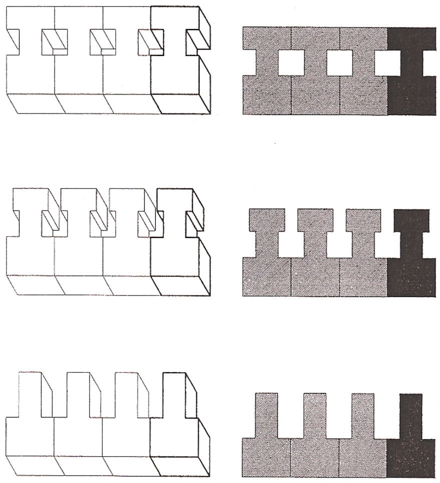


Figure 66 – Composition of plan of inner yards and their evolution. Opening up and widening of lateral yard (Reis, 2000: 57)

According to Reis (2000: 56), the shape of the rear of the "rabo-de-bacalhau" is the result of the widening of the (side and interior) yard to the back of the building, meaning that the inner yard was completely merged with the open space in the rear. In various Lisbon blocks it is possible to observe the evolution of the inner yard from its beginnings, when it was enclosed in the centre of the building or adjacent to the side wall, to its complete opening out onto the open space in the rear (Figure 66).

According to Teotónio Pereira (1995), the need for large areas for more expensive housing required buildings with greater depth which was only possible through the trick of the "rabo-de-bacalhau" shape. In fact, this solution, involving projecting wings, took advantage of the best perimeter-area relationship for the building and enabled rooms set halfway along the depth of the dwelling to receive natural light and ventilation.

The main façade overlooking the road or garden is the most representative area of the building where the prime rooms are preferably located. The service areas, dining room and private area are preferably located in the rear façade and rear wings are, in various cases, the secondary stairs for the building.

In the universe studied the evolution of this type can be clearly observed in terms of the geometry of the side yard, which would certainly have had its origins in the evolution of the building regulations in force at the time. According to Reis (2000: 80), the RGEU banned the use of indirect, reflected or diffused light as the only form of natural lighting in certain parts of buildings (forbidding it in inner habitable rooms) and introduced what may be called the 45º rule which banned inner yards and rooms with windows bordering on neighbouring buildings. Some of the buildings studied pre-date the RGEU, and the inner yard is extremely deep, containing the only exterior door/window opening in several of the rooms. In other buildings constructed after the RGEU the inner yard has practically disappeared and the effect of the "rabo-de-bacalhau" shape is minimal.

The repetition of "rabo-de-bacalhau" buildings throughout a street enabled the width of the inner yard to be doubled, increasing the quality and amount of sunlight and ventilation (Figure 67). This creates a "*compromise*" in terms of building "*in which buildings can interact, due to their continuity and complementarity, to define the shape and size of this source of ventilation and natural lighting*" (Reis, 2000: 63).

The area for "rabo-de-bacalhau" buildings, excluding the garages which extend along the open space in the rear and annexes, varies between a minimum of approximately 170m^2 and a maximum of 575m^2, with the average being 290m^2. The width of the façades ranges from a minimum of 11.5m to a maximum of 36.65m, with an average of 17.7m. The depth of the buildings ranges from a minimum of 14m and a maximum of 28.4m, with the average being 20.6m. The width of the façades and the depth of the buildings are characteristics used later in this study to define different sub-types of "rabo-de-bacalhau" buildings.

Figure 67 – Plot occupied by "rabo-de-bacalhau" buildings, whose repeating inner yard arrangement over several neighbouring buildings allows their area to be doubled. (source: http://lisboainteractiva.cm-lisboa.pt/)

All the examples studied have a left/right arrangement with symmetrical plans in most cases. The asymmetrical plans found in 5 of the 25 examples are due to the uneven number of rooms in the main facade, meaning that one dwelling has one more room than its symmetrical pair (generally used to supplement the social area). The universe studied contains 6 small 4-story buildings (8 dwellings) and 19 medium-sized buildings with 5 to 9 floors (18 dwellings). The average number of floors is 6, with the top floor usually designed as a mansard.

The buildings with the largest number of floors are located in areas with recent constructions in the more central districts of the city, namely Avenidas Novas and Alvalade, whilst the buildings with the smallest number of floors are in the more peripheral areas of the city, such as Benfica, Ajuda and Restelo.

The accommodation is arranged centrally on each floor around a vertical access column, with two dwellings per floor. In all cases, this column stands in the central nucleus of the building and in 13 cases there is also a second access column in the form of a stairway in the rear of the building.

Access

The building is accessed from the exterior by the main door (Figures 68 – 4 and 6) and also, in several cases, by a service door (Figures 68 – 1). There is often a flight of steps in the entrance hall leading from street to ground floor level (Figures 68 – 5 and 7). Less frequently, the street level is virtually the same as the ground floor, which facilitates access for elderly people or those with restricted mobility, or even people overloaded with shopping.

Figures 68 – Av de Roma, 85 (1: Main and secondary door of building, 2: Main entrance hall, 3: Service entrance hall); Pr. Afrânio Peixoto 12 (4: Main door of building, 5: Entrance hall); Av. Barbosa du Bocage, 90 (6: Main door of building, 7: Entrance hall). (photos: SE 2010)

Great importance is attributed to the service entrances, since in 44% of the examples two entrances to the building (main and service) can be found and in 88% of the cases there are also two entrances to the individual dwellings. The service entrance to the building usually serves as an emergency or service stairway and is connected to the caretaker's home and rubbish storage area (if it exists), in addition to providing access to the open space in the rear.

The two different entrances to the building enabled domestic employees to be segregated from the family and their guests, from ground floor level onwards.

With regard to vertical access within the buildings, two vertical access nuclei to the various floors can be found – a main nucleus and a service nucleus. The vertical access nuclei consist of two completely separate (adjacent or distant) nuclei in 15 cases (Figure 69 and Figure 70), two nuclei in separate areas that are connected in 7 cases (Figure 72), and a single nucleus in 3 cases (Figure 71). As the buildings have a symmetrical left/right arrangement, all the nuclei are located in the axis of symmetry for the building. The main access nucleus is found inside the building and in 13 cases (52%) the service stairs are adjacent to the rear façade.

The main vertical nucleus takes the following forms: stairs and lift (11 cases), stairs only (8 cases) and lift only (6 cases). 72% of the buildings have a main lift and only 32% have a service lift.

All the buildings analysed have at least one staircase and 60% also have a service staircase.

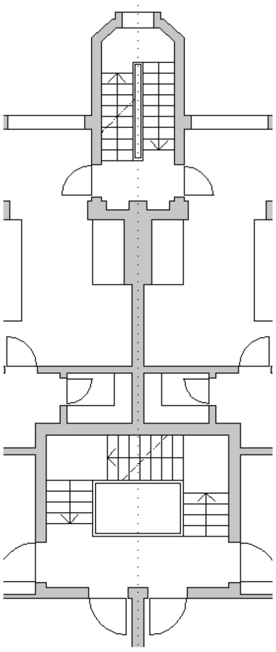
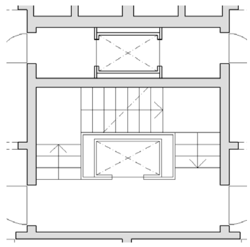
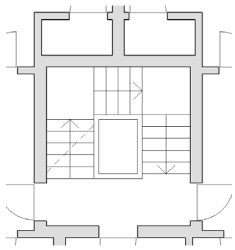
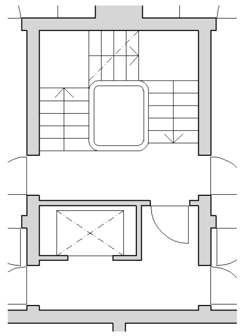





Figure 69 (left) – Two separate distant nuclei

Figure 70 (top left) – Two separate adjacent nuclei

Figure 71 (top middle) – Single nucleus

Figure 72 (top right) – Two nuclei in separate but connected spaces

The lifts are either located in the stairway (Figure 70) or in their own area (Figure 72). In all the buildings, the existing lifts are not of an appropriate size for wheelchair users. The position of the lifts is influenced by the morphological structure of the building and any alterations, if feasible, would only improve the building if they allowed for a larger cab, which would only be possible if part of the private areas of the dwellings were used.

There are three different solutions for the layout of the lobby on each floor:

1) A single lobby with only one entrance to the dwelling (Figure 71);
2) A single lobby with two entrances to the dwelling;
3) Two communicating lobbies, each with a different entrance to the dwelling (Figure 72);
4) Two non-communicating lobbies, each with a different entrance to the dwelling (Figure 69 and Figure 70).

Caretaker's home and service areas within the building


Figure 73 (left) – Caretaker's home. (photo: SE 2010)

Figure 74 (right) – Rubbish collection area, inadequate by today's standards. (photo: SE 2010)

The caretaker's home is a common feature in these buildings, and is included in 72% of them, either on the ground floor or on the top floor mansard. Some buildings still retain a caretaker, whilst in others the position no longer exists and the space is used for other purposes.

The following other communal or semi-private areas can be found in the buildings: 24% of the buildings have individual condominium store-rooms; 28% have parking spaces in the open space in the rear; 88% have an area where rubbish can be put out for collection (although very small and not including the current requirement for containers for recycling paper and packaging); in 52% of the buildings the ground floor is totally or partly occupied by shops.

THE DWELLINGS

Dwellings in "rabo-de-bacalhau" buildings are characterised by the very marked segregation of the various functional areas, particularly the room between the service and the social or private areas.

The private sector contains the family bedrooms and associated bathrooms, the social sector contains the sitting rooms and office and the service sector contains the kitchen and supporting rooms.

The segregation of the private sector reveals a clear intention to preserve family intimacy, placing greater importance on individuals and their privacy (Pereira, 2006: 11). The totally separate service sector containing the kitchen, maid's bedroom and bathroom, larder and glassed veranda, is located in the less prestigious part of the dwelling, set apart from the family living area. This distance reinforces the social hierarchies evident in the organisation of domestic space, together with the role of the woman – "*the professional home-maker*" (Pereira, 2006: 11).

As a legacy of the 19th and earlier centuries, the presence in middle and upper class households of one or more live-in domestic employees, commonly known as "maids", remained until roughly the 1970s in Portuguese urban districts. This had its origins, even amongst the less well-off families, in the need for help not only in looking after children at home until they reached school age, given the lack of facilities such as crèches and kindergartens, but also in supporting elderly people living in the home. It should be noted that this work was mainly undertaken by young girls from rural areas and was very badly paid, which meant that families could easily accommodate the expense. In this context, it was common for the programme for Portuguese middle and upper class urban housing built between the 1940s and 1960s to include a bedroom and separate bathroom for the "maid".

This marked separation between the service areas and the other functional areas reflects the social segregation that is characteristic of the period.

The social sector maintained the tripartite features of the "gaioleiro" model with the existence of three areas in the better quality dwellings:

- A living room for receiving formal visitors;
- A dining room established as the informal family living area;
- An office for the head of the household who, even if working outside the home, needed a work area in order to reinforce his role. This space, if it exists, is autonomous as it usually has a separate entrance. In some cases the space was also used as a guest bedroom.

The large circulation areas, consisting of corridors and anterooms in the connections between the different functional sectors, are another general characteristic of these dwellings.

On average the dwellings analysed had 7 habitable rooms[42], ranging from a minimum of 4 (1 room, 2 bedrooms, 1 kitchen) to a maximum of 10 (4 rooms, 3 bedrooms, 1 dressing room, 1 maid's bedroom, 1 kitchen). On average, the dwellings had only two bedrooms (excluding the maid's room).

Access to dwellings and circulation areas

The buildings studied often had two entrances (88% of cases) – a main entrance linked to the social and private areas and a second or service entrance linked to the service area.

All the dwellings had an entrance hall with direct access to the social areas and access by corridor to the service and private areas. In 32% of cases there is direct access to at least 1 bedroom via the entrance hall.

The design of the circulation areas in dwellings is the result of their position within the system and the relationships between the social, private and service areas. The corridors are L-shaped or winding and vary in size (Figure 75).

Most dwellings typically have large circulation areas averaging around 17.7m^2 and totalling approximately 16% of the average floor area.

Figure 75 – Circulation areas.

Social areas

Most of the social areas face onto the main façade. In only 3 of the 22 cases analysed the only living room was located in the rear façade (Figure 77). All the dwellings had at least one living room and 71% also had a dining room. In only 5% of cases one of these rooms was an interior room, demonstrating a concern for health, ventilation and lighting issues stipulated in the RGEU from 1951 onwards.

In 41% of the cases there is a habitable room adjacent to a living or dining room with a door to the outside landing. This room is usually known as an "independent room" and may exist on both sides of the building or only one if the dwellings are asymmetrical. The independent room was used as an extension of the living room or sitting room, as a possible guest bedroom or as an office for the head of the household and could also be used as a reception room on special occasions or even as a room that could be let. It should be noted that many people who lived in Lisbon came from rural areas or areas with little urban development and it was common to let members of the family stay with them free of charge when visiting Lisbon, or to rent out these rooms. Only 10% of the dwellings have an office area specifically designed as such in the plans and all the offices were located in this "independent room".

The family rooms are divided into living rooms, dining rooms or, in the more modest dwellings, a combined living/dining room. Where two spaces exist for this purpose they are either adjacent and face onto the main façade (Figure 78) or are separate, with the living room on the main façade and the dining room nearer the service area (Figure 76).

Since the "reception room,", generally called the *living room* or *family room* in the plans, was a room reserved for receiving visitors, this justified the existence of a dining room for the various functions that were part of the daily routine within the living area where people usually gathered together at various times of day. The dining room, as it is called in the plans, functioned simultaneously as a place where meals were eaten and as a family living room – for reading, studying, sewing, recreation and listening to the radio and TV.

The areas of the rooms in the social area vary as follows:

- Rooms with areas of 8.6m^2 to 26.1m^2.
- Dining rooms with areas of 10.3m^2 to 26m^2.
- Offices with areas of 10.6m^2 to 15.1m^2.
- The average for all social areas is 14.3m^2.

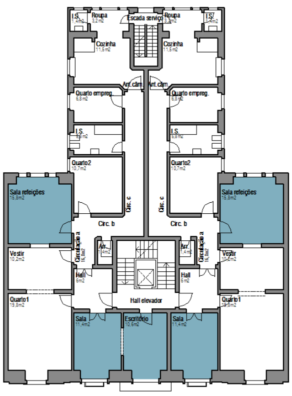


Figure 76 – Social area consisting of living room, dining room and office.

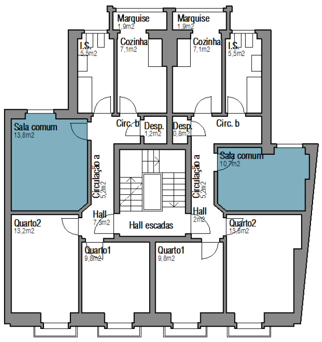


Figure 77 – Social area consisting of living/dining room only, overlooking the rear facade of the building.

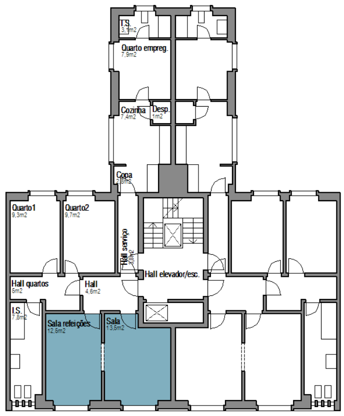


Figure 78 – Social area consisting of living room and dining room only.

PRIVATE AREAS

The private areas (bedrooms, dressing rooms and bathrooms) are usually located in the front wing of the building and are served by a nearby bathroom (Figure 79). The bathrooms are located near the service areas and further away from the private areas only in the older or smaller typologies (Figure 81).

The private areas have the following features: all the dwellings have at least one bedroom and one bathroom; 80% of the dwellings have at least 2 bedrooms; 36% of the dwellings have 3 bedrooms; 8% of the dwellings have 4 bedrooms; in 3 cases the second bedroom is an interior room; 24% of the dwellings have a dressing room (an interior space annexed to a bedroom, Figure 80).

The bathroom facilities occupy two rooms: one for the residents, usually in the private area and another near the "maid's" room for the use of domestic employees.

In 18% of the sample the private bathroom is very close to the service area, given the narrow ground plan which meant that the building required greater depth (Figure 81). Only three of the dwellings studied had one single bathroom. In addition, only one case had three bathrooms, namely two private and one service bathroom. In 24% of cases there was a washbasin near the social area.

The areas of the rooms in the private area vary as follows:

– Bedrooms with areas of 9.9m^2 to 20.2m^2 , with an average area of 12.75m^2;
– Dressing areas (inner rooms) with areas of 6.3m^2 to 10.2m^{2,} with an average area of 7.45m^2;
– Private bathrooms with areas of 3.4m^2 to 9.3m^2, with an average area of 5.65m^2.

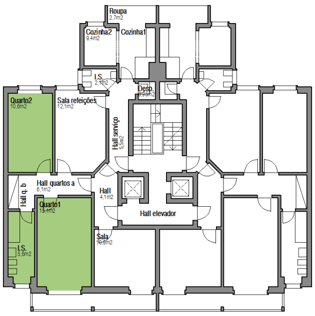


Figure 79 – Private area consisting of two bedrooms and a bathroom.

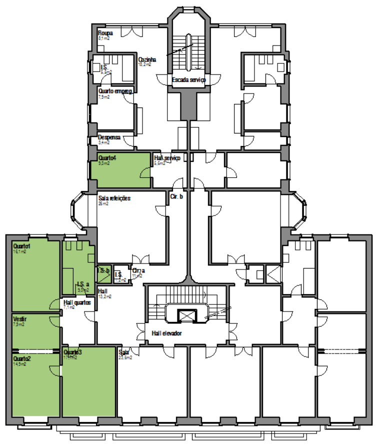


Figure 80 – Private area consisting of three bedrooms, a dressing room, a bathroom and a separate bedroom near the service area.

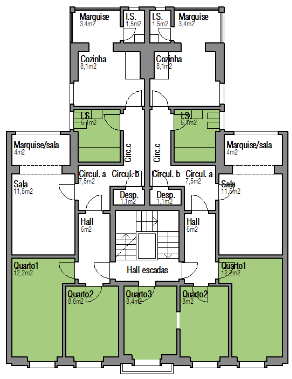


Figure 81 – Private area consisting of two bedrooms with door/window openings onto the main façade and one bathroom near the service area.

SEERVICE AREAS

The rabo-de-bacalhau typology is characterised by service areas located in the rear of the dwelling, clearly set apart from the social and private areas so that domestic employees never intruded on residents and visitors. These areas generally consist of a kitchen, glassed veranda/laundry, maid's bedroom, service bathroom and larder (Figure 82 to Figure 85).

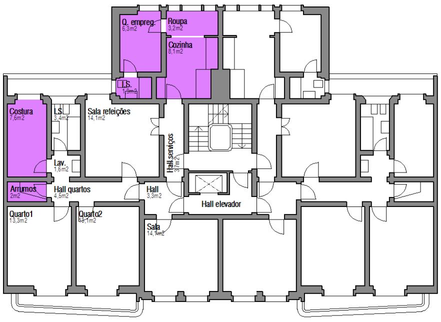
The following features were found in the cases studied: all the dwellings had a kitchen; 12% had a pantry; 84% had a laundry; 12% had an ironing or sewing area (separate from the maid's room and glassed veranda); 76% had a maid's room; 84% had a service bathroom, 80% had a larder and 36% a second storage space.

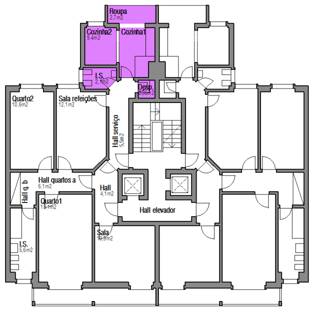
The areas of the rooms in the private area vary as follows:

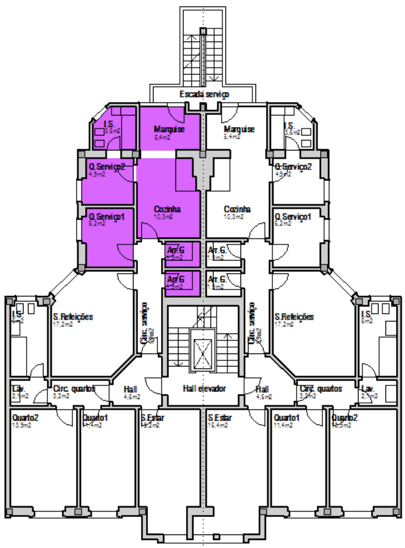
– Kitchens with areas of 7m^2 to 18.2m^2 , with an average area of approximately 9.7m^2;
– Glassed verandas/laundry areas with areas of 1.8m^2 to 8.1m^2, with an average area of approximately 3.68m^2;
– Service bathrooms with areas of 1.4m^2 to 5.5m^2, with an average area of approximately 3m^2;
– Maid's bedrooms with areas of 4.9m^2 to 9.5m^2, with an average area of approximately 7m^2;

- Ironing or sewing areas with areas of 4.4m^2 to 7.6m^2, with an average area of approximately 5.6m^2;
- Pantry with areas of 2.8m^2 to 7.3m^2 (identified in 2 cases only).

The “rabo-de-bacalhau” rooms with a window opening onto the side inner yard are usually the service rooms and include the maid’s bedroom. The 1930 Regulamento Geral da Construção Urbana para a Cidade de Lisboa (RGCUCL – General Urban Building Regulations for the City of Lisbon) state that inner patios/yards were only permitted to provide lighting and ventilation for larders, corridors, bathrooms, toilets, cloakrooms, stairs, kitchens and only one habitable room for storage. These rooms ranked lower in the hierarchy of the dwelling.







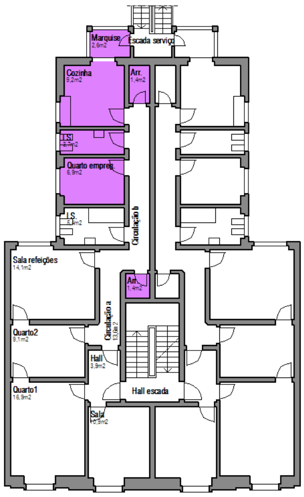


Figure 82 (top left) – Atypical service area due to the sewing area near the private area of the dwelling.

Figure 83 (top right) – Service area with kitchen divided into two, glassed veranda/laundry area, larder and bathroom.

Figure 84 (bottom left) – Very complete service area occupying a large area of the dwelling.

Figure 85 (bottom right) – Typical service area with kitchen, glassed veranda, bathroom, larder and storage area.

Private outdoor spaces

84% of the dwellings studied had balconies. If they faced the main façade these were very small, serving only as a compositional feature of the façade. It is therefore unusual to find enclosed balconies on the main or rear façade[43] (only four buildings had at least one enclosed balcony).

7.2.3 Constructional characterisation

The buildings studied were expected to present a considerable number of construction solutions, given the number of master builders cited in the records. Nevertheless, it is possible to identify certain patterns of construction which are analysed in *Part 1: Chapter 2* in terms of identifying the intervention work that should be carried out.

The constructional characterisation which follows is based on an interpretation of data gathered from the building project records consulted in the CML (the architectural and stability specifications) or provided by architects responsible for rehabilitation projects involving these buildings and, in some cases, rehabilitation work on "rabo-de-bacalhau" dwellings which the author had the opportunity to observe. In most cases the existing CML data proved not to be very detailed. The design documents are generally on a scale of 1:100 and construction details on scales of 1:10, 1:5 e 1:2 were only available in a few cases.

PRIMARY CONSTRUCTION COMPONENTS

FRAME STRUCTURE AND FOUNDATIONS

Buildings constructed during the period 1940-1960 generally have a mixed structure of reinforced concrete and stone or brick masonry. The so-called "fully reinforced concrete" structures first appeared in the 1930s-40s but only became common in the 1950s. The period that extends to the mid 1960s features reinforced concrete frames, with double walls in brick masonry and inner dividing walls also in brickwork, generally in stretcher bonds.

The cases in the study include buildings with reinforced concrete in side walls and some of the more essential parts of the building (Monteiro, 1948b) such as pillars and beams (on some floors) and others which use reinforced concrete only in the floor structures. In some cases there are references to beams in interior walls on "*alternate floors*"[44] only.

The flooring on each storey consists of reinforced solid concrete slabs or light flooring in the form of prefabricated and pre-stressed reinforced concrete components (Cabrita *et al.*, 1993: 59) (DELNEC, 2005). In some cases the slabs on the top floor ceiling are also made of reinforced concrete. The thicknesses referred to in the specifications are extremely small, ranging from 0.10m to 0.12m. The ground floors consist of concrete grout on "*irrigated and compressed landfill*". Only one reference was found for floors composed of 16x8cm pine beams throughout the dwelling with the exception of the bathroom/kitchen/laundry areas where reinforced concrete slabs were used.

In most cases the foundations are made of reinforced concrete (some cases refer to ordinary concrete) beneath pillars and continuous foundations of hydraulics masonry beneath dividing walls. One case was also found in which the foundations were made of timber piles or pier foundations.

Some buildings constructed at the beginning of this period also have a glassed veranda in the rear with a metal structure typical of the "gaioleiros" buildings (Appleton, 2007: 35). However, in the examples presented, which date from the 1950s, this area is integrated into the kitchen, and joined to the rest of the building using reinforced concrete. This constructional change does not alter the functional organisation of the service areas in any way, and these remain in the same arrangement in the rear of the dwelling.

EXTERIOR WALLS (FAÇADES AND SIDE WALLS)

In most cases the main and rear exterior walls have a reinforced concrete beam and pillar structure filled with two panels of solid stretcher bond brickwork and airspaces of varying sizes (0.05 to 0.08m). The thickness of the main façades varies between 0.35 and 0.4m. In some cases the main façade is made of reinforced concrete up to the level of the first floor.

The side walls are frequently built from reinforced concrete with thicknesses ranging from 0.2m to 0.3m. In some cases the side walls are built from reinforced concrete up to the level of the first floor with a (pillar and beam) reinforced concrete structure on the floors above, filled with brick masonry (to a thickness of 0.25m) or concrete blocks.

INTERIOR WALLS (LOAD BEARING AND NON-LOAD BEARING PARTITION WALLS)

There are three types of interior wall: partition walls between rooms, partition walls between different dwellings and staircase partition walls.

The partition walls are built from hollow or solid stretcher bond brick masonry[45], depending on the floor in question. The most common arrangements are: double stretcher bond solid brickwork on the ground floor, normal stretcher bond solid brickwork on the middle floors (e.g. the 1st and 2nd floors) and stretcher bond hollow brickwork on the upper floors (e.g. the 3rd and 4th floors). Indications that non-load bearing walls are made built from hollow stretcher bond brickwork appear frequently. Interior walls which separate neighbouring dwellings (described in the specifications as "*party walls*") and stairways and lifts are made from header bond[46] solid brick masonry (on the lower floors) and hollow brick masonry (on the upper floors) also using a cement and sand mortar.

STAIRS

The communal (main and secondary) stairways in the buildings are made of reinforced concrete and consist of straight flights separated by landings.

If there is a lift in the stairway, there is a support of up to approximately 0.9m high for a metal grating partition up to 1.5m high which surrounds the lift. In cases where the stairs are separate from the lift, the support consists of concrete walls approximately 0.6m high on which protective iron and wood railings or painted iron railings stand, approximately 0.9m high.

ROOF COVERINGS

The coverings are mainly sloping and consist of Marseille clay tiles, with the necessary tile steps, laid on a wood structure (usually national pine). In some areas there are flat surfaces built from reinforced concrete slabs.

SECONDARY CONSTRUCTION COMPONENTS

EXTERIOR DOORS AND WINDOWS

The exterior openings, standard and full-length windows, are embellished with cut stone masonry and have enamel-painted frames made of resinous wood, pine or "casquinha" (Scots pine).

In the majority of cases the main door to the building is made of enamel-painted iron with geometric designs. Main doors in wood, also enamel-painted, are less common (Figures 86). The panes of glass referred to in the specifications are 3mm thick "*national smooth sheet glass*".

The windows often have blinds/jalousies which roll up into a case concealed in the lintel. The standard and full length windows are casement windows with 2 or 3 panes. The window panes either contain a single pane of glass or are divided into 3 or 4 horizontal panes (Figures 87).

INTERIOR WOODWORK

The doors, skirting boards and other interior woodwork are usually in national pine or "casquinha" (Scots pine) finished with three coats: one undercoat and two oil-based coats, the latter in enamel.

In some cases better quality timber has been used in the communal areas of the building.

Sections of some interior doors are glassed using "*false cathedral sheet glass*".

Figures 86 – Entrance doors to the building (photos: SE 2010)

Figures 87 – Windows (photos: SE 2010)

Figures 88 – Balconies (photos: SE 2010)

Balconies and metalwork

The full length windows have small balconies with reinforced concrete or stone supports set in the façade. In most cases the protective panel consists of a low masonry wall with a wrought or cast iron enamel painted railing on top. There are also panels made entirely of wrought or cast iron and entirely of brick masonry, as used in the façade. The iron panels normally have simple geometrical, usually linear, designs (Figures 88).

Enamel-painted ironwork is also applied to interior railings and in some cases there are enamel-painted iron glassed verandas in the kitchens.

Coverings and finishings

Exterior wall coverings

On the exterior the decorative work on doors and windows and the decorative motifs on the façade are in cut stone masonry, generally hammered and smoothed limestone ("lioz" limestone). The remaining parament area is covered with a rendering simulating stone, (composed of air lime and calcareous aggregate) using a special technique, known in Portugal as marmorite, or a painted coating (made of lime and sand mortar or cement and sand mortar) The rear façades have an oil-based paint coating and, in some cases, cut stone masonry covering the walls of the ground floor up to the level of the first floor.

Interior wall coverings

The interior walls and ceilings are covered with plaster over a sand-based rendering or plastered with a cement and sand or lime and sand mortar. The final coating consists of an oil-based paint (usually matt) or a light plaster the same colour as the rendering.

In the bathroom, kitchen and laundry areas the walls are covered with marble or decorative tiles to a height of 1.5m and the rest of the wall is enamel-painted.

Decorative wall plates are usually applied.

Floor coverings

Inside the dwellings, in bedrooms, family rooms and corridors the flooring consists of wooden floorboards, parquet in national pine or cork tiles. In bathroom, kitchen and laundry areas the flooring consists of ceramic or hydraulic tiles. In the balconies the floors are covered with hydraulic tiles.

Floor and stairs coverings in communal areas

In the entrance hall to the building the coverings mainly consist of flooring and wall panelling in stone ("lioz" limestone) or wood. The ceilings and remaining wall areas are covered with painted plasterwork.

The stairs and landings are covered in pine and the surrounding walls are sometimes panelled in wood, corkboard or plaster.

Special installations

Domestic wastewater and rainwater drainage

In most of the plans analysed there was no description of the sewage network and they only stated that the project complied with the requisite legislation.

The scant information available indicates that the drop pipes and drains are made of glazed sandstone. Only one case in the study describes the drop pipes and the guttering as made of galvanised iron, as were the ventilation pipes.

Water supply network

In most of the plans analysed there was no description of the water supply network and they only stated that the project complied with the requisite legislation.

In only two of the cases in the study the licensing plan described the water pipes as being made of lead. The individual water meters were located inside the dwellings.

Electrical installations

In most of the plans analysed there was no description of the electricity network and they only stated that the project complied with the requisite legislation.

Only one of the cases in the study stated that the electrical installations in each dwelling consisted of a private panel and two circuits with interior *Bergman* ducting.

The individual electricity meters were located inside the dwellings.

Gas installations

There were no references to gas installations in the plans that were consulted.

However it is known from the intervention work carried out on some of the dwellings that were analysed and on the basis of the surveys that all the homes have original gas installations.

LIFT

52% of the buildings in the study had a lift and 29% had a second service lift. In the majority of cases the lift was located in the stairwell, although in some more recent buildings it has its own area.

OTHER TECHNOLOGIES

In addition to the infrastructures analysed previously and included in the licensing records that were analysed, it was also possible to verify the existence of the following systems in the dwellings analysed:

- Water-circulation central heating, using wood as a fuel. Wood burning stove in the kitchen with pipes set into the walls and linked to all rooms with wall radiators (Figure 89 and Figure 90);
- System for communication between rooms to contact the "maid" based in the service area (Figure 91).

Figure 89 (left) – Wall mounted heating equipment (photo: AC 2009)

Figure 90 (middle) – Wood burning stove for central heating (photo: AC 2009)

Figure 91 (right) – Communications system (photo: AC 2009)

7.2.4 Characterisation of technology used at the time of construction

In the 1940s/50s new technology appeared for the home and, consequently, new ways of using space emerged. Kitchens were redesigned to accommodate fridges, electric ovens and washing machines and television rooms began to appear.

The Second World War and the consequent entry of women into the world of work meant that after the war the ground was prepared for the development of domestic technology. The 1950s saw the start of high levels of consumption of domestic technology in terms of time-saving devices for women. However, it was only in the 1960s/70s that the first electrical domestic appliances became available at accessible prices and from this time onwards the home began to include countless items of equipment.

The domestic technology in use at the time when the "rabo-de-bacalhau" buildings were constructed was restricted to some simple items that were not in general use in Portuguese households but had been introduced into the domestic environment throughout the 1950s and 60s.

These included certain items whose use in the home depended on the financial resources of individual families: the radio (telephonic), record player, fridge, washing machine, black and white TV, vacuum cleaner, waxer, electric iron, fan, electrical push button controls, automatic system for opening the main door of the building, bar heater (Figures 92). Other electrical equipment for use in the kitchen included the mixer, coffee machine, hot plate, juice extractor / liquidiser/ squeezer, pressure cooker, toaster and, for the garden, the lawn mower and hedge trimmer.

Figures 92 – Some electrical domestic appliances used in the 1940s/50s: TV, bar heater, radio, waxer, Electrolux vacuum cleaner, fridge (sources: http://bragacity.olx.pt/ and http://www.ibiubi.com.br/)

7.2.5 Stylistic characterisation

The period under study was part of a controversial age in terms of the collective ideas underlying the practice of architecture in Portugal. This period was marked by the appearance of nationalist revivalisms associated with monumentalism and the end of modernism in Portuguese architecture (Tostões, 2004: 119). A great deal has, in fact, been written and debated on the subject of the role played by the Estado Novo regime in the eventual imposition of stylistic languages on architects and on the relationship between the latter and the fascist regime, both on an institutional and an ideological level.

At the 1948 Congress on Architecture, Pardal Monteiro[47] (1948a: 5), characterising the factors that contributed to the lack of freedom for the architect, referred to:

> "*obeying* (…) *the whims and almost tyrannical demands of municipalities* (…) and the *pretentions of a clientele dazzled by a lust for profit, demanding luxury and lies to the detriment of the art we* (the architects) *are qualified to serve*".

At the same Congress, Jacobetty Rosa[48] (1948: 73) stated:

> "*In official building programmes no form of subordination to architectural styles should be imposed on the planning process, or even suggested.*" On the same subject, he also concluded that "*The search for (…) the most appropriate form of architectural expression for a building should be governed by the artistic criteria of the architect who is designing it, (…)*".

Figures 93 – Façades of some of the buildings studied (Av. de Roma 47; Av. de Roma 82; Av. João Crisóstomo 70; R. Actor Isidoro 16; Av. da Igreja 63; Av. Guerra Junqueiro 7; Av. António Augusto de Aguiar 9, designed by Jacobetty Rosa, winner of the Prémio Municipal in 1943). (photos: SE 2010)

In the first half of the 20th century, residential architecture, principally in Lisbon, "*was modernist, but not yet completely modern, since it accepted the urban site plan of the time (deep and poorly ventilated) and it accepted the traditional urban plot with a façade overlooking the street and a back yard, although there were experiments with partial applications of concrete*" (Fernandes, 1993: 67). However, the abolition of decorative façades and their replacement with abstract compositions, as well as the new emphasis given to "*elements such as balconies, stairways and full length windows (…) in chiaroscuro* [accentuated] *the volumetric line and the vertical or horizontal predominance of the design*" (Fernandes, 1993: 68).

Some of these "rabo-de-bacalhau" buildings constituted what João Rodolfo (1999: 208) termed the "Estado Novo Model", which is characterised by a formal structure with classical features and "*a base, consisting of the ground floor* (…) [and] *entresol; four floors defined by a projecting façade, with the first window designed as a full length window and the remainder standard sized, and a top floor which resembles an attic.*"

Regarding the composition of the façade for the Av. António Augusto de Aguiar nº9 project, Cristino da Silva, the project coordinator, also appointed supervisor of architectural projects for the city of Lisbon in 1943, stated:

> "*Good classical examples adapted to our times and the main details, such as balconies and the tympanum of the first floor windows, the base and the main entrance, the decorative features of the windows, the cornice at the top of the building, etc…, were all developed within the spirit of national architecture.*"[49]

Reports of contemporary architectural design practices are available for the composition of the plans as well as the visible elements of the buildings, such as the façade:

"A while ago Lisbon City Council put a set of plots next to the Avenida António Augusto de Aguiar on the market and decided to "orientate" the architecture for this new area of the city. It began by deciding that the designs could only be produced by architects whose merits were recognised by the Council. Afterwards it attempted to explain to them what kind of architecture was intended – a difficult and impressive task – : it advised them to take inspiration from the Palácio Ludovice, the Companhia das Águas building, an eighteenth century property on the Rua dos Bacalhoeiros … a devil of a confusion. And so the good architects who were recognised by the Council began to rack their brains to satisfy its requests … and to invent the architecture the Council had dreamed of. I almost forgot to say that this guessing game only referred to the façades, since the plans were provided by the Council, as a suggestion of course, but making it clear that they thought it would be difficult to improve on them.

Only one architect, to my knowledge, refused to work under these conditions. And there you have it: the architecture of pomp-and-compromise resulting from the conditions under which these architects agreed to work became the standard for new buildings in the city." Keil do Amaral (1948)

The buildings studied have, on average, 6 floors and a right/left arrangement, with an axis of symmetry emphasising the location of the entrance door and the design of the façade.

One typical feature is the work on the volume of the façade, frequently achieved through a projecting façade on the intermediate floors with a row of windows on both sides on the lower and attic floor (Figures 93). The balconies and features such as pilasters and cornices defining the slabs create the effect of an interplay of horizontal and vertical volumes on the main façade which accentuates the chiaroscuro contrast.

The main entrance occupies a key position in the façade and in some cases is very impressive due to its design and pediment, whilst in other cases it is very simple.

With few exceptions, the design of the door and window openings is simpler and clearer than in previous periods and the panels also have simpler geometric designs.

In most cases the door and window openings on the main façade are small and uniformly sized. The rear façades also have small door and window openings (from bedrooms and bathrooms) with one larger opening in the service area (from the kitchen or glassed veranda) and, in some cases, a service stairway attached to the façade.

Eleven buildings in the sample were designed by architects and the remaining fourteen by engineers and engineering technicians, or else the designer's qualifications were not clear in the CML files.

7.3 Typification of the study universe

The criteria for analysis used in the previous sections enables the selected dwellings to be classified into categories which have similar features, known as typologies, and eventually for these categories, called types (Habraken, 1988), to be illustrated with concrete examples.

The typification of buildings constitutes a methodological procedure which aims to identify the unchanging characteristics that explain and distinguish types.

A type is based on a set of rules: typological design rules (organisation of the whole and particular type shapes) and technological design rules (the physical concretisation of the dwelling).

Van Leusen (1994: 22) considers type as a class of objects. Those objects can be understood as specific buildings and are designated by instances of the type. Types may be divided into sub-types by specifying differences in the essential properties they share with others of their type.

According to Habraken, the final result of the development of a type allows all the dwellings generated to be different but belong to the same family. From the moment we are familiar with a house type, we can rapidly identify another of the same type, since it is "written" using the same typological rules.

The choice of the universe of "rabo-de-bacalhau" buildings is, in itself, already a typological choice, in the sense that these buildings are characterised by their very similar functional, constructional, social and aesthetic aspects, amongst other factors, since they emerged during the same period of history. However, throughout the analysis it can be seen that even within an apparently similar sample there are clearly certain characteristics that enable individual cases to be "catalogued" under different "headings".

To produce a possible typification of the universe studied in this analysis, it was found necessary from the outset to have an understanding of the constructed plot, the building and the individual dwelling, given that the each one affects the others.

With regard to the plot available for construction, the sample does not contain differences that allow for differentiation between individual cases. Almost all the plots studied are rectangular. Solar orientation varies according to the location in the city where the building stands and does not affect the position of habitable rooms within the buildings. In other words, regardless of solar orientation, the dwellings are always designed in the same way.

7.3.1 Type

In the universe analysed in this study, it was possible to typify the "rabo-de-bacalhau" dwelling in accordance with characteristics common to all the cases in the sample. Within the base type (Figure 94), 4 sub-types of dwellings can be found which can be described as follows.

The base type has characteristics which are common to all sub-types:

- 2 dwellings per floor, on the left and right, which are symmetrical (except in rare cases due to the shape of the plot);
- A front wing with a façade overlooking the road which contains most of the rooms and is occupied exclusively by the social, private and circulation areas;
- A rear wing in the rear façade where the service areas are concentrated;
- A main access nucleus in the centre of the building which is not connected to either of the façades.

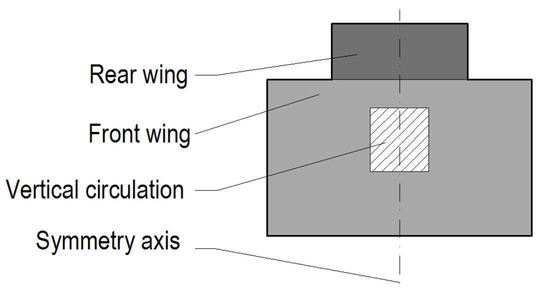


Figure 94 – Base type for "rabo de bacalhau" dwellings.

The 4 sub-types encountered were labelled "***Type A***", "***Type B***", "***Type C***" and "***Type D***". The characteristics used to distinguish between these sub-types were:

- Width of front wing;

- Depth of rear wing;
- Functional use of rear wing;
- Location of vertical accesses in building;
- Shape of interior circulation areas in the dwelling.

Type A

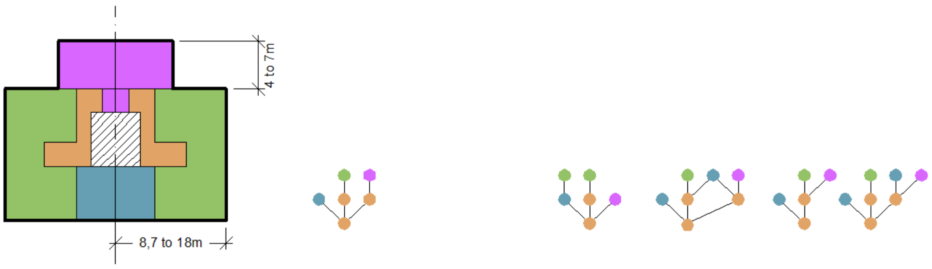


Figure 95 – Schematic floor plan and simplified graph of ***type A*** and other graphs based on examples of this type

There are 8 ***Type A*** (Figure 95) examples in the sample, all of which have the following characteristics:

- A front wing width of 8.78 to 18.33m – a wide plot;
- A rear wing depth of 4.15 to 7m – little depth to rear wing;
- A rear wing occupied only by service areas (circulation areas exist only if linked to service areas);
- 1 or 2 adjacent vertical access nuclei in the centre of the building;
- An inner circulation area consisting of a hall with two sections of linear perpendicular corridor leading off from it, creating an "L" shape;
- 3 or more habitable rooms in the façade overlooking the road;
- 3 to 6 circulation nodes and a total of 13 to 22 nodes in the dwelling;
- 4 to 7 bedrooms and rooms with natural ventilation. This number rises according to the width of the façade overlooking the street.

Type B

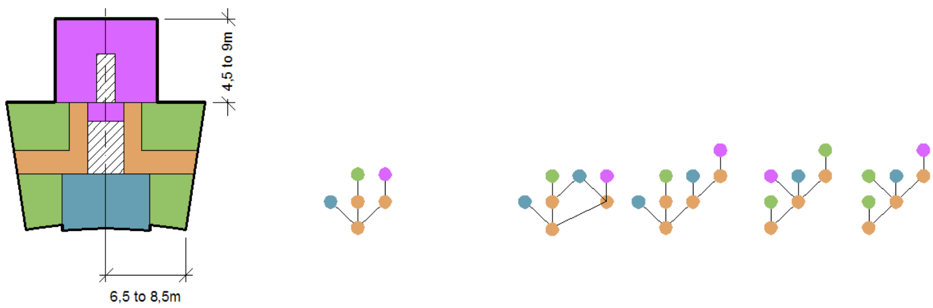


Figure 96 – Schematic floor plan and simplified graph of ***type B*** and other graphs based on examples of this type

There are 4 ***Type B*** (Figure 96) examples in the sample, all of which have the following characteristics:

- A front wing width of 6.28 to 8.50m;
- A rear wing depth of 4.50 to 9.15m;

- A rear wing occupied only by service areas (circulation areas exist only if linked to service areas);
- 1 or 2 adjacent vertical access nuclei in the centre of the building;
- An L-shaped inner circulation area;
- 3 or 4 circulation nodes and a total of 10 to 14 nodes in the dwelling;
- Only 2 habitable rooms in the façade overlooking the street;
- 3 to 4 bedrooms and rooms with natural ventilation.

TYPE C

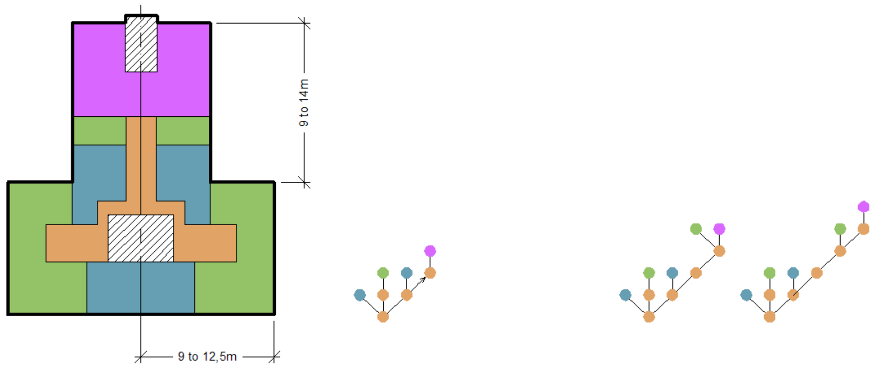


Figure 97 – Schematic floor plan and simplified graph of ***type C*** and other graphs based on examples of this type

There are 4 ***Type C*** (Figure 97) examples in the sample, all of which have the following characteristics:

- A front wing width of 9.15 to 12.45m;
- A rear wing depth of 8.94 to 14.35m;
- A rear wing occupied by service areas and also private and/or social areas;
- 2 vertical access nuclei in the building: a main nucleus in the centre of the front wing and a secondary nucleus projecting from or incorporated into the rear wing;
- A winding inner circulation area, with an entrance hall;
- 3 to 7 circulation nodes and a total of 16 to 20 nodes in the dwelling;
- 3 or more habitable rooms in the façade overlooking the street;
- 4 to 6 bedrooms and rooms with natural ventilation.

TYPE D

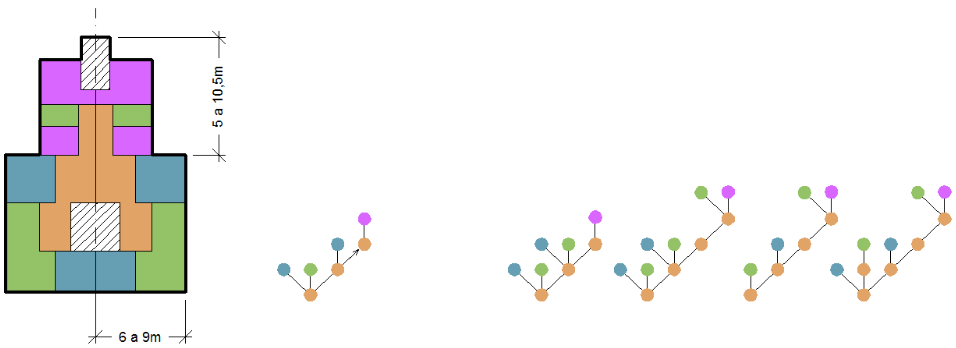


Figure 98 – Schematic floor plan and simplified graph of ***type D*** and other graphs based on examples of this type

There are 9 ***Type D*** (Figure 98) examples in the sample, all of which have the following characteristics:

- A front wing width of 5.75 to 8.88m;
- A rear wing depth of 4.93 to 10.50m;
- A rear wing occupied by service and private areas;
- 2 vertical access nuclei in the building: a main nucleus in the centre of the front wing and a secondary nucleus protruding from or incorporated into the rear wing;
- A winding inner circulation area, with an entrance hall;
- 3 to 5 circulation nodes and a total of 12 to 17 nodes in the dwelling;
- Only 2 habitable rooms in the façade overlooking the street;
- 3 to 5 (average 3.4) bedrooms and rooms with natural ventilation (excluding inner bedrooms).

COMPARISON

Type A	***Type B***	***Type C***	***Type D***
Rear wing not very deep		Rear wing very deep	
Wide front wing	Narrow front wing	Wide front wing	Narrow front wing
Service areas only in rear wing		Service, private and/or social areas in rear wing	
1 or 2 access nuclei (in centre of building)		2 access nuclei (in centre and rear wing of building)	
L-shaped circulation		Winding circulation	
3 or more habitable rooms in façade overlooking road	2 habitable rooms in façade overlooking road	3 or more habitable rooms in façade overlooking road	2 habitable rooms in façade overlooking road
3.8 circulation nodes	3.5 circulation nodes	5.25 circulation nodes	3.8 circulation nodes
12.5 nodes in total	12.5 nodes in total	18.5 nodes in total	13.7 nodes in total
4.8 bedrooms and rooms with natural lighting	3.5 bedrooms and rooms with natural lighting	5.25 bedrooms and rooms with natural lighting	3.4 bedrooms and rooms with natural lighting

Lowest values   Highest values

Table 13 – Comparison of the 4 sub-types

In accordance with the above description and as schematised in Table 13, the sub-types were grouped into sets with similar characteristics: width of front wing; depth of rear wing; functional use of rear wing; type and number of vertical accesses; circulation typology within the dwelling; number and type of rooms.

In the dwellings studied, certain adaptations of the type were found with regard to spatial organisation designed to include larger areas in the dwelling whilst maintaining the spatial relationships between them unchanged (Table 14). Thus, the larger dwellings are not only so due to the size of the rooms but also the inclusion of a greater number of rooms. In the smaller dwellings, some of the spaces characteristic of the type have been omitted (e.g. the maid's bedroom). Habraken emphasises that there is an apparent hierarchy within a type in which certain features should be omitted before others and some should never be omitted. These differences, which are deliberately created, constitute variations within a type.

With regard to syntactic properties it can be seen that, in general, there are no great variations between type and sub-types (Table 14). However, a more detailed analysis by functional area shows that, with regard to depth, the types have marked differences, in particular Type C –

which has deeper areas – and Type B – which is not very deep. These results suggest that "rabo-de-bacalhau" dwelling types A to D have particular characteristics which enable specific rehabilitation strategies to be carried out, which will be discussed in Chapter 4.

	Type		***Type A***		***Type B***		***Type C***		***Type D***	
	i	TDN	i	TDN	i	TDN	i	TDN	i	TDN
Min	1,78	34,00	1,73	35,33	1,87	20,50	1,82	52,50	1,75	29,33
Mean	3,14	48,74	3,11	51,98	3,32	**29,86**	3,01	**72,60**	3,12	42,18
Max	5,18	69,60	5,17	76,00	6,00	40,50	4,44	102,50	5,15	60,67
Private area	2,55	53,84	2,64	58,17	2,41	**34,50**	2,52	**79,05**	2,59	45,58
Social area	3,10	47,23	3,14	51,00	3,37	**28,00**	3,32	**65,38**	2,72	44,17
Service area	2,48	55,40	2,61	55,33	2,56	**33,17**	2,21	**88,70**	2,46	48,10
Circulation area	4,36	38,21	4,27	40,22	4,89	**23,25**	3,83	**58,77**	4,44	32,47

Table 14 – Integration (i) and total depth for current node (TDN) of original dwelling according to type (all calculations performed using AGRAPH software).

7.4 DIAGNOSIS OF CURRENT SITUATION

With regard to the characterisation of current conditions of use, two procedures were carried out in order to obtain data: i) consultation of the building project records in the CML archives to analyse all the existing alteration plans for the various dwellings studied; ii) a survey administered to the households in the 25 buildings studied.

There is very little information on the alteration plans submitted to the CML and after the survey was completed it was noted that in many dwellings alterations had been undertaken without formal authorisation by the CML. Efforts were therefore made to compare the data from the respondents with the data in the CML files in numerical terms, in order to analyse the scale of the work carried out without local authority approval and technical supervision[50]. It was found that in 5 cases there was official authorisation for changes to the morphology of the dwelling, whereas at least 21 interventions involving demolition and new building work had taken place.

The current conditions of use allow for an understanding of conflicts of use given current housing requirements, as well as the potential this building type affords.

Most of the residents proved very resistant to completing the survey. Only 39 of the 215 surveys placed in mailboxes were completed, corresponding to a return of 18%.

A single type of survey was used for all the dwellings, which included:

- A plan of the dwelling with a request for any alterations undertaken to be marked, together with the function of each room (e.g. bedroom, living room, etc.);
- Questions on the characterisation of the family (number of occupants and age);
- Questions on the characterisation of the dwelling (floor, year of occupation, building work carried out);
- Questions on water and sewage, electricity, gas, telecommunications, water heating and air conditioning infrastructures;
- Questions on technologies used, their location in the house and whether their installation had any impact on functional and/or constructional organisation.

With regard to the occupation of dwellings, the average number of occupants was 3.2, varying from 1 to 5 residents. It was common to find that the dwellings had been recently occupied by smaller households than those they had originally been planned for.

58% of the households that responded to the survey were sublet and contained only 1 or 2 residents. This situation mainly affected elderly people who had opted to stay in their original home and young couples without children.

Only 20% of the homes had been occupied since they were built by the same family and 23% had been reoccupied since the beginning of the 21st. century.

The aim of the analysis in this section was to understand functional change patterns in "rabo-de-bacalhau" dwellings and to assess the impact of technology on the homes.

7.4.1 Functional and constructional alterations to the dwellings

The data for this study came from the CML alteration records, information supplied by architects (4 cases) and valid responses to the surveys (35).

The intention was to understand interventions which had changed the functional arrangement of the dwellings, and any work which, for this reason, had weakened the load bearing capacity of the buildings.

The main alterations involving alterations to rooms correspond to recent occupations and are derived from a desire/need to provide more space.

In the majority of cases the number of rooms in the initial typology was reduced, usually by eliminating one or more rooms. The room most frequently altered was the living room (the room nearest the hall), which was extended by being joined to the adjacent bedroom. This was achieved in two different ways: either by entirely removing the dividing wall or by creating a wide opening in the wall between the two rooms. 22 families out of the 39 respondents used one room to create an office.

The creation of one or more new bathrooms, the room of the main bathroom into two or even the relocation of the service bathroom were also common practices. In some cases the decision was made to create an en-suite bathroom to avoid having bathrooms connecting to circulation areas.

As expected, the surveys revealed that the same rooms in a building were used in different ways.

There is no concrete data on the construction procedures involved in the demolition and construction of new walls, with the exception of three CML alteration records and information provided by architects which referred to two kinds of intervention work:

- New walls constructed using:
    - *"Omnilite board"* (very thin plates made of pressed wood chips with cement) which, due to its low weight, does not overload the structure;
    - A metal structure covered with plasterboard;
- Demolition:
    - Without intervention to the structure;
    - Replacement of demolished walls with metal beams supported by new reinforced concrete posts or existing pillars and steel mesh reinforced plaster on walls parallel and perpendicular to the demolished section.

Demolition of brick masonry which, unfortunately, was common has an effect on the load bearing capacity of the original reinforced concrete constructions, often creating structural deformations in areas where entire walls were demolished. These deformations took the form of deflection or sagging in slabs which were often the cause of other non-structural pathologies, such as infiltration and cracking.

Situations in which larger sections of walls in the dwellings were demolished affected the wall separating the two rooms on the main façade closest to the hall. In buildings containing two or more examples of alterations it could be seen that the demolition of this wall was a common feature, since it was also common practice to use the rooms as a living and dining room.

7.4.2 Use of technologies by residents

The survey included various items on the presence of technologies in the dwelling but, as was the case with the questions on functional organisation, few of the residents responded.

From the 39 responses to the survey, one family did not answer this set of questions and one reply came from an office, meaning that only 37 replies could be considered. The results were as follows:

- Equipment most commonly used in dwellings:
  - Fridge and freezer in 100% of cases;
  - Conventional telephone in 95% of cases and telephone via Internet in 13%;
  - Conventional television in 92% of cases and plasma or LCD television in 38% of cases (the most common television service is via cable TV);
  - Microwave in 89% of cases;
  - Washing machine in 81% of cases;
  - Personal computer in 76% of cases;
- Equipment and services with average use in dwellings:
  - Internet (various operators) in 68% of cases;
  - VHS or DVD player/recorder in 68% of cases;
  - Dishwasher in 62% of cases;
  - Audio equipment in 59% of cases;
  - Printer in 57% of cases;
  - Scanner in 48% of cases;
- Equipment and services found more rarely in dwellings:
  - Chest freezer in 27% of cases;
  - Drier in 24% of cases;
  - Washing machine/drier in 19% of cases;
  - Games console in 19% of cases;
  - Home cinema in 5.4% of cases (2 cases);
  - Fax in 5.4% of cases (2 cases);
- Automated systems related to domotics:
  - Gas detector in 3 cases (8.1%);
  - Smoke detector, flood detector, electric blinds and centralised control of air conditioning in 2 cases (5.4%);
  - Lighting sensor in one case;
- Domestic water heating system:

- 89% used a water heater;
- 11% used a boiler and thermoacumulator;

– Air conditioning system:
  - 19% used a heat pump;
  - 11% used a central gas system;
  - 65% had no central system;

Only 27 families out of the 37 respondents replied to the question on the location of equipment, enabling the following to be determined: with regard to television, all the families have a television set in the living room, 18% have one in the kitchen, 48% have one in the bedroom and 15% have one in the office. In terms of computers, 26% have a computer in the living or dining room, 26% have computers in bedrooms, 43% have a computer in the home office and only 1 resident said that their computer was portable and so was not used in any specific space.

From this sample of replies it could also be established that 32% had renewed the water and sewage network and 48% had carried out work on the gas supply network. The infrastructures updated in the largest number of dwellings were electricity and telecommunications, both in 55% of cases.

7.4.3 Main conflicts in use of space

In terms of the construction of the building the main conflicts of use analysed were the following: small lifts; lack of communal service areas; lack of distribution ducts for networks; lack of space for meters on the ground floor, lack of condominium storage and parking space.

The main conflicts in spatial organisation in "rabo-de-bacalhau" dwellings essentially concern the following aspects: the imbalance between habitable and non-habitable areas; the duplication of identical dwellings throughout the building; the existence of inner yards and consequently rooms with less illumination and ventilation; the segregated service areas; the existence of oversized service zones but small kitchens; small living rooms; the existence of interior rooms; few bathrooms; the existence of two nearby accesses to the dwelling; the excessive length of the circulation areas; small habitable areas; the lack of storage space; over-rigid partitioning.

From this analysis of the cases in the study, it may be stated that the residents' strategies generally followed the same path: expansion of the social area, reduction in the number of residents and the addition of a bathroom.

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[42] "A habitable division is a division in a dwelling designed for functions that imply lengthy presence, such as sleeping/relaxation (e.g. a bedroom), preparing meals (e.g. a kitchen), eating (e.g. a dining room), gathering/socialising (e.g. a living room), receiving visitors (e.g. a reception room) and recreation/study/ work (e.g. an office). In order to be considered habitable, divisions must comply with the conditions for area, floor-to-ceiling height and natural lighting defined in the current regulations. Habitable divisions do not include bathrooms, cloakrooms, corridors, stairs, glassed verandas, store rooms and larders." In **Laboratório Nacional de Engenharia Civil** (s.d): *Memorando. Definições de espaços e de áreas utilizados na Ficha Técnica da Habitação.* Available at WWW: <URL: www.fep.up.pt/disciplinas /PGI921/LNEC_memorando_areas.pdf>

In the analysis carried out, the divisions defined in the project as ironing and sewing areas were also considered to be habitable divisions. In addition to those excluded in the above definition, pantries, glassed verandas and dressing rooms were not considered habitable divisions.

[43] This excludes enclosed terraces in the mansard.

[44] Specifications for Av. de Roma nº 85 and Av. de Roma nº89. Cited for the Av. de Roma nº89 project.

[45] A brick stretcher bond involves laying bricks so that their width corresponds to the thickness of the wall ("aparelho de tijolo a meia vez").

[46] A brick header bond involves laying bricks so that their length corresponds to the thickness of the wall (as of they were bondstones) In this case, the rows alternate between one row of bricks laid lengthways and two parallel rows laid widthways ("aparelho de tijolo a uma vez").

[47] Pardal Monteiro was responsible for the Av. João Crisóstomo, 72 project included in the case study.

[48] Jacobetty Rosa was responsible for the Av. António Augusto de Aguiar, 9 project included in the case study.

[49] SILVA, Luiz Cristino da (1942). *Projecto de uma casa de rendimento que a firma José de Sousa Braz, lda., pretende mandar construir no seu terreno, sito na Avenida Oriental do Parque Eduardo VII – lote nºIV – Memória Descritiva*. Lisbon. Cited in (RODOLFO, 1999: 211)

[50] As the questionnaires are confidential, only the total number of alteration records and alterations carried out were compared, but comparisons were not made between specific cases.

PART 2 Rehabilitation Methodology

1 DEFINITION OF THE REHABILITATION METHODOLOGY

This research aims to define a rehabilitation methodology for Lisbon's existing housing stock to enable it to respond to new technology requirements and new lifestyles. The fundamental goal of rehabilitation is to upgrade houses by incorporating and updating ICT and domotics infrastructures, solving emerging conflicts affecting the use of space prompted by the introduction of new functions associated with these technologies.

Interventions to existing buildings are carried out for functional and technical reasons in order to improve dwellings. The rehabilitation of a building always means adapting it to meet current standards, either because of changes in user demands, which cause conflicts in terms of use, or the emergence of new technical regulations. The fulfilment of this goal requires a synthesis of architectural and technological work.

The proposed methodology provides for different rehabilitation solutions according to variable factors. As stated by Lawrence (1987: 251), rehabilitation or remodelling should not be carried out on the basis of "standard goals" as this approach would be inappropriate, given the diversity of families and their needs and lifestyles.

To tackle the problem of developing a general methodology for housing rehabilitation we used a case study, the "rabo-de-bacalhau" building type (*see Part 1: Chapter 7*). This allowed us to apply the methodology to concrete buildings so that transformation principles could be inferred and then tested. Only with a specific morphology would it be possible to test different hypotheses for functional rehabilitation. This means that, although the proposed methodology is generic to all residential buildings, applying all the steps of the methodology as presented in the following chapters, presupposes the rehabilitation of a "rabo-de-bacalhau" building type. However, the proposed methodology can be used simply to define the functional housing programme (Figure 99, path c) and the ICAT pack (Figure 99, path a or b), as described later in this chapter.

The work started with an analysis of contemporary demands for dwellings and the development of a knowledgebase for the existing ICAT sets for homes, to be taken into account in the application of the rehabilitation methodology The framework derived from this analysis is discussed in *Part 1*.

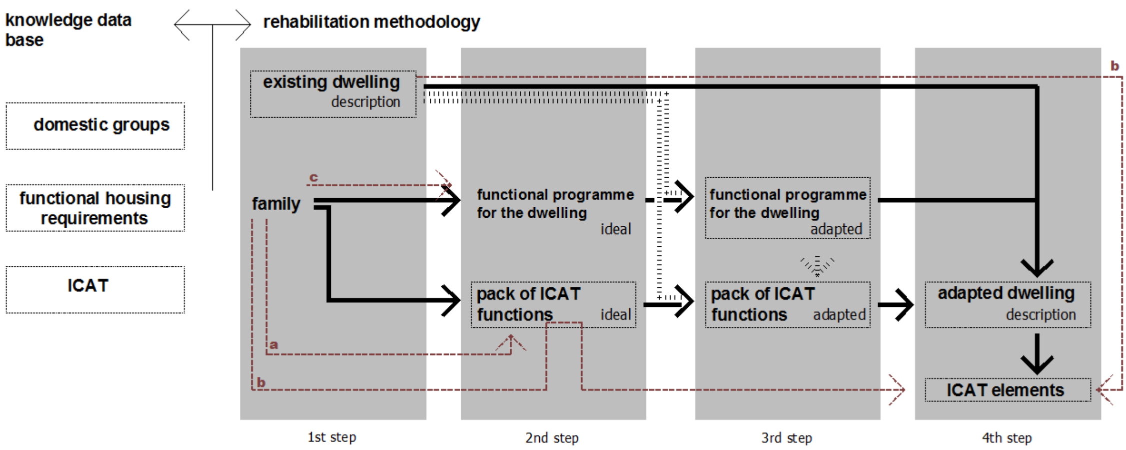


Figure 99 – Basic steps in the planned rehabilitation methodology.

We then proposed a hypothesis for such a methodology, based on the conceptual schema for the design process proposed by Duarte (2001) for the mass customization of housing, following March and Stiny's "Design Machines." (1981) According to this conceptual schema, the design process consists of two sub-processes: a formulation process that takes user and site data and generates a description of an appropriate house, and a design process that takes this description and generates a matching solution within a given design language. Accordingly, it was hypothesized that a rehabilitation methodology should encompass four steps, as shown in Figure 2.

Prior to the first step in the methodology a knowledge database was created, which plays a key problem-solving role (Bento and Côrte-real, 2000: 32). It contains the following knowledge, which is required in order to perform the proposed rehabilitation (Figure 99):

1. Domestic groups _ this knowledge base contains information on the various domestic groups and their characterisation Figure 2 (kinship, age, number) (*Part 1: Chapter 4*);
2. Functional housing requirements _ this knowledge base contains data on the functional and spatial requirements for the housing (*Part 1: Chapter 5)*. This information is cross-referenced with the family when the aim is to obtain a definition of the ideal functional programme for the dwelling;
3. ICAT _ this knowledge base contains data on ICAT for housing. In addition, there is information about the impact of these technologies on the dwelling and the inhabitants (*Part 1: Chapter 1*). This information will be cross-referenced with the family when the aim is to obtain a description of the ideal pack of ICAT functions;

This data constitutes the knowledge database for the methodology represented on Figure 2. With this knowledge and a set of algorithms and rules which determine how to act on the information, a particular dwelling can be rehabilitated for a particular family.

The first step in the rehabilitation methodology consists of gathering the data needed for the rehabilitation process, namely a profile of the household and a description of the existing dwelling:

1. Existing dwelling _ a description (characterisation, analysis and diagnosis) of the existing dwelling. The existing dwelling represents the major constraint on the rehabilitation process, (*Part 1: Chapter 7)*;
2. Family _ a profile of the future dwellers. Characterisation according to kinship, number and age is a condition for the proposed solution. If the future inhabitants are unknown a typical family will be assumed, according to the profile defined by the client (property developer) and developed in *Part 1: Chapter 4*;

In the second step, the household profile is used to determine the ideal functional programme for the dwelling – following Pedro's and Duarte's work on the housing programme mentioned above – as well as the ideal pack of ICAT functions.

1. Ideal functional programme for the dwelling _ this description comes from data obtained from the family and responds to their expectations and needs in terms of space. The functional programme in this case is a description of an ideal housing solution for the family that is not bound by any existing morphological structure or design language, since we are not yet considering the existing dwelling, (*Part 2: Chapter 2.2*)*;*
2. Ideal pack of ICAT functions _ this ideal ICAT description includes all the useful technologies for the family profile. Like the ideal functional programme, this ideal ICAT

pack does not consider the existing dwelling and therefore does not have any functional or constructional limitations, (*Part 2: Chapter 3.1*);

In order to incorporate ICAT into the dwellings, two complementary methods were established. Firstly, the introduction of ICAT in dwellings changes some aspects of living (e.g. home cinema, telework, etc.) which are taken into account in defining the functions of contemporary houses. Secondly, the introduction of ICAT in dwellings leads to physical changes in the house due to the need to accommodate cabling infrastructures and terminal elements.

In the third step, the existing dwelling, the ideal functional programme, and the ideal ICAT pack are used to derive a description of a compromise or adapted solution based on the existing dwelling. Since the solution is influenced by the existing morphological structure, it is necessary to transform the description of the ideal solution obtained in step 2 into the description of the adapted solution. The phases are as follows:

1. Adapted functional programme for the dwelling _ in this phase, the data obtained from the ideal functional programme is combined with the characterisation of the existing dwelling in order to define the adapted functional programme. This adapted functional programme will need to accommodate the morphological and constructional restrictions on the existing dwelling whilst still meeting the family's requirements, (*Part 2: Chapter 2.3*);
2. Adapted pack of ICAT functions _ in this phase, the data obtained from the ideal pack of ICAT functions is combined with the characterisation of the existing dwelling in order to define the adapted pack of ICAT functions. This adapted pack will consist of a set of functions which can feasibly be integrated into the existing dwelling, whilst still meeting the family's requirements, (*Part 2: Chapter 3.2*);

Finally, the layout of a design solution for the particular family in the particular dwelling is obtained from the description of the adapted dwelling, including the ICAT components needed in the dwelling. The data obtained from this final step is as follows:

1. Description of the adapted dwelling _ this phase is a result of the previous steps and consists of the final solution chosen for the existing dwelling. There are some examples of this step in *Part 2: Chapter 4;*
2. Description of ICAT elements _ when the adapted pack of ICAT functions and the description of the adapted dwelling are known, a full description can be provided of the ICAT elements that are to be included, such as the layout of the wiring, sensors and appliances.

The methodological hypothesis is to use description grammars, shape grammars, and space syntax as tools for identifying and encoding the principles and rules underlying the adaptation of existing houses to meet new requirements. The idea is to use such rules as part of the methodology for the rehabilitation of existing dwellings, as mapped out in Figure 2.

This chapter begins by discussing the possible scenarios for rehabilitation work within the context of this research, for which the proposed methodology is intended as a response. It then considers the phases involved in the rehabilitation design process and demonstrates the innovations which the proposed process brings to the traditional process.

Following this, the tools used to generate a housing transformation are identified and the advantages of their use within the context of this research are discussed. Finally, reference is made to the way in which the experiments that enable the transformation rules to be inferred and which are part of the rehabilitation methodology were carried out.

1.1 REHABILITATION SCENARIOS

When carrying out rehabilitation work on housing the following scenarios may be encountered:

i) A family intends to rehabilitate its current dwelling;

ii) A family is looking for a dwelling to rehabilitate;

iii) A property developer intends to rehabilitate an existing dwelling or building to sell or rent (in this case the future inhabitants are unknown).

In the first scenario the situations regarding both the dwelling and the family are known and the rehabilitation work should therefore be personalised. The functional programme for the dwelling and the pack of ICAT functions can be obtained by following the proposed methodology.

In the second scenario there is a family in mind but no dwelling. In this case the role of the proposed methodology is to propose a potential dwelling within the case study that could meet the family's needs.

The third scenario envisages a situation in which the building or dwelling destined for rehabilitation is known, but not the inhabitants. In this scenario, the property developer (a private or state developer) has to define a typical family profile according to the characteristics of the dwelling. Thereafter, the process is identical to the first scenario defined above. It may be undertaken by a private property developer intending to increase the value of the property and consequently the rent or sale value or by a state property developer with the aim of including rehabilitated housing on the market at accessible, controlled prices (as first homes for young people, or for the purposes of re-housing, for example).

In this scenario the default ICAT pack will be the minimum level, allowing for future upgrades according to the wishes of the residents. Integration at minimal level with full cable infrastructures will avoid any excessive use of ICAT that might be unsuitable for future residents.

These three cases characterise different types of demand and different owners. In the first and second cases the owners are specific families who engage in direct dialogue with the designers regarding the rehabilitation project for the dwelling they will inhabit. In the third case, the owner is an entity that will not live in the dwelling or building that is to be rehabilitated and, although they have well-informed intentions regarding the target market for their product, have no knowledge of the actual needs and characteristics of the domestic group that will inhabit the rehabilitated dwellings.

Scenarios i), ii) and ii) fall within the scope of this research because they include both families and dwellings.

Although it does not respond to the stated problem of this thesis, the data presented in Figure 2 can also respond to project requests that are different from those described above. Figure 2 shows three responses to different project requests, indicated by a dashed red line:

a. The ideal pack of ICAT functions can be obtained on the basis of knowledge of the family. This sequence of steps is defined in Figure 2 by the dashed red line labelled *a.*;

b. If the family and the existing dwelling are known but there is no intention of rehabilitating the dwelling, the pack of ICAT functions and description of the ICAT elements can be obtained. This sequence of steps is defined in Figure 2 by the dashed red line labelled *b*.

c. If the family is known, the ideal functional programme for the dwelling, as defined in PAHPA[51] software by Duarte (2001), can be obtained. This sequence of steps is defined in Figure 2 by the dashed red line labelled *c*.

Hypotheses *a* and *c* can be used to generate ideal functional programmes and ideal ICAT packs for any new construction or traditional rehabilitation process involving any building type. If this is the case, the functional adaptations of the dwelling may be drafted by hand.

Hypothesis *a* and *b* may be answers to scenario i) if a family intends to integrate ICAT but does not intend to do any rehabilitation work on the dwelling. This hypothesis may occur when an elderly or disabled person needs assistive technologies to perform daily tasks but lacks the financial means to rehabilitate the dwelling. The use of technology to support ageing in place is addressed in *Part 1: Chapter 6.2.6* and *Part 2: Chapter 3*.

1.2 THE REHABILITATION PLANNING PROCESS: PROPOSAL VS TRADITIONAL

In any form of building work and/or rehabilitation of existing buildings the design process is developed in phases which vary according to who carries them out and the aim of the work. In accordance with *Part 1 – Chapter 3*, the following sequence is used to designate the phases in the planning process: planning, intention, conception, construction, maintenance (Figure 100).

In a rehabilitation procedure the designers have to redefine the phases according to needs and conditions which are different from those involved in procedures for new buildings. Therefore, according to Paiva (Paiva *et al.*, 2006: 295), if it is a case of rehabilitation work on a traditional building, the methodology in the conception phase must include an analysis and diagnosis sub-phase for the existing object, followed by the actual design sub-phase. This analysis and diagnosis sub-phase complements the latter, emphasising the responsibilities of the designers and underlining the need to understand the existing building before intervening.

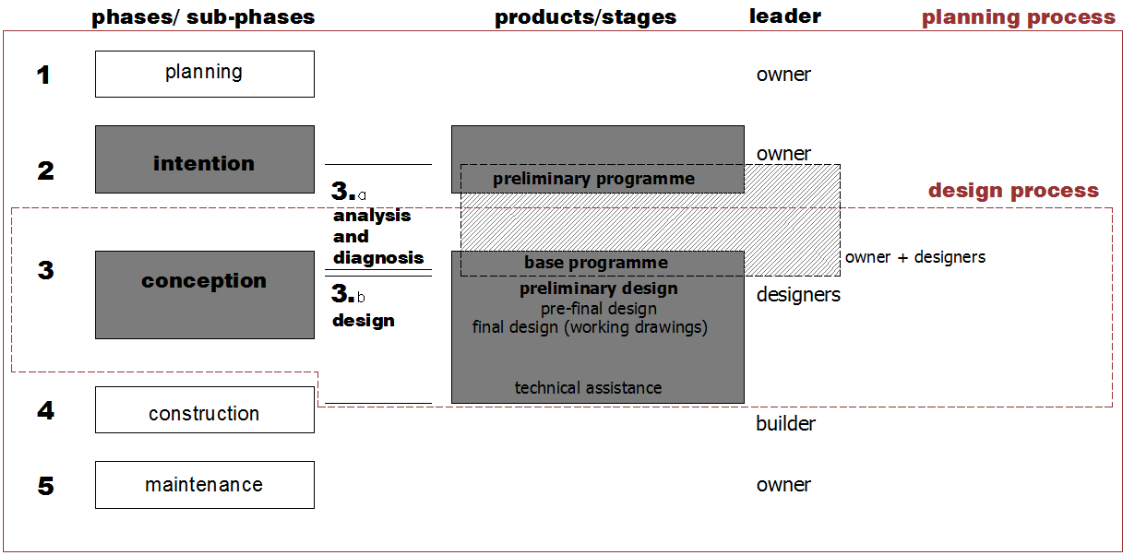


Figure 100 – The rehabilitation planning process (the phases and products covered by this rehabilitation methodology are shown in bold and shaded grey; stages from the analysis and diagnosis sub-phase are omitted)

This study, which proposes to define a rehabilitation methodology, covers a part of the intention phase and the first steps in the conception phase (the bold phases and products within grey shaded areas in Figure 100). The preliminary design constitutes the final step in the proposed rehabilitation methodology. The remaining products in the conception phase are not considered in this research, since they correspond to phases associated with the complete definition and adjustments to the major decisions emerging out of the preliminary design. It is therefore considered that the methodology presented here enables the phase involving major space design decisions, namely the links between the different rooms and the definition of the required ICATs, to be completed. In the design process stages which follow, the details and any specific alterations to the preliminary design are introduced, official approvals are obtained and the briefing is given for the construction work, and it is not the aim of this research to extend to this point.

In accordance with the diagram which defines the rehabilitation methodology (Figure 2) and the phases of the planning process (Figure 100), a diagram has also been produced showing the links between the traditional phases of the process, the role of the actors involved and the proposed methodology – Figure 101. The following sections define how the proposed phases differ from the traditional project phases and the advantages of this methodology for rehabilitation work.

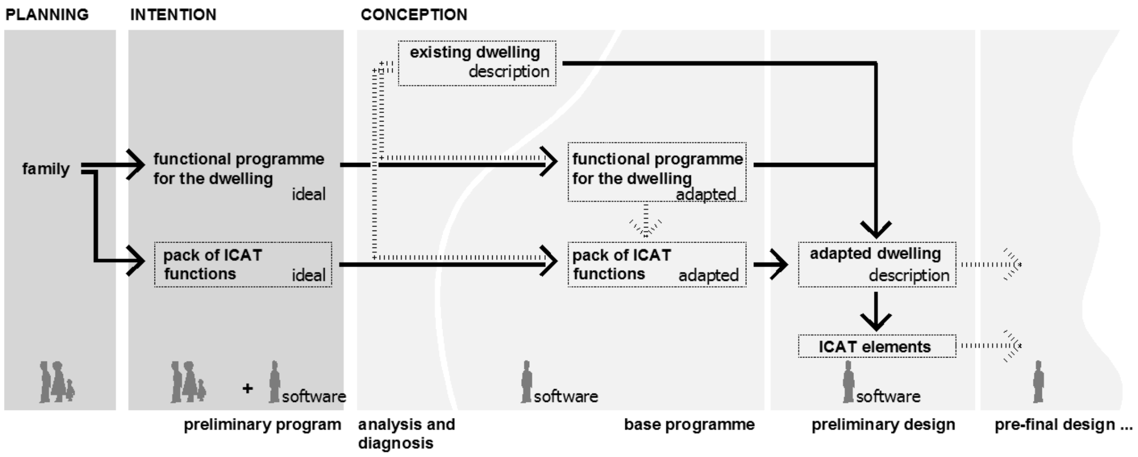


Figure 101 – Cross-referencing of proposed rehabilitation methodology and the phases in the traditional planning process.

This proposed process for rehabilitation work was developed on the basis of studies by Cabrita (Cabrita *et al.,* 1993), Plácido (1999), van Leeuwen *et al.* (2000), Aguiar *et al.* (2005), Huang and Shih (2005), Paiva *et al.* (2006), Cóias (2006), Pedroso (2007), Durmisevic (2007), Giebler *et al.* (2009), and Teixeira and Póvoas (2010). Some of these studies were discussed in *Part 1: Chapter 3*.

INTENTION PHASE

The intention phase corresponds to point at which, after verifying the need, the client (in this case a family or property developer) decides what their intentions are. The phase materialises in a set of intentions expressed in a preliminary programme which combines the expectations of a particular family.

Traditionally, in the preliminary programme the client defines the order for the project, or the project and building work, according to the available resources and the needs that must be met.

In this case the preliminary programme gives rise to two outputs: the ideal functional programme for the dwelling and the ideal ICAT pack.

Within the scope of the methodology proposed here, it is proposed that the functional programme and the ICAT pack for the dwelling already constitute a step that is undertaken by the client and the designer together, making use of an expert system which, like the PAHPA (Duarte, 2001), enables an ideal functional programme to be defined for a particular family (Figure 101). Traditionally this depended only on the client, whereas during the intention stage communication between expert designers, clients (developers and/or users) (non-experts) is vital (Huang and Shih, 2005).

In this way, the proposed preliminary programme corresponds to the needs of the family on a functional level and in terms of ICATs and is a document which contains the client's objectives in these areas. In this study, the preliminary programme contains:

- A definition of the ideal functional programme:
  - Identification of intended quality level (minimum, medium, optimum);
  - The functional definition and amount of spaces required;
  - The characteristics of the spaces in terms of area and minimum size;
  - The basic requirements for habitable space (ventilation and natural light);
  - Relationships between spaces, and between spaces and functional areas;
  - Extra spaces and the topological relationships desired by the family in addition to the automatically defined programme;
  - Priorities for extra family options.
- A definition of the ideal ICAT pack to be included:
  - Identification of intended level of integration (minimum, medium, optimum);
  - Definition of type of communications network (cable, wireless or mixed);
  - Definition of ICAT equipment;
  - Definition of desired functions.

Evolving features which the dwelling should be able to accommodate should also be included in the preliminary programme.

The preliminary programme is divided into two phases: in the first phase the ideal default programme is automatically defined for the family in question and in the second phase this programme may be adjusted by the client by adding features that had not been taken into account or by altering the initial definitions. In fact, the client may accept or change features of the description that is presented e.g. by requesting another bedroom or work area, or by defining different topological relationships between the rooms.

CONCEPTION PHASE / ANALYSIS AND DIAGNOSIS

As previously stated, when the aim of the project is rehabilitation two major sections are included in the conception phase: analysis and diagnosis of the situation and the conception phase itself.

Good results in project and rehabilitation work are due, to a large extent, to a comprehensive analysis and diagnosis phase in which the aim is to develop an exhaustive set of measures that will provide detailed knowledge of all aspects of the project: the building destined for rehabilitation and the population for whom it will be rehabilitated. Through analysis and diagnosis of the situation it is possible to assess the feasibility of the project objectives, as well as the level of intervention required.

In the analysis of the building or dwelling, sufficient information should be obtained to allow for its functional, constructional and formal characterisation and, consequently, an initial diagnosis of the situation (Paiva *et al.*, 2006: 296). In this phase the client expects a report on the quality and conversion/adaptation potential of the dwelling.

In the light of the proposed objectives, the analysis should include the following:

- A survey and analysis of the spatial organisation of the accommodation;
- An analysis of conflicts of use and the reasons for this;
- Testing or surveying of structural elements;
- Testing or surveying of constructional elements of the original building and any subsequent alterations;
- A survey of the existing infrastructures;
- Factors influencing the location of equipment and installations required for ICATs;
- Factors influencing the level of maintenance, use and expansion of ICATs.

In the case being studied, the targets for rehabilitation are multi-family residences in which work may be totally or only partially carried out (either on a group of dwellings or just one individual dwelling). In the first phase, the existing building is studied and analysed in terms of its constructional, functional and social aspects. The analysis of the "rabo-de-bacalhau" building contained in *Part 1: Chapter 7* enabled the various types of buildings to be characterised, calculating the functional features of their spaces, the existing construction system, and the potential and conditions affecting rehabilitation.

A detailed characterisation of the existing national stock of buildings in terms of their functional, constructional, stylistic and social features is extremely important to planning work and should be the subject of specific studies. The availability of this characterisation would be extremely important in rehabilitation work, leading to better informed and more flexible analysis and diagnosis phases.

A detailed analysis of the existing buildings, achieved in this case through the characterisation of the case study, enables the frequent surprises that emerge during the process of rehabilitation work to be reduced. In fact, in a process of this kind it is not always possible in the initial phases of the project to anticipate and design all the solutions and all the details, given that surprises generally emerge during building work as the intervention develops. The possibility of working on the basis of a building type that has been studied and classified enables the surprise factor to be substantially reduced.

In the context analysed in this research, the architect was provided with a set of features and common problems that were very likely to emerge in the building due for rehabilitation, thus allowing for a more accurate intervention. Throughout the study, although it had been noted that the original building permission files were reasonably well documented, there were also countless aspects that contained omissions or alterations, either during construction work or during the life of the building itself. These included the characteristics of the mains water, sewage and electricity networks, whose plans were not in the archives, and structural features whose plans, in the majority of cases, were rarely documented. Thus the characterisation of the existing buildings required a more detailed study than could be obtained from an analysis of the design elements.

In addition to the dwelling due for rehabilitation, the analysis also included the future residents. These could be a real group of people or a target market – a typical family – resulting from a market study carried out by the developer. In either case the designers work with a preliminary programme elaborated during the intention phase and corresponding to the needs of the family in functional and ICAT terms, which served as an intermediary between the objectives of the client and the proposals of the architect.

CONCEPTION PHASE / DESIGN

The actual conception sub-phase, in which design solutions begin to be explored, follows on from the analysis and diagnostic sub-phase. Unlike the previous phases, which were objective, the start of the conception phase is commonly termed the "black box" in the design process. In this phase, countless items of data intersect and designs vary with designers. In addition to the objective issues involved in the project in question, other issues intrinsic to the designers and their knowledge and experience also intersect.

The objective issues are the information originating from the previous phases and the existing building regulations. This data is used by designers to define, in an initial phase, the base programme aimed at verifying the feasibility of the project and studying alternative solutions.

According to the methodology presented and the context of the work, the proposed base programme should include:

- Compatibilisation of building with needs, in terms of total net floor area and number of habitable rooms;
- Verification of the feasibility of proposal in terms of space conditions (area and number of habitable rooms available) and possible alternative proposal if the accommodation does not correspond to the preliminary programme;
- Definition of alternative rehabilitation options.

During the conception phase, given the existence of an ideal functional programme, an ideal ICAT pack and an existing dwelling, it is necessary to appraise the programme options and adapt them to the existing situation. This process will give rise to the base programme which consists of the adapted functional programme and adapted ICAT pack (Figure 101).

It is intended that this base programme should be as exact and accurate as possible, clearly responding to the potential of the dwelling in question in order to meet the requirements that have been presented.

The traditional method of producing the base programme, frequently supported by inadequate knowledge of the existing building and rehabilitation requirements, leads to a process that is full of uncertainties and poorly justified decisions. In fact, using the traditional method the results of the analysis of the preliminary programme in terms of the existing building leads to results that may be as different as the number of designers consulted. This is not intended to imply that it is only possible to find one solution that satisfies the requirements of the family and the constraints of the building. What is intended is that the decisions taken during the base programme are fully informed and lead to unequivocal results without the need for a more extensive study which is only clarified in the more advanced phases of the project. The accuracy of the assessment made in the base programme is vital to the speed at which the project unfolds and prevents a project from being pursued which provides accommodation that is not suited to requirements or requirements that are unfeasible for the accommodation in question.

The use of a rational system that provides practical results does not hamper the architect's creativity but instead ensures that the intervention objectives are met.

The definition of the base programme (the adapted functional programme and adapted ICAT pack) is based on defining a system that brings together four sets of information from the outset:

_ The composition of the family unit;
_ A clear, concise and informed preliminary programme, produced by the residents in collaboration with the designer;
_ An analysis and informed diagnosis obtained from a typological characterisation based on a broad case study;
_ A database of planning solutions which cross-references family profiles, needs in terms of useable area and types of building.

This information is analysed in accordance with the adaptation principles defined by all the "rabo-de-bacalhau" types of building, according to area, typology and number of habitable rooms. A definition of these principles is developed in *Part 1 – Chapter 2* and *Chapter 4*.

The use of a database of design solutions involves applying Case Based Reasoning (CBR) which makes use of previous cases of rehabilitation in order to find solutions for new ones (Huang and Shih, 2005), (Van Leeuwen *et al.,* 2000).

According to Van Leeuwen (Van Leeuwen *et al.,* 2000) in *"apartment buildings, general layout principles can be recognised for a large percentage of all apartments. Consequently, it is possible to compile a database of typical housing layouts that, when filled with a sufficient number of cases, will offer a fair chance of finding acceptable resemblance to the refurbishment situation at hand. CBR is a useful methodology for structured access to such a database of existing design cases. In this approach, matching cases will be searched for on the basis of geometrical, material, functional, and economical constraints."*

Despite considering CBR a tool capable of producing the best results in the base programme and preliminary design stages, this has not been developed in this thesis.

After the base programme stage has been concluded, preliminary design follows, consisting of adjustments to items in the base programme and the existing accommodation in accordance with the priorities stated by the residents. The preliminary design must, on the one hand, endeavour to fully exploit the existing resources in the building by taking advantage of its physical and spatial features whilst, on the other hand, find the solution best suited to the programme. The result of this stage is the "adapted dwelling description" (Figure 101) which emerges in the context of this thesis as the final stage of the proposed methodology.

Preliminary design allows for:

- A detailed definition of the solution adopted for the accommodation by exhaustive verification of its feasibility;
- Development and analysis of any possible variations on the solution;
- Clarification of the functional and constructional impacts of the proposed architectural solutions;
- A definition of the space solutions which best respond to functional use and residential requirements;
- A definition of construction solutions that guarantee the most appropriate solution and respond best to the characteristics of the stressed structure, both in terms of safety and in terms of respecting functional and use requirements.

The proposed preliminary design includes the following:

– A definition of space solutions, the organisation of space and the size of the dwelling, which contemplates:
    - The prevailing morphological characteristics of the dwelling and its rooms;
    - The general rooms within the dwelling and the uses envisaged for these rooms;

    - The connections between the different rooms and functional areas and between these and the dwelling as a whole;
    - The dimensions of the proposed alterations;
    - Compliance with functional use, habitability and safety requirements, as well as with the requirement for the programme to make flexible use of space;
- A general definition of constructional solutions:
    - Proposed criteria for the conservation or demolition of building components;
    - Dimensions of alterations in terms of demolition and new building work;
    - A definition of solutions resulting from demolition and a general approach to any structural reinforcements required;
    - A definition of construction solutions for areas through which ICAT networks will pass;
    - A definition of the construction processes and materials proposed for the construction of new features affected by the passage or installation of ICAT networks or equipment (walls, ceilings, floors);
- A definition and justification of ICAT needs:
    - Definition of the paths of the new communications infrastructure networks;
    - Definition of the distribution of equipment connected to the network;
    - Definition of domotic functions to be taken into consideration;
    - Analysis of the main construction implications resulting from ICAT integration;
    - Requirements for other specific features resulting from the use of ICATs;
- An analysis of variations on the proposal presented, with regard to space and installation solutions and their construction implications, taking into consideration the advantages and disadvantages of these variations;

The list of decisions taken during the base programme stage which culminate in the definition of the programmes adopted are covered in *Part 2: Chapter 2 and Chapter 3*. The methodology used to obtain the preliminary design document is covered in *Part 2: Chapter 4*.

1.3 Tools used in the application of the rehabilitation methodology

To obtain an architectural object that complies with the programme and the appropriate quality requirements, a vast and complex set of data has to be cross-referenced between the architect, the other planners and the client. If satisfactory results are to be achieved from the rehabilitation work, the various types of data which affect planning decisions must be evaluated before the conception phase begins (Palmer, 1981: 3). As previously stated, in addition to information about client requirements, this data includes a series of other types of information ranging from human, physical and social factors to the constructional, spatial and functional aspects of the building work.

The design process, whether for a new building or for rehabilitation work, consists of searching for a solution to a design problem and includes a succession of steps forwards and backwards using trial and error procedures (Figure 102), with the aim of generating solutions that respond to the demands of the problem.

It's necessary to evaluate whether each solution or hypothesis that is generated represents a possible solution. This evaluation has to be made on the basis of objective criteria which clearly enable the potential and the weaknesses of each solution to be identified.

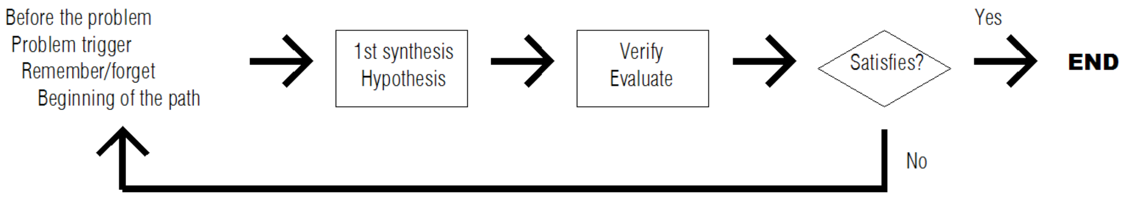


Figure 102 – Interpretation of the design process

Traditionally, both the design and the evaluation process are carried out manually, with or without the aid of tools such as tables, graphs and indexes.

The traditional design process, based on trial and error, needs a verification mechanism which validates the result or hypothesis in accordance with a series of criteria or predicates included, for example, in a checklist. This process, which is traditionally only carried out by one architect or a team of architects, may be, at least in theory, carried out entirely by computerised tools or by dividing the tasks between the architect and the computer (with the architect generating and the computer testing and validating, or the reverse).

In order to carry out an evaluation process using computer software, it is necessary to include large amounts of data of various types (including functional, quality, legislative, environmental, social and economic data) which constitute criteria that are indispensible to the evaluation of the solutions. In this context, see the QUARQ software by Pedro (2000) for assessing the quality of residential architecture.

Various tools may contribute towards the design process, not only in terms of calling up all the project data but also in analysing, organising and transforming it into design solutions. Design programming is part of the conception process and requires an efficient processing system that is able to include the complex, varied and extensive information required for conception and for the efficient management of this information. In Palmer's view (1981: 3) architectural programming includes the following advantages:

- As a systematic process, it ensures the designer that all aspects relevant to client needs are included in the process. It provides a mechanism that assesses the multiple factors affecting client and design requirements. It creates a structured fabric for entering and classifying information.
- As an analytical process, it allows the designer and client to base project decisions on factual evidence obtained from an accurate, objective and systematic base rather than assumptions and past experiences.
- As a support tool for decision-making, it allows the designers to reach decisions even before beginning the design which will invariably influence it. It also allows clients, particularly the users, to be involved in the conception project at the time when their contributions are most important.

The interest, within the context of this work, is to explore planning systems that allow solutions to be generated on the basis of design rules. In order to define these processes, a generation mechanism, test mechanism and control mechanism are required to inform the user step by step about what to do next (Mitchell, 2008: 194). The generation mechanism includes all the previous knowledge which the designer possesses, not only about the specific problem raised by the project, but also more general issues arising out of the problem. The test mechanism is also an intelligent process, since the problem must be understood in order for it to be validated or verified.

The inclusion of all the designer's knowledge within a computerised tool may lead to the idea that this knowledge is quantifiable and therefore limited, which would be a false assumption. Architects, in fact, work with complex data structures, rules and objectives, as well as with the unexpected and throughout the design process changes frequently occur in all the previous parameters. According to Mitchell (2008: 194), the use of a tool such as a shape grammar in which all the generation rules are already encoded, may simplify or even resolve the generation process, making the verification mechanism redundant.

Throughout this research several hypotheses have been raised as to how the proposed rehabilitation methodology should be formulated.

The tools chosen both to carry out the rehabilitation task and test its feasibility were expert systems, shape grammars, descriptive grammars and space syntax.

This chapter provides the theoretical context for these tools and an explanation of their use in developing the rehabilitation methodology.

1.3.1 Using a rule-based system to solve rehabilitation problems

The implementation of the design process using computer software is a complex task, given the large amount of data involved.

To generate solutions for this particular problem we developed an expert system which contains data (on families, ICAT and dwellings) and rules that act and transform data into solutions.

It is therefore possible to build such a system to help designers define solutions. As an example, we refer to the selection of an appropriate ICAT set.

For this purpose, the knowledge base would contain facts such as the following:

Fact 1: The family has 1 non-working elderly person

Fact 2: The dwelling is occupied during the day

Rule 1: <u>IF</u> family includes non-working elderly people, <u>THEN</u> integrate emergency assistance system.

Rule 2: <u>IF</u> dwelling is occupied during the day, <u>THEN</u> integrate an energy saving controlled temperature system.

Rule 3: <u>IF</u> family includes non-working elderly people, <u>THEN</u> dwelling is occupied during the day.

The existence of an elderly non-working person in the domestic group is a fact. The rule base will be searched and the rule whose condition meets this assertion will be applied. Both Rules 1 and 3 contain the same fact and both can be selected and used. When Rule 1 is used the system tells us to integrate the emergency assistance system. Calling up and using Rule 3 declares Fact 2 which, in turn, satisfies the Rule 2 condition.

Despite the apparent efficiency of expert systems, the issue of when to create one is debateable.

How big should the problem be to make the creation of an expert system viable? This is a crucial decision.

In terms of architecture, certain specialist subjects have been translated into computer software. Examples in this research include the QUARQ software for the evaluation of architectural quality (Pedro, 2000) and the PAHPA software for the definition of functional housing programmes (Duarte, 2001). Computerised applications of expert systems speed up the output response, despite the innumerable amounts of data and evaluation process within the knowledge data base.

However, in some applications of expert systems, the nature of the application and the amount of information that has to be stored in order to simulate the human reasoning process is simply too vast for the computer's active memory. In this case, the system may not give a solution because unpredictable facts have occurred.

The spatial needs for a particular design context can be defined by using countless different decision-making tools such as trees, decision tables and flowcharts which, despite working more slowly, achieve the same results as a computerised expert system.

The PAHPA software created by José Duarte and described in Heitor (Heitor *et al.*, 2004) enables a housing programme based on the design language of Architect Siza Vieira's Malagueira houses to be generated by introducing data on future occupants. The software, kindly provided by the author, was used in this research to test both the elaboration of functional programmes based on occupant needs and the definition of priorities for occupant needs.

The PAHPA software enables results such as the following to be obtained:

> "IF family includes couple, THEN double bedroom exits"
>
> "If double bedroom exists, THEN area must be 12m^2 or more"

Within the context of this thesis it was decided not to computerise the expert system that was developed since this task, in addition to being very time consuming, was not included in the original output goals and, in architectural terms, would not differ substantially from the manual system.

To develop an expert system for the project problem addressed by this thesis the following steps are necessary:

- Identification of all the elements of the problem through assertions, goals, requirements, restrictions and specifications. These elements are: families; functional housing demands; characterisation of ICAT in the home; characterisation of existing dwellings.
- Grouping these elements into interactive acts (e.g. relating them as If ⇒ Then)
  - Defining a functional housing programme according to a family profile:

    <u>IF</u> family X <u>THEN</u> definition of the functional programme of the dwelling

    This interaction is carried out and represented by three types of entries: tables, fluxograms and lists.
  - Defining an ICAT pack according to a family profile:

    <u>IF</u> family X <u>THEN</u> pack of ICAT functions

    <u>IF</u> domotics function Y <u>THEN</u> wire network or domotics appliance

    This interaction is carried out and represented by three types of entries: tables, fluxogram and lists.
  - Definition of a methodology for adapting the functional housing programme and the ICAT pack for an existing dwelling:

    This task is developed by using a transformation grammar, as in *Part 2: Chapter 4*.

- Transcribing the above rules into a mathematical language and then into a computer programming language. This task was not carried out during this research.
- Representation of the final solution, e.g., by a floor layout or space graph. See examples of the application of the methodology in *Appendix 4*.

1.3.2 The contribution of Shape Grammar to rehabilitation methodology

In this current research, a new type of grammar, called transformation grammar, has been developed to adapt existing dwellings to new requirements. As shape grammars, a transformation grammar is a set of rules that apply step-by-step to existing shapes to generate a language of designs. The proposed transformation grammar is a type of shape grammar that enables architects to transform dwellings, instead of generating new ones, in the same design language. This transformation grammar enables a rehabilitation solution for a given dwelling to be generated based on compositional principles defined by transformation rules. These rules are derived from knowledge acquired in previous stages of the process. The generation of "appropriate" transformations involves the fulfilment of the *a priori* requirements (Duarte, 2007: 330).

A transformation grammar needs to be parametric because of the variety in the shapes and dimensions of the rooms found in existing dwellings. A parametric shape grammar is an extension of the basic shape grammar formalism and is used to neatly encode a wider range of formal variations for the same rule. In parametric shape grammars, each rule consists of a set of several rules. By using parametric rules we can encode varying features of shapes so that a greater variety of shapes can be matched to the left-hand side of the rule and then be transformed by the right-hand side. As an example, instead of a square a convex quadrilateral can be used whose edges and internal angles may vary within a certain range. The positioning of this quadrilateral shape on the left-hand side of the rule enables this rule to be applied in a larger number of circumstances. This shape parameterization may state that the vertices of the convex quadrilateral can be any point, since the form remains a convex quadrilateral.

According to Stiny (1980a), the difference between shape grammars and parametric grammars reflects the normal division between Euclidean transformations and other more complex transformations. Shape grammars usually look for proportional shape transformations, while parametric grammars represent other transformation principles.

To transform "rabo-de-bacalhau" dwellings using shape grammars, a grammar was needed that could identify rooms, walls, and spaces whilst taking several features into account, namely area, length, width, function, and material properties. For instance, a bedroom is represented by a quadrilateral shape that satisfies certain requirements such as minimum area, a certain proportional range between length and width, the need for natural light and ventilation, and the need for a door connecting to a circulation area. In this context, a bedroom could be a 4 x 3 m or 3.5 x 4 m rectangle or a 3.5 x 3.5 m square or even a quadrilateral shape with walls that are not perpendicular to each other.

Even though designs represent shapes, it is possible to refer to them in terms of function or other terms, such as utility.

In addition to the shape of an architectural space, which is defined by the position of the construction components, it is essential to consider the functions that will be carried out there.

This implies that if we want to apply a shape grammar to architecture, functional predicates have to be introduced into the language of the grammar, otherwise we may be considering an architectural problem as if it were a "shape game" (Mitchell, 2008: 197).

The activities that may take place in a space or the function for which it was conceived are inseparable from the design process. The human activities and space functions constitute the frame within which architects work. Sleeping is the main function of a bedroom. Nevertheless, resting, working, playing and entertaining friends are other functions that frequently occur in bedrooms. A bedroom and a living room are not conceived in the same way since they serve different living purposes. Thus, two identical shapes (e.g. rectangles) with two distinct functions may require different space approaches.

The ability to functionally describe a building depends on our ability to identify the systems and subsystems within it. This functional description can be undertaken in various ways, by describing functional areas, materials and construction systems, among other aspects.

A functional description of a building lists the different functional spaces as well as their relative adjacency and proximity. These spaces and relations constitute "predicates to satisfy" (Mitchell, 2008: 212).

According to Mitchell (2008), the design of architectural spaces or elements requires rules able to relate shape to the position in space of the functional attributes.

A door has a specific range of shapes that enables it both to function properly and to fulfil its main function – to allow passage from one space to another. Alternatively, in the presence of an element that allows passage from one space to another (and also prevents passage) we can state that we are in the presence of a door.

Thus, a bedroom may be considered a space that meets certain functional requirements such as: a net floor area of 7m[52] or more; a connection to a hallway via a door; the capacity to contain a bed, bedside table and wardrobe (i.e. a defined minimum width and depth); inclusion in the private area of the dwelling; easy access to a bathroom; etc.

Accordingly, a space is a bedroom when one can demonstrate that "*the chosen values for the shape parameters satisfy the specified functional requirements*" (Mitchell, 2008: 234) (Figure 103).

However, in rehabilitation work (as well as in a new construction), it is hard to reconcile these shape parameters. This task often ends with a compromise rather than an optimum solution, in which the space requirements are not always met. The priority given to each of the parameters can be defined by many factors, such as solar orientation, the client's financial resources and construction properties, among other aspects.

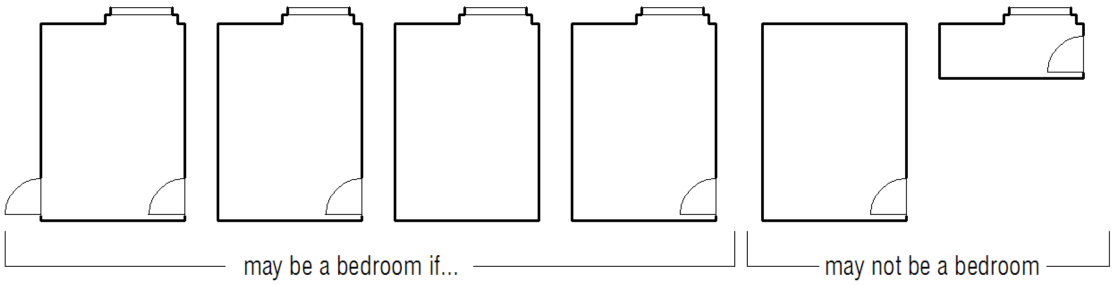


Figure 103 – examples of bedrooms.

1.3.3 The contribution of Space Syntax to rehabilitation methodology

To evaluate the functional conditions, and living space of the dwellings studied it was necessary to define their evaluation criteria. This implies the definition of both the key functional criteria that allow for the validation of the dwelling, and the definition of the various components of built space involved.

To analyse the original dwellings and the rehabilitation proposals integration, relative asymmetry, and depth were considered. As previously mentioned integration expresses the degree of space centrality and measures the complexity of reaching a space within a given spatial system. Thus, the integration core is obtained by measuring the relative distance of this space from all others in the system. For instance, the degree of integration is usually higher in rehabilitated dwellings than in original ones, as will be seen in *Part 2: Chapter 4*

The use of space syntax measures in this research aims to:

1) Analyse original dwellings in terms of the time when they were built in order to understand their particular spatial structure and its social effects (Figure 104 to Figure 107);
2) Analyse dwellings as they are being used nowadays (original dwellings or dwellings rehabilitated by tenants);
3) Using the previous results, define present day housing requirements in terms of new lifestyles according to space syntax parameters;
4) Define the transformations needed to adapt the original dwelling, (1) or (2), to the new housing requirements (3);
5) Evaluate the proposed rehabilitation solutions according to housing requirements (3) based on space syntax measures.

The space syntax approach can be used both to understand how existing dwellings work and to simulate the likely effect of the proposed interventions. Both goals consist of a 'diagnosis' of the existing situations in order to identify a range of spatial factors that strongly influence the activities of the inhabitants as well as the social value of places. A knowledge of these factors allows us to identify intervention opportunities.

In using these syntactic measures the aim is to understand which transformations could be proposed for dwellings in order to meet present day requirements and how these transformations could be handled using space syntax methods. The use of the space syntax approach predicts whether the proposed transformation will be successful in creating the expected social benefits. Thus, the proposed methodology can ensure the design develops in a favourable way.

Depending on the strategy followed in the rehabilitation process, (see strategies in *Part 2: Chapter 2.3.2*), the integration of different functional areas in the dwelling may change. This analysis can be used to choose an adequate rehabilitation strategy, taking family needs and demands into account.

Representation of the case study

During this research space is represented by graphs with nodes and arcs that describe the accessibility and permeability of the spaces. Convex maps, such as the ones shown in Figure 104, Figure 105, and Figure 106 are also used to describe space contiguity, adjacency (shared walls), and proximity in a more explicit way.

The syntactic measures analysis for this research was performed with AGRAPH software for all the calculations shown. This means that the criterion used to define values for integration[53], control[54] and depth[55] is the one used by the AGRAPH software (Manum *et al.*, 2005).

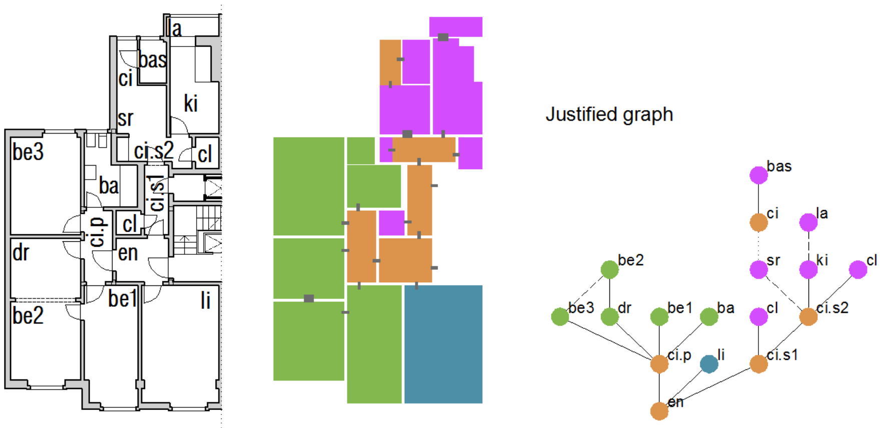


Figure 104 – Original floor plan (left), convex map (middle) and justified graph (right)

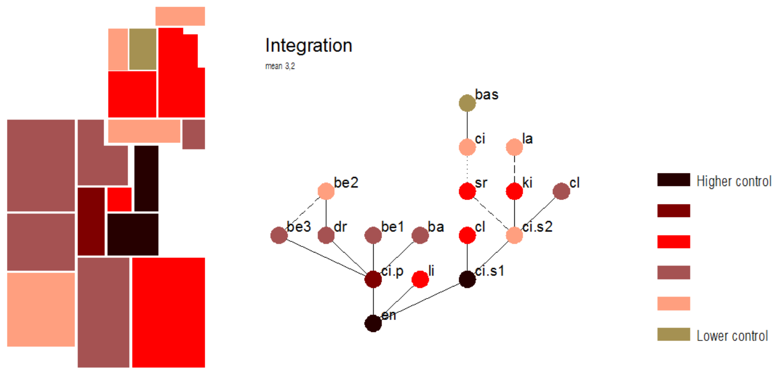


Figure 105 – Convex map and justified graph of integration values

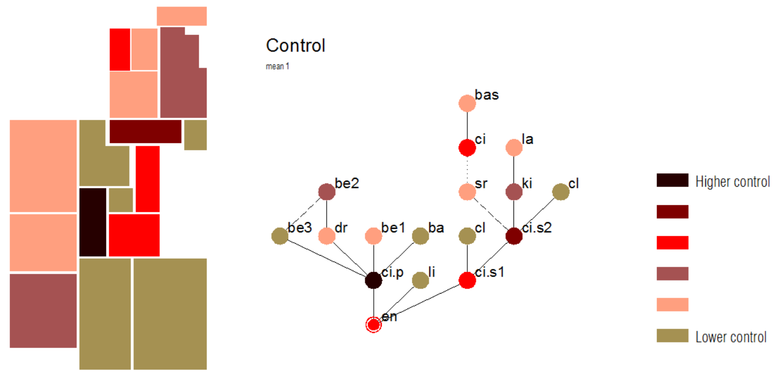


Figure 106 – Convex map and justified graph of control values

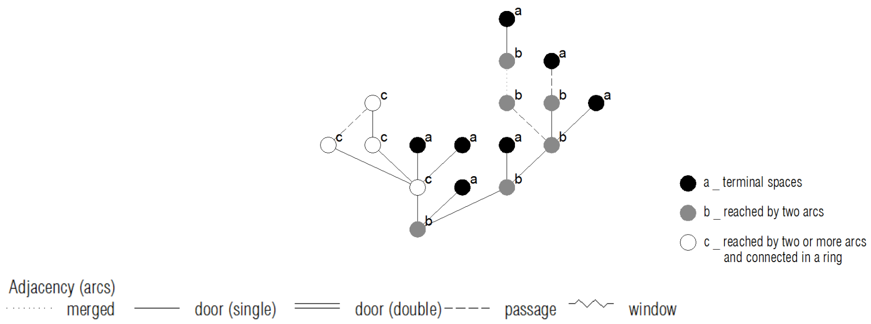


Figure 107 – Justified graph showing distributedness

Figure 104 represents the floor plan of a typical "rabo-de-bacalhau" dwelling and shows how it was broken down into convex space. The nodes presented in the justified graph are coloured according to the functional sector and labelled with the name of the room to which they belong. The entrance hall was taken as the root in all the sample dwellings.

The definition of convex polygons in this dwelling, and in all the cases studied, was not taken to its maximum extent. In fact, some rooms which were not convex, such as the bathroom (ba) and kitchen (ki), whose functionality would not be altered by their shape, were considered a single cell. Others, in which space functionality could be altered due to their shape, were considered different cells. An example of this situation is the definition of the service room (sr), and corridor (ci) in Figure 104.

In this case, Figure 107 shows the distributedness of the original dwelling. It can be seen that the non-distributed "*a*" and "*b*" spaces are the most common in the spatial network and there are fewer distributed "*c*" spaces ("*d*" spaces do not exist). The distributedness measure amounts to 0.3, meaning that this dwelling has a rigid distribution that does not allow for different paths to reach the same space. The degree of ringiness is 1.05 which also means a very low choice of alternatives.

The symmetry ratio is 0.7 in this case, which means that the segregation is even higher than the previous sample and, according to Holanda (1999), enables higher status differentiation within the dwelling.

Comparing circulation spaces (ci) and activity spaces (ac) with the index of "circulation saving" proposed by Holanda (1999) enables the importance of circulation within the dwelling to be understood. The example shows 5 circulation spaces and 12 activity spaces which represents an index of ac/ci=2.4. A higher "circulation saving" index denotes the possibility of strengthening the inhabitants' privacy within their spaces through their isolation (Holanda, 1999).

1.3.4 Combining shape grammars and space syntax

According to Hillier and Hanson (1984), space should be seen as a dynamic, rather than a static entity. Space syntax is a theory that gives no importance to shape, which is a static set (Bellal, 2004). Instead, space syntax emphasises only the configuration of a given space. In the Social Logic of Space, Hillier and Hanson write: "*We are convinced that it is unnecessary to specify shape in order to model real world generative processes; indeed, that the concept of shape obscures the fundamental relational notions that underpin human spatial order*" (Hillier and Hanson, 1984: xii).These authors state that shape grammars are "*in general too over-refined to model the untidy systems which are found in the real world of settlements and buildings*" (Hillier and Hanson, 1984: xii).

Despite their differences, shape grammar and space syntax are both methods which use descriptive techniques to discover patterns (Robinson and Thompson, 2005).

Research has been developed (Heitor *et al.*, 2004) that combines shape grammar and space syntax in order to formulate, generate, and evaluate designs. In this research, the authors used space syntax to provide an accurate means of describing and evaluating spatial properties and therefore, to "*increase the likelihood of generating solutions that closely correspond to the user's requirements.*" (Heitor *et al.*, 2004: 494). The main goal of the study was to explore how the formal principles applied in the design process interact with the spatial properties of the objects designed.

Further research was carried out by Westphal (2007), the aim of which was to describe the elements that characterise João Filgueiras Lima's architectural language. The author used space syntax to analyse space articulation and its hierarchy due to programme requirements. This analysis helps to formulate patterns of spatial articulation between the samples of the buildings studied (hospitals). Shape grammars were used to analyse the vault sheds used in all the roofing in the sample. Westphal's purpose was to define a design language capable of generating all the roof sheds in the corpus and he uses colour grammars to study the links between building components and space functionality.

In this research, shape grammar is used as a tool to define the methodology for rehabilitating existing types and space syntax as a tool to evaluate the spatial properties of the existing and proposed dwelling designs. The combination of a shape grammar with an analysis tool such as space syntax offers the possibility of producing rehabilitation projects that conform to the requirements stipulated by the inhabitants and the specifications set by the architect. In this context, space syntax is used to determine the universe of valid solutions generated by the grammar and to validate them in terms of social properties.

1.4 EXPERIMENTS

The methodology used to infer the transformation grammar was divided into three steps, each corresponding to a particular type of experiment:

- Step 1: testing the feasibility of the experimental setup by the main author of the research and defining a set of preliminary rehabilitation rules that could be transmitted to the experimental subjects in step 2;
- Step 2: finding rehabilitation solutions that could satisfy the functional and constructional requirements of each family in a given dwelling. These solutions, designed by hand, were used to infer transformation rules;
- Step 3: testing the transformation rules inferred in the previous step to confirm whether the solutions generated following these rules were satisfactory;

The goal was to relate domestic groups (families) to dwellings (existing houses). Prior to applying the methodology, data concerning the domestic groups, the case study dwellings, new housing functions, and the pack of ICAT functions was gathered and organised, as described below. These elements were then given to the experimental subjects in steps 1, 2 and 3.

FAMILIES/FUTURE INHABITANTS

We used five families, differently composed in term of numbers, age, and family relationships, namely couples with children, young couples without children, old couples, and couples with children from previous marriages (see *Appendix 2*).

Initially, people living alone were not considered because the sample dwellings were too big for this family type. Later, the study focused on how couples with no children or one-person households could be accommodated by dividing each dwelling into two autonomous smaller dwellings, since this accounts for one of the most sought-after types of accommodation in the rehabilitation market in Lisbon (Caria, 2004: 163). The division of dwellings is studied in *Part 2 – Chapter 2.3.2* and some rules for the implementation of this strategy are cited there. Nevertheless, the proposed transformation grammar does not include this rehabilitation strategy.

HOUSING FUNCTIONAL PROGRAMME

The minimum functional programme for each family was determined in accordance with Pedro's guidelines and then combined with the requirements expressed by each family in an interview especially designed for this purpose.

Families were presented with what would be the minimum functional programme assigned according to the number of inhabitants and their relationships within the family. In the interviews, the families were asked to describe the dwelling they thought they needed i.e. not an ideal dwelling but one that could fulfil their real needs. They also were told that the dwelling would be in a rehabilitated building with small rooms (the average area of the habitable rooms is 13 m^2) and that they would have to consider economic constraints. The description had to include the required housing functions or rooms, as well as the topological relations between them. Finally, they were asked to rank their requirements in order of priority.

The results of the interviews are presented in *Appendix 2*.

EXISTING HOUSES

The housing sample is composed of 25 dwellings, some of which were chosen for use in the experiments in the 1st and 2nd steps. The selection criterion for the 1st and 2nd steps was to choose ten dwellings of varying types and areas that could potentially satisfy the requirements of the functional programmes for the selected families (see *Appendix 2*). To verify this criterion, the area of each dwelling was compared with the area requirements of each family. Two different dwellings that satisfied this criterion were then assigned to each family to obtain 10 different dwelling proposals at the end of the experiment (5 families x 2 dwellings.)

The 10 chosen dwellings corresponded to 3 "type A" dwellings, 2 "type B" dwellings 2 "type C" dwellings and 3 "type D" dwellings (see *Appendix 2*).

For the third step, three different dwellings were chosen that were not used in the 1st and 2nd experiments.

As stated above, the case study dwellings are characterised by small social areas. It was therefore established that the social areas (living room, dining room and home office) should occupy at least two rooms or not less than 18m^2 (depending on the number of inhabitants).

Thus a dwelling, e.g. for a couple with 2 children, would require at least four inhabitable rooms[56] (two bedrooms plus two social rooms).

PACK OF ICAT FUNCTIONS

In the experiments that were carried out the ICAT pack was reduced to technologies that had an impact on spatial organization. The resulting requirements were then added to the functional programme.

The technologies and space requirements considered were:

- Home cinema or large TV screen. These technologies require a spacious living room with a distance of at least 3m between the screen and the couch or chairs;
- Home office, isolated or integrated into another area such as the living room, according to the needs of the new dwellers;
- Definition of independent night and day areas for sector alarms.

1.4.1 Step 1

The first and second steps aim to identify the fundamental functional, spatial, and constructional transformations to be carried out on the dwellings that were studied. The first step consisted of an experiment in adapting the dwellings performed by the main author of the research in order to infer some basic transformation rules and to test the feasibility of the exercise, before assigning it to other subjects in steps 2 and 3.

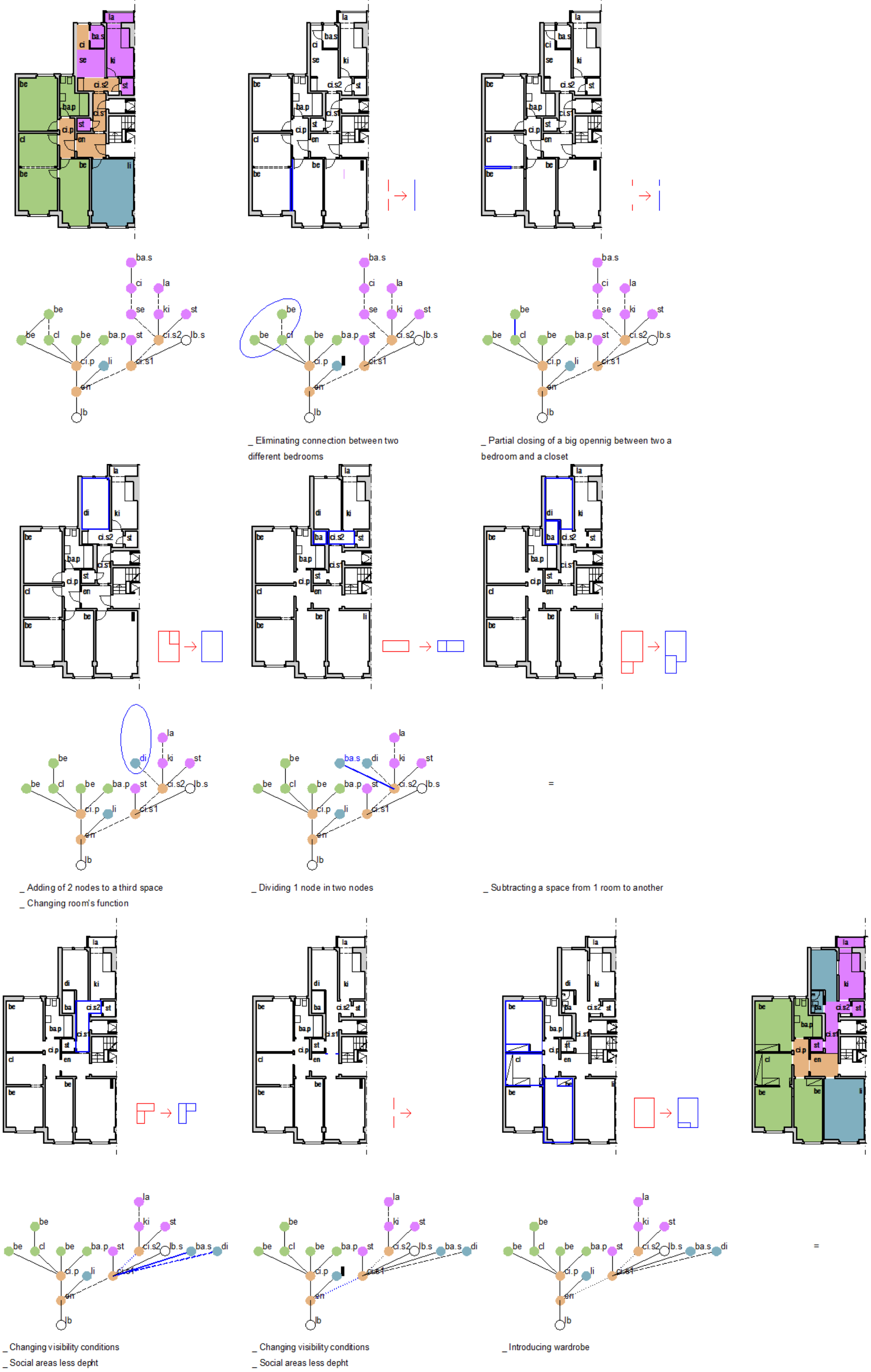


Figure 108 – Derivation of a rehabilitated dwelling - sequences of rehabilitation decisions made through changes in layout, application of shape rules (first draft of rules) and graph transformation.

This step included two tasks. The first task consisted of proposing transformations to the dwellings taking the future dwellers' requirements and constructional constraints into account. This resulted in 20 different layout proposals, two for each family/dwelling pair, in order to explore the various possible solutions. The plans corresponded to possible solutions for the transformations that fulfilled most of the requirements in accordance with the constructional restrictions of the building. The procedures required to perform this experiment included use of data concerning the family, the functional programme and the dwelling, design rehabilitation solutions on tracing paper and the subsequent use of CAD for verification purposes (e.g. net areas, extent of demolition).

The second task consisted of inferring transformation rules from the transformations proposed in the first task. Only higher level transformation rules were inferred, meaning that detailing rules were not considered.

The rules were firstly inferred by text, then by drawings. In the first stage all the transformations and the implementation sequences were written. Subsequently these transformations were drawn, step by step, in order to simulate a possible sequence of actions.

Space syntax was also used to help clarify the transformation principles and make them more simple and rational. To this end, a transformation sequence was produced using both the floor plan and the graph (Figure 108). The results revealed that not every shape action has an immediate corresponding graph action. In fact, in the fifth step of the derivation in Figure 108, a change in shape – the enlargement of a room – did not have an impact on the justified graph. Nevertheless, changes in the graph are usually linked to changes in the shape and function of a room in terms of the dwelling layout. Changes in arcs and nodes in the dwelling graph occurred as a result of changes in door positions, the size of openings, connections between rooms, division of rooms or the addition of different rooms within a single space.

The conclusion of 1st step enabled the following to be accomplished:

- After the first transformation, all others followed substantially the same criteria;
- When the functional programme requested two or more bedrooms, the first decision was the location of the private area;
- When the functional programme requested less than two bedrooms, the first decision was the location of the social area;
- Transformation rules differed according to different dwelling types.

1.4.2 Step 2

The experimental subjects in step 2 were architects with experience in designing houses. The goal of this experiment was to enlarge the set of rehabilitation solutions in order to understand how different approaches may be used to solve the same problem and, therefore, to obtain a larger basis for inferring rules.

This experiment aimed to identify the functional, spatial, and constructive transformations performed by human designers by hand, in order to infer the corresponding transformation rules and encode them into a transformation grammar.

In this experiment, the same data from experiment 1 was used, namely, 10 existing dwellings and 5 different families. Two of the architects participating in the experiment were asked to design a solution for all 10 family/dwelling pairs (two dwellings for each family,) which yielded 20 different drawn proposals. Three architects designed for 5 family/dwelling pairs (one dwelling only per family), producing 15 different drawn proposals.

The experimental tasks were explained to each of the experimental subjects separately and they then completed the work in their offices.

In addition to a verbal explanation, the other elements given to the experimental subjects were the dwelling layouts (plotted on a scale of 1:100 or DWG drawing), a written description of family desires, and a brief description of the major functional and constructional aspects they had to follow (see some examples at *Appendix 2*).

The experimental subjects were asked to perform two tasks: firstly, using paper or CAD software, to draw a design solution for each family/dwelling pair, taking the functional programme into account as well as the construction constraints; secondly, to explain the strategy they used to obtain each design proposal.

The data that resulted from these experiments included sketches (two of the architects designed by computer and therefore did not produce sketches), final drawings of the proposed layouts, and texts explaining the process followed in each case (two of the architects explained the process verbally and therefore did not write texts.)

The data was analysed and transformation rules were inferred. It was possible to identify two types of design proposals: only 1 architect proposed transformations like the ones shown in Figure 109b), and 4 architects proposed transformations like the ones shown in Figure 109c), d), e). All the architects respected the given constraints and the priorities expressed by the families. One architect did not comply with the constraint of not demolishing more than 2 m of wall. In general, they said that it was difficult to respond to the functional requirements because of the original morphology of the dwellings and the demolition constraints.

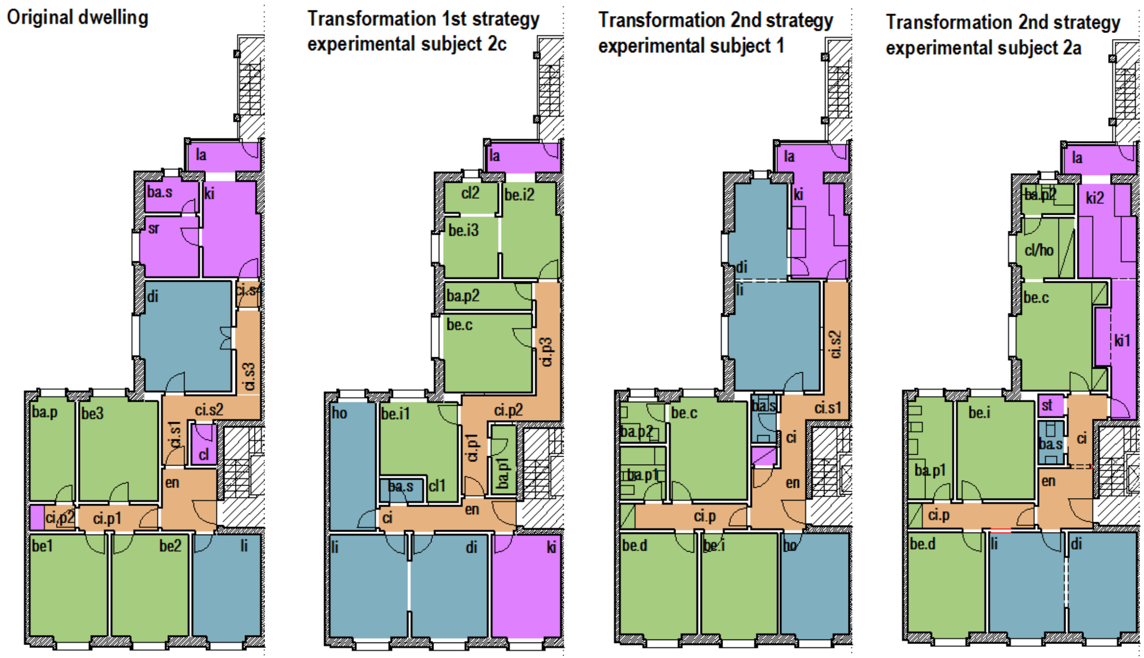
The solutions proposed by the experimental subjects were evaluated in order to calculate the level of satisfaction of the dwellers and fulfilment of the functional and constructive rules. The following criteria were used in the evaluation: satisfaction of functional programme; satisfaction of the extra areas requested by families and the connections between them; satisfaction of the general functional aspects for housing; satisfaction of constructional aspects in accordance with "rabo-de-bacalhau" buildings. The highest level of satisfaction was obtained when the proposal fulfilled most of those aspects (see proposed solutions from step 2 in *Appendix 2*). The evaluation enabled the different project options to be selected and the reasons why one option was more successful than the others to be understand. It also enabled them to be assigned to different family profiles and therefore for the transformation processes to be chosen before a given family.

The general opinion expressed by the experimental subjects was that the rules were:

i) difficult to respond to in functional terms because of the original morphology of the dwelling. It was difficult to ensure that the private area was kept intact whilst also keeping the social area together and close to kitchen.

ii) very restrictive in constructional terms, due to demolition restraints. In most cases the rule of not demolishing more than 2m of wall was a huge restriction. This rule restrains actions such as merging different areas to create larger ones, and the incorporation of circulation areas within social areas.

The result of this step was a transformation grammar that can be used to adapt existing dwellings to specific families. This grammar is described in *Part 2 – Chapter 4*. The plans for step 2 are shown in *Appendix 2*.



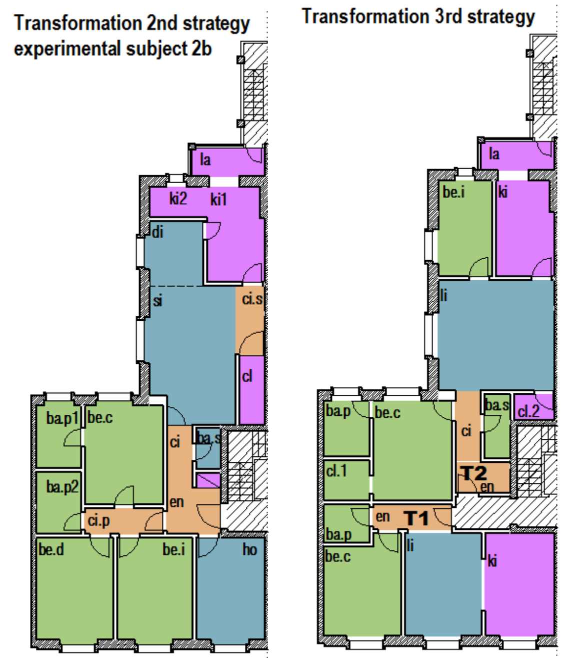


Figure 109 a, b, c, d, e, f (from top left to bottom right) – Example of the results of step 2 – original dwelling and transformations performed by four experimental subjects.

1.4.3 Step 3

The third experiment was carried out by a class of 22 architecture students on the "Shape Grammar and Digital Tools" course from the 3rd year of the Integrated Masters in Architecture at the ISCTE-IUL. The students had had previous classes on the subject of shape grammar so they were familiar to some extent with the mechanics of using rules and shapes.

The goal was to test the proposed grammar on dwellings that had not been used to infer its rules. This enabled us to check whether the inferred rules provided the compositional means for making new transformations in other existing dwellings for other families. The experiments were explained by the author to all the experimental subjects at the same time and the work was subsequently completed in the presence of the author. The author explained the aim of the experiment, the tasks, how they had to be executed and how to use the grammar and the rules.

The experimental subjects were divided into 10 different groups – consisting of 1, 2 or 3 people (see *Appendix 2*). The aim of putting the experimental subjects into groups of different sizes was to test different approaches to using the grammar. The approaches examined were attempts to use the grammar by one person only and attempts involving two or three people, thus allowing for dialogue and exchange of ideas.

This first session lasted 3 hours, during which only five groups were able to finish one dwelling derivation. Three of the remaining five groups took part in a second 2-hour session in order to finish the dwelling derivation. The groups worked in a computer room, each using one computer equipped with Autocad software.

The groups worked with five dwellings that were part of the corpus but had not been used in previous experiments. The five family profiles used in Step 2 were also used in this step. Each of the ten experimental subject groups had to transform one dwelling for a family.

In addition to a verbal explanation, the following additional information was given to each group:

- The adapted functional programme (the ideal programme plus the description of the family's extra requirements, in order of priority), including the net floor areas required for each room - printed on a page of A4;
- The dwelling layout in a DWG file;
- A version of the transformation grammar rules in which the function and dimension conditions were simplified in natural language in Portuguese. These rules were printed on sheets of A4 and comprised 81 rules grouped according to the sequence specified in *Part 2: Chapter 4*.

The dwelling transformations obeyed the following task sequence:

1. The author of the research started by explaining the grammar, the sequence of rules and the aim of the experiment;
2. The experimental subjects had to read the family's adapted functional programme. This functional programme had a description of the spaces required and the topological relationships, as well as the net floor area required;
3. One dwelling, previously chosen by the author in accordance with Table 22 and Table 23 (page 228), was given to the experimental subjects as a DWG file. The initial labels – hs, nhs, Xki, Xba, Xla, Cbc – were already marked on the dwelling layout. In addition to the floor plan, the DWG file included a grid in which the new dwelling layout had to be entered, step by step after each rule application. One dwelling layout and the number of the rule used had to be inserted in each space in the grid (Figure 139), thus enabling the options chosen by the experimental subjects to be understood, step by step.

   The first derivation had to be recorded on the white grid. If the choices proved wrong, the last valid option had to be copied to the yellow grid and the dwelling derivation continued following this step. If there was any need to go back during the derivation, the pink grid had to be used and, if necessary, another grid could be added to the drawing.
4. The experimental subjects then started the dwelling transformation, using the given functional programme and shape rules document;

5. The experimental subjects drew onto the DWG file. Each new rule applied had to be written in the file and the resulting application drawn. They were asked not to delete anything and to change to a new colour grid if they made a mistake or chose another approach to the design (as explained in 3.).

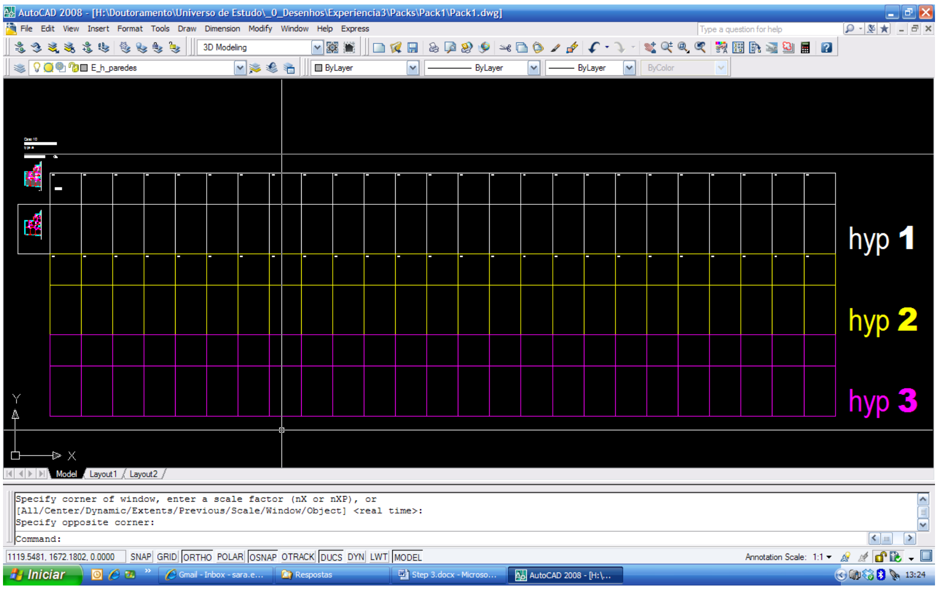


Figure 110 – DWG file with the dwelling layout and grid given to experimental subjects to enable them to complete the experiment.

This experiment allowed the behaviour of the experimental subjects to be observed in terms of the way they approached the application of the grammar.

Three profiles emerged for the approach to the problem of rehabilitation (see *Appendix 2*):

- Some experimental subjects first analysed the entire dwelling and tried to mentally simulate the final result before starting to apply the rules. This occurred with experimental subjects who were organised in groups. These groups began the transformation by analysing the architectural features of the dwelling.
- Some experimental subjects began by applying the shape rules without first analysing the entire dwelling. Some of these cases produced valid results. In other cases the sequence of rules was applied wrongly and the final result was impaired. One of this situations occurred when the application of rules was initiated by assigning private areas rather than social areas;
- Some experimental subjects applied the rules correctly, in the right sequence and, as they had anticipated each step, their derivation never produced conflicting results.

The following conclusions could be drawn from this experience:

- Contrary to what happened in the second step of the experiment, the demolition restrictions were not considered a problem in transforming the dwelling, except in one case involving one group derivation;
- The major difficulty was finding rooms that met the net floor area conditions. Almost all the rooms were smaller than the areas requested. This obstacle led to some possible solutions that need to be integrated into the rules:
  - Assigning a tolerance to the requested area, e.g. 10% (F≥9m2 means that F≥8,1m2) → this was included in the revised grammar rules;
  - Allowing a room, e.g. a double bedroom, to be allocated to a smaller space if the floor area could be enlarged. This possibility is difficult to introduce as a rule

because a large number of shape, dimensional and functional conditions have to be met in relation to all the surrounding rooms;

- Allowing a space to first be enlarged and then assigned a function;
- Using the areas required for the minimum level, even if the recommended level had been chosen by the family → this was included in the revised grammar rules;

_ Instead of having a sequence of *assignment* then *changing shape* rules for each functional area, the experiment revealed that it would be better to have the *assignment* rules for all the functional areas and then all the *changing shape* rules separately. This would enable room shape to be changed whenever necessary rather than based only on the predefined sequence → this conclusion was included in the revised grammar rules;

_ Instead of having different *changing shape* rules for each of the functional areas, it was preferable to have a group of *changing shape* rules with the shape part equal and the conditions differing according to functional or dimensional restrictions → this conclusion was included in the revised grammar rules;

_ As there are mandatory rooms (those required by the functional programme) and optional rooms (the extra ones required by the family, in order of priority) and it is sometimes not possible to satisfy all requirements, it would be better assign in the following order:

  - Firstly, allocate and ensure the mandatory rooms;
  - Secondly, allocate the optional rooms.

Although this option is an interesting possibility, its application would solve some problems but also create others. The main new problem would be the difficulty in keeping the rooms in the different functional areas together, given that they would be attributed at different stages.

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[51] PAHPA stands for Portuguese Housing Programming and Evaluation Grammar. PAHPA is a discursive grammar which includes a programming grammar and a projecting grammar (Duarte, 2001).

[52] For single bedroom.

[53] *"Integration Value: A parameter that (contrary to RA) describes integration by a high number when a node is highly integrated is the |integration value" (i). The integration value is found by inverting the RA, i=1/RA5."* (Manum *et al.*, 2005)

[54] *"Control Value: The Control Values (CV) are found by letting each node give the total value of 1 equally distributed to its connected nodes. The Control Value of node n, CV(n), is the total value received by node n during this operation."* (Manum *et al.*, 2005)

[55] *"Total Depth: Total Depth of a node n, TD(n), is the total of the shortest distances from node n to the other nodes in the systems, i.e. TD(n) is the total of line n (or column n) in the distance matrix."* (Manum *et al.*, 2005)

[56] We used the expressions "inhabitable room" to describe room as bedrooms, living and dining rooms that have more then 6,5m^2 as well as natural ventilation and light.

2 THE FUNCTIONAL PROGRAMME FOR THE DWELLING

The aim of this chapter is to identify how the use of technology influences lifestyles and creates new dwelling requirements, and how this affects the spatial and functional organisation of dwellings. This work complements Pedro's (2000) and Duarte's (2001) frameworks for incorporating new residential patterns, new domestic groups, and ICAT-related demands.

The chapter is divided into three parts:

- The first deals with the functional housing requirements which will feature in the proposed functional programme;
- In the second part (the 2nd step of the rehabilitation methodology, see Figure 111), household profiles are used to determine the ideal functional programme for the dwelling, following Pedro's and Duarte's work on the housing programme mentioned above. The functional programme in this case is a description of an ideal housing solution for the family, which is not restricted by any existing morphological structure or design language.
- In the third part (the 3rd step of the rehabilitation methodology, see Figure 111) the existing dwelling and the ideal functional programme are used to derive a description of a compromise or adapted solution based on the existing dwelling. Since the solution is influenced by the existing morphological structure and construction of "rabo-de-bacalhau" buildings, the description of the ideal solution must be transformed into a description of an adapted solution.

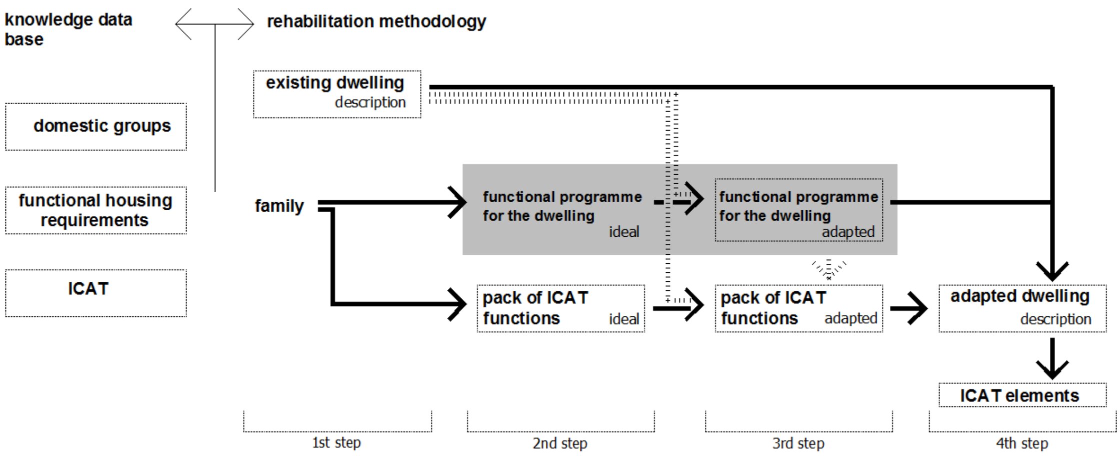


Figure 111 – Rehabilitation methodology. The steps defined in this chapter are highlighted in grey.

As previously mentioned in *Chapter 4.1*, the transition from the ideal functional programme to the adapted functional programme involves moving from the preliminary programme to the pre-design phase.

2.1 FUNCTIONAL REQUIREMENTS IN HOUSING REHABILITATION

The rehabilitation project involves a process of synthesising a wide range of information and knowledge of the architectural and urban context and construction materials and processes, together with a respect for the "*conservation ethic*" (Paiva *et al.*, 2006: 295). To this may be added knowledge of the future residents who will occupy the rehabilitated property and their requirements and expectations.

In addition, the rehabilitation project also involves complying with applicable standards and regulations.

In terms of requirements, this chapter addresses the main issues associated with housing rehabilitation to the extent to which they are relevant to the objectives of this study.

As previously stated, the current legal and regulatory framework for new buildings cannot always be applied to housing rehabilitation projects (Paiva *et al.*, 2006: 293) in its entirety. Within the context of this legal framework, the aim has been to analyse the functional requirements applicable to housing rehabilitation projects and focus on those which are relevant to this study. Since the objective is to define a methodology for integrating ICAT within housing rehabilitation and, at the same time, to propose functional changes that will allow dwellings to respond to new lifestyles, particular attention has been paid to housing requirements that are related to these objectives. This chapter discusses the construction, functional and energy efficiency requirements that contribute towards the aims of this research, and the way in which each of these requirements is approached.

Construction requirements should address authenticity, durability and compatibility. Within the context of this research, construction requirements are not explored in detail in the proposed rehabilitation methodology, as it deals with functional rehabilitation and the integration of technology rather than constructional rehabilitation. Therefore reference is made only to the following: in *Part 1: Chapter 7.2*, restrictions on intervention work on façades and interiors from the point of view of authenticity and, in *Part 2: Chapter 2.3.4* and *Part 2: Chapter 3.2.2*, recommendations for the introduction of new materials for walls and ceilings from the point of view of durability, future maintenance and reversibility. The functional requirements which apply to housing rehabilitation focus on use, habitability and safety requirements, as shown in Table 16.

Use requirements	Spatiality	Capacity
		Spaciousness
		Functionality
		Accessibility
	Topology	Adjacency
		Connections
		Depth
		Integration
		Distributedness
	Flexibility	
Habitability requirements		Acoustic comfort
		Visual comfort
		Hygrothermal comfort
		Air quality
		Hygienicity
Safety requirements		Structural safety
		Fire safety
		Protection against intruders
		Everyday safety

Table 16 – Housing functional requirements (adapted from Paiva *et al.* (2006), Pedro (2000: 98) and (Heitor *et al.*, 2004: 513))

Use requirements refer to various factors that reflect the need to adapt the organisation of existing living spaces to current family lifestyles. From this perspective, there are numerous conflicts of use between existing structures and current requirements regarding comfort, size and the connections between different areas. To this should be added conflicts resulting from the differences between the functions for which the spaces were originally designed and their present and future uses.

These aspects are essential and take priority when adapting the dwellings covered by this study to meet current requirements. The ways in which they are incorporated into rehabilitation work are discussed throughout this chapter.

With reference to the use requirements described in *Part 1: Chapter 5*, this study covers spatiality (capacity, spaciousness and functionality), topology (adjacency, connections, depth, integration and distributedness) and flexibility. With regard to the latter, it should be noted that the functional programme proposed in this thesis was produced for a rehabilitation context and therefore does not cover issues relating to flexibility and adaptability achieved through the use of components that can be moved or dismantled, as may be the case in new buildings.

With regard to capacity, spaciousness and functionality requirements, the proposed methodology includes size specifications (areas of rooms and minimum wall sizes) for rehabilitated housing. From a functional point of view, dwellings should be designed to provide residents with suitable conditions in which the proposed functions can be carried out.

Connections between rooms are extremely important in terms of how residents use space, given that contemporary residential lifestyles differ considerably from those of around fifty years ago. By taking flexibility into account in housing rehabilitation work, housing solutions can be designed which address the various requirements the accommodation must meet throughout its useful life, rather than just the needs of the family that will occupy the dwelling in the near future. The social factors already described, such as the new types of households, greater residential mobility, e-work and access to communications networks are all reasons for considering housing rehabilitation from the point of view of flexibility. The changes which are introduced should not be irreversible and should allow for different kinds of use.

With regard to making these buildings and dwellings accessible to all types of users, it should be noted that the intention here is not to propose solutions for all access difficulties. The proposals that are presented and the proposed methodology essentially seek to ensure that the entrance to the dwellings offers access to individuals in wheelchairs and that their movement around the interior is not worsened in comparison to the original solution. The proposals therefore include certain size criteria, such as the use of wider doors. It should be emphasised that, in general, the proposed alterations aim to simplify the organisation of the existing space, therefore helping to create a more fluid space. The buildings studied include several examples of cases in which areas within dwellings, such as bathrooms, halls and circulation areas, do not meet present-day access criteria. Nevertheless, the proposed alterations do not aim to resolve access issues, since they are not part of the research aims of this thesis. However, when intervention work is justified in these areas, the criteria taken into consideration (e.g. regarding corridor width) are informed by current legislation on access to buildings. No adaptations are proposed to ensure access for all residents in areas not affected by work involving the installation of ICAT or functional reorganisation.

In the case study analysed, habitability requirements do not present any problems serious enough to warrant enumeration, given the objective of this thesis. In fact, there are acceptable levels of acoustic, visual, and hygrothermal comfort, air quality and hygienicity in the dwellings analysed in *Part 1: Chapter 7* and improvements would involve construction processes sufficiently well-researched in the specialist bibliography. With regard to acoustic comfort, there should be adequate sound insulation between different dwellings and between dwellings and communal areas. In terms of hydrothermal comfort, improving the existing situation involves ensuring appropriate thermal insulation for door or window openings and in specific areas of the building, such as upper and ground floors. In relation to air quality and hygienicity, the inadequate rooms adjacent to inner yards opening onto the rear façade, the existence of interior rooms that lack ventilation and natural light and the small number of bathrooms for the size of the dwellings should be noted. In this context, the aim was to resolve conflicts of use involving interior rooms and the number of bathrooms.

In addition to use and habitability issues associated with comfort, the safety of residents is an essential factor in any project, and it is therefore important to consider structural safety, fire safety, protection against intrusion and everyday safety, for which different levels of recommendations have been outlined.

With regard to structural safety, the research presents different approaches to rehabilitation work, involving various levels of intervention (see rehabilitation strategies in *Chapter 2.3.2*). Amongst these approaches, priority is given to those which, above all, are not very intrusive in constructional terms. Therefore, the transformation principles proposed in the transformation grammar (*Part 2: Chapter 4*) define explicit and very restrictive rules for the demolition of building components, to avoid reducing the structural safety of buildings. However, given that this is an architectural study, a detailed approach to structural safety in rehabilitation work is not proposed.

As far as fire safety is concerned, the aim of the proposals and recommendations is to not worsen the current situation in terms of the building and the compartmentalisation of dwellings. The installation of automatic domestic systems in dwellings and communal areas within buildings allows fires to be detected quickly, setting off an alarm and safety measures (*Part 2: Chapter 3.1*). No proposals are made for construction materials and finishings for dwellings and buildings, or for the communal spaces within buildings.

In terms of protection against intruders, the recommendations made and the proposals for changes presented in morphological terms, both for buildings and dwellings, do not alter the conditions for protection against intruders. Automatic detectors and controlled access are proposed both for buildings and dwellings, thus raising the safety level for buildings (*Part 2: Chapter 3.1*).

In dwellings, the elements generally involved in accidents and which compromise everyday safety are the components of doorways, flooring, stairs and furniture (Paiva *et al.*, 2006: 384). Most of these will not be altered during the proposed rehabilitation procedures. However, with regard to interior doorways, the intervention work that takes place will take safety into account in terms of normal residential use.

In addition to construction and functional requirements, energy efficiency requirements must also be considered. As stated in *Part 1- Chapter 6.3.1*, ICATs have numerous mechanisms that can be used to manage energy consumption. Therefore, within the scope of this study, the recommendations for energy efficiency focus on active control and management systems, rather than passive systems, although they are a priority, such as the rehabilitation of the surrounding environment, in order to improve thermal insulation. Active measures include automated artificial lighting and air conditioning systems, which represent 12% and 17% of domestic energy consumption in Portugal respectively (Paiva *et al.*, 2006: 458).

Housing rehabilitation employs various strategies to meet these requirements, both in terms of spaces and the construction – passive strategies – and in terms of incorporating technologies –

active strategies. Table 17 explains the housing requirements considered for rehabilitation work and proposals for responding to them.

Requirements	Sub-group	Requirement	Passive strategies	Active strategies (technology, ICT and domotics)
Habitability requirements		Acoustic comfort	*Sound insulation;* Functional definition of spaces	
		Visual comfort	*Sunshades*; Functional definition of spaces	Control of artificial and natural lighting; control of sunshades; sensors, actuators.
		Air quality	*Transversal ventilation;* Functional definition of spaces	Active ventilation systems; automatically controlled ventilation; sensors, actuators.
		Hygrothermal comfort	*Thermal insulation;* Functional definition of spaces; *ventilation*	Air conditioning systems (heating/cooling); humidity control, ventilation; sensors, actuators.
		Hygienicity	Redefinition of bathrooms and kitchen; *new requirements for disposal of rubbish*	
Safety requirements		Structural safety		
		Fire safety	*Evacuation plans, Functional definition of spaces*	Systems for preventing, detecting, warning and fighting fires; alarms, opening and shutting down ventilation systems, doors.
		Everyday safety		Detection systems (flooding, gas leaks) and systems for disconnecting water, gas, electricity
		Protection against intruders /aggression/ robbery		Detection, communication and alarm systems; video surveillance, systems for controlling access, alarms.
Use requirements	Spatial-functional suitability	Capacity	Functional definition of spaces	
		Spaciousness	Functional definition of spaces	
		Functionality	Functional definition of spaces	Automated support systems for all residents, in particular the elderly and the disabled
		Accessibility	Functional definition of spaces	Solutions for elderly people and individuals with restricted mobility – assistive technologies
	Topology	Adjacency	Functional definition of spaces	
		Connectivity	Functional definition of spaces	Access to IC networks
		Depth	Functional definition of spaces	
		Integration	Functional definition of spaces	
		Distributedness	Functional definition of spaces	
Economy requirements		Economy		Energy management, renewable energy systems; automated renewable energy systems according to time, consumption etc.

Table 17 – Housing requirements and the approach to these requirements contained in this chapter. Aspects concerning the passive solutions covered in this chapter are highlighted in dark grey. Active solutions for housing requirements, involving the use of technology, are highlighted in light grey. Aspects not covered by this thesis appear in italics.

2.2 THE IDEAL FUNCTIONAL PROGRAMME FOR THE DWELLING

The ideal functional programme for the dwelling constitutes the preliminary programme which corresponds to the needs of the family on a functional level and is a document which contains the client's objectives.

This chapter first examines the building, then the dwelling, in physical terms. As it does not fall within the specific scope of this study, the building is analysed in less detail than the dwelling.

This ideal functional programme for the dwelling contains the following: an identification of the intended quality level; the functional definition and amount of spaces required in terms of capacity, spaciousness and functionality of spaces and dwelling; relationships between spaces, and between spaces and functional areas; recommendations for ensuring the flexibility of the home; safety recommendations for the building.

This ideal functional programme is divided into two phases: in the first phase the ideal default programme is automatically defined for the family in question and in the second phase this programme may be adjusted by the client by adding features that had not been taken into account or by altering the initial definitions. These features may involve a request for extra spaces or different topological relationships between rooms, and priorities for meeting requirements.

The following sequence is used to define the ideal housing programme for the dwelling:

- Firstly, the new residential functions resulting from the use of technology are defined;
- Secondly, these new uses are incorporated into the definition of use requirements for the dwelling (Table 16).

The use requirements for the dwelling are defined in accordance with family profiles referring to the number of residents and the relationship between them.

In families which include elderly people or individuals with restricted mobility or any other form of disability, priority should be given to functional aspects which ensure full use of the dwelling by these individuals. In order to accomplish this, various criteria that aim to ensure access for all residents by eliminating existing physical barriers were taken into consideration. Although it is advisable that these criteria are applied in all interventions regardless of the current status of household members, the constructional constraints on the buildings meant that they were only proposed in certain, duly justified cases. Alterations made in terms of morphology and connections between rooms, justified by the inclusion of ICAT or functional adaptations, as well as changes in the composition of the household, are the factors that lead to the inclusion of accessibility criteria, rather than the reverse. Therefore, proposals are not made for cases in which the question of access would lead to other interventions.

Failure to meet access criteria, even in cases in which the household does not apparently need them, signifies a reduction in housing quality and consequently in the adaptability and the economic value of the dwelling. Nevertheless, in exceptional cases in which the technical and building work would be very difficult to execute and would involve disproportionate expense, it is acceptable not to meet all the access criteria (Paiva *et al.*, 2006: 356).

A simulated definition of the ideal functional programme is provided on *Appendix 4,* initially generated "automatically" by the use of tables, diagrams and flow charts and later adjusted by residents.

Although the ideal (functional and ICAT) programme may be used as a product that can be applied to any type of housing, whether newly built or rehabilitated, certain questions that concern recent residential buildings only are not included in the definition.

2.2.1 The building

In terms of the physical building, the proposals presented are limited to aspects essentially associated with functional adaptations resulting from incorporating ICAT into dwellings.

Although there are possibilities for more substantial intervention work in the communal areas, the proposals contained in this thesis aim only to respond to changes in lifestyles due to the use of technology.

NEW USES

INDIVIDUAL WATER, ENERGY, AND GAS METERS

Ideally water, electricity and gas consumption should be read remotely, meaning that the companies responsible for billing do not need to employ staff to read meters and/or send estimates. However, if this procedure is not fully implemented, in rehabilitation projects the water, electricity and gas meters should be located in the following places, in order of priority:

1. In a specific place (cupboard or room) on the floor containing the entrance to the building which can be accessed via the communal areas;
2. On stair landings or the landings on each floor;
3. Inside dwellings

SECURITY SYSTEMS

In medium-sized multi-family residences such as the rabo-de-bacalhau building type, access and protection against intruders should be controlled by automatic systems. Although these systems are not very intrusive in communal areas and their presence amounts only to wiring, small cameras and sensors, a specific space is required to house the controls for the security system where images are recorded and the interface for the system can be accessed.

TELECOMMUNICATIONS NETWORKS

The possibility of adapting a building to requirements and needs resulting from advances in technology should be contemplated for the entire useful life of buildings. In order to accomplish this, it is necessary, when designing the rehabilitation project, to promote strategies which make the building more adaptable to infrastructure upgrades. The need to update technology is nowadays an accepted fact and it is crucial that free space is reserved in new buildings for future installations of equipment and wiring resulting from technological advances and the consequent need for their incorporation.

The current Portuguese regulations for the installation of telecommunications infrastructures in buildings and their connections to public telecommunications networks are called the ITED. Although they only apply to buildings constructed after 1 January 2005, they enable us to understand the space requirements for the restructuring of telecommunications networks in rehabilitation projects.

There are no existing telecommunications networks in the buildings in the study and television, telephone and Internet networks have to be installed after construction. Consequently, networks have been installed in areas unsuited to this purpose, such as outer walls or stairwells. Redefining these networks involves the need to create vertical ducts for the cabling extending over several floors, allowing for distribution to each individual floor. This requirement is severely restricted by the size of the communal areas available, which do not have enough space to yield the desired results.

Individual storage units

The present-day trend for purchasing items via the Internet requires individuals to be at home to receive deliveries. Traditional mailboxes cannot be adapted to meet this requirement and frequently are barely capable of containing the larger periodicals. Apart from mailboxes, there are no other larger spaces in the building or in individual dwellings that allow for deliveries to made without people present. There is therefore a need for storage areas, jointly managed by condominium dwellers, which would provide a solution for home deliveries at any time of day.

Use requirements

Functionality

In terms of the building itself, it is important to ensure that rooms used for the same purposes are vertically superimposed, or at least that private areas are not superimposed on social or service areas. This criteria aims to provide, on the one hand, economy in the construction of infrastructures, and also to prevent the different dwellings from being disturbed by noise.

Flexibility

A range of housing should be offered within the same building in order to provide freedom of choice and to ensure that the building is occupied by different kinds of households in terms of size, gender and age. This also promotes social integration for groups which tend to be at risk of social exclusion, such as the elderly, the disabled or even single-person households.

To supplement the diversification of the dwellings available in the building, another means of offering flexibility would be through the inclusion of multipurpose units serving both as residences and workplaces.

In addition to promoting a range of dwelling types within the building, the same diversity should also be promoted in the local neighbourhood, so that nearby urban areas foster social diversity.

Accessibility

In building rehabilitation process there is no obligation in carry out barrier-free upgrades provided that this does not lead to or increase non-compliance with standards (DL 163/2006). However, it is advisable to examine all the design components to see whether an alternative could be designed to provide barrier-free access, thus offering additional convenience to all users. In this context it is necessary to ensure that rehabilitation work does not compromise emergency access, normal access (allowing access for individuals with restricted mobility) and service access (the storage and collection of rubbish, transport of goods and packages, domestic deliveries by services such as the post office or supermarkets, meter reading, and maintenance work on building).

From 2016, all buildings must comply with the technical standards for access stipulated in DL 163/2006, with the exception of cases in which the building work required would be unduly difficult or involve disproportionate or inaccessible financial and economic resources. For a building to be considered accessible there must be at least one path, designated accessible, which offers safe and comfortable access for individuals with restricted mobility from the public road to the main entrance/exit and all the interior and exterior areas it contains.

SAFETY REQUIREMENTS

FIRE SAFETY

In buildings where it is not possible to comply with all current fire safety regulations, the use of active detection and alarm systems may reduce the risk of fire (Paiva *et al.*, 2006, 381).

The following are therefore recommended:

- A full re-wiring;
- Repair, improvement or (full or partial) replacement of gas installations;
- Repair, improvement or (full or partial) replacement of heating facilities;
- Adoption of measures to facilitate evacuation: installation of automatic detection and alarm systems (see *Part 2: Chapter 3.1*);
- Fire detection activated by smoke detectors located in communal areas of the building.

PROTECTION AGAINST INTRUDERS

Proposals to protect the physical building against intruders are based on adopting automatic controlled access systems and video surveillance, amongst other measures, and are discussed in *Part 2: Chapter 3.1.*

2.2.2 The dwelling

The ideal function programme for a particular family is defined in accordance with a methodology based on the PAHPA program produced by Duarte (2001). This methodology encompasses a series of steps during which the future residents are asked questions in order to define its contents in terms of the amount, area and topology of the spaces required by a particular household.

This process of defining a functional programme in accordance with the characteristics of a particular household may be undertaken as follows:

1. Using computer software designed for this purpose. One example of this software is the PAHPA program, whose main structure was followed in this process;
2. Using tables and flow charts which cross-reference data and supply values for it, thus establishing a sequence of actions to be followed in order to obtain the functional programme.

Although it has a similar objective, the software referred to in 1 was not used directly in this thesis, since it defines functional programmes adapted to a particular type of housing with specific characteristics. In the case of the PAHPA software the housing analysed – in Bairro da Malagueira – consists of two-story dwellings with patios, which are different from those contained in multi-family residences such as the ones analysed here.

The second procedure for defining the ideal functional programme was therefore chosen for this study and in this chapter the steps leading to its definition are identified. The Table 18 shows the sequence for the list of data that must be introduced (inputs) and how the programme definition is obtained (outputs).

Input stages 1, 2, 3 and 4 assume that the rehabilitation work is being carried out for an actual family who are consulted throughout the process, so that the planner can determine their preferences and use them to define an ideal functional programme.

However, this method of producing the functional programme is not feasible if the rehabilitation work is being carried out by a property developer with the aim of putting the property on the market for sale or for rent. In this case it is necessary to carry out a market analysis to estimate the family type for the potential buyers or tenants and the future dwellers will be anonymous. If the target market is known, the future residents may be included in the types defined in *Part 1-Chapter 4* and, using this definition, input stages 1 and 2 of the process can be carried out. The result will be the 'final ideal functional programme' rather than the 'preliminary ideal functional programme', since it will not have been personalised.

Input	**1**	Define family			
			Composition	Typical	(choose from **Table 19 - page 208, Table 20 - page 209**)
				Personalised	No. of residents
					Name/ ages
					Kinship
					Share (bed, bedroom, none)
			Frequency of occupation	Name / % occupancy	
			Special needs	Does any resident have limited and/or restricted mobility? *	
				Does any resident is visual impair?*	
				Does any resident is hearing impair?*	
				Does any resident have any other disability?*	
Input	**2**	Define desired quality level		Recommended, Minimum (choose from **Table 19 - page 208, Table 20 - page 209, Table 21 - page 213**)	
Output	**1**	Preliminary ideal functional programme			
				List of spaces / articulation (isolated, demarcated, included) / areas **(choose from Table 20 - page 209, Table 21 - page 213)**	
				Priority topology (passage to, door to, window to, adjacent to, next to, close to, far from) (see topology requirements on page 214)	
Input	**3**	Define additional spaces			
				Spaces (bedroom, dining room, home office, media room, private bathroom, guest bathroom, storage) (see page 222)	
				Spaces in order of priority	
Input	**4**	Define additional topology			
				Relationship between spaces and functional areas (passage to, door to, window to, adjacent to, next to, close to, far from) (see page 222)	
				Relationships in order of priority	
Output	**2**	Final ideal functional program			
				List of spaces / articulation / areas	
				Priority topology	

Table 18 – List of questions to ask future residents (input) and definition of the functional programme for the dwelling (output). * If the answer to any of these questions is "Yes", go to *Part 2: Chapter 3.1.2* to integrate assistive technologies. In terms of physical adaptations to the dwelling, access for individuals with reduced mobility is not considered in this thesis.

New ways of using housing

The presence of technologies in housing has increased exponentially in recent years and, in general, these technologies are no longer emerging as isolated elements but have instead become an integral part of the home and its components. Domestic automisation and the Internet are not local technologies, but ubiquitous functions that we encounter, or may encounter, in all areas of the home. This way of considering and using technologies has had implications for the ways in which housing is used which, in turn, have repercussions on individual areas within the home. If the incorporation of new technological equipment and functions is important, the new types of behaviour that result from their use are even more important.

As this thesis focuses on housing rehabilitation and is subject to constructional and morphological restrictions, consideration of these new uses is limited to those which can feasibly be implemented within this context.

Sleeping, resting and associated functions

One of the most important aspects of contemporary society which is reflected in housing is the need for individualisation and, within the household, the need for family members to enjoy autonomy (Pereira, 2006: 1). This need is reflected in a desire for larger bedrooms where a greater number of functions can be carried out.

In addition, we are witnessing the significant "privatisation" of areas for couples, in which the bedroom is additionally provided with bathroom facilities, often the most complete in the dwelling, and storage and dressing areas. This "privatisation" extends throughout the private zone, together with the emergence of bathroom facilities for visitors in the social area to prevent them having to access the private family area. In this context, the private area is currently the most segregated zone in the home.

Pereira (2006: 17) states that the future trend, mainly in larger dwellings, will be the "privatisation" of private areas for all members of the family through the creation of bedroom and bathroom nuclei for each family member. This privatisation leads to the autonomisation of family members, who can carry out numerous functions in their "little house" within the home. In addition, efforts are also made to create homogenous spaces, testifying to the greater equality amongst the different members of the family. The existence of more bathroom facilities and their location next to bedrooms is a sign of the central focus on the body in present-day society.

Furthermore, bedrooms are no longer reserved for sleeping and spending the night in, due to the autonomy they have acquired through the adoption of information technology. In fact, traditional bedrooms are nowadays areas for socialising in, playing games, working, recreation and study and therefore require more space to enable these functions to be integrated in a balanced way. Leisure and work/study activities associated with bedrooms include the presence of technological equipment such as computers, television, printers, CD and DVD players and games consoles.

According to Francisco Oliveira (2000: 187), bedrooms are nowadays autonomous multifunctional areas within the private domain, in which a significant amount of activities take place, both during the daytime and at night. For young people the bedroom is synonymous with the need for privacy and social status and identity.

Although closed areas, bedrooms are also spaces which allow for communication with the outside world, annulling or reversing the forms of contact between physical and virtual occupants. In fact, through the Internet we can communicate with anyone without leaving the house, or bedroom, and, taken to extremes, can be in touch with them as frequently as we are with the people who physically share our home.

To meet the requirements of privacy and incorporate leisure and work-related technologies, it is acknowledged that in present day housing individual bedrooms are required for all children. In larger households where certain members require greater privacy, such as elderly people, those with no immediate family ties or young adults, this requirement for privacy and autonomy within the bedroom area is more important.

Autonomy may be provided by exclusive access to a bathroom, a larger bedroom that can accommodate more furniture and equipment (e.g. a sofa, TV or computer) and by being closer to the exit.

The adult bedroom should function as an area that provides privacy through its size and the way in which it is related to other spaces, enabling it to extend its functions to include work, leisure, hygiene and/or personal care or supervision of small children.

Young people's bedrooms should be designed for multipurpose use, favouring functions such as leisure activities, receiving friends and using ICT, whilst also promoting autonomy and privacy. These latter factors are more important in the case of young people who are almost adults and/or young people from different marriages sharing a house with other young people who are not their siblings.

The children's bedroom should offer the possibility of functioning as a play and learning area, which can be controlled to a certain extent from the adult bedroom or social areas.

It is equally important that all bedrooms offer the possibility of using computers (fixed, laptop or tablet) with an Internet connection and equipment for listening to music. In a study carried out by the Communications Observatory (Cardoso, 2007: 58), approximately 33% of young people aged 8 to 24 stated that they would like to use a mobile phone to view television content and watch films and other multimedia content. On this basis, it may be concluded that audiovisual content will increasingly be viewed on small-sized mobile equipment.

Despite the growing need for individualisation and privacy in living space reported by Pereira (2006), the pressing need for sustainability has led us to consider floor area an expensive commodity that should be used profitably. In fact, larger bedrooms with private bathrooms have greatly increased the amount of floor space per person and consequently the environmental cost (energy, land use, materials, among others). A balance therefore needs to be sought between the need for individualisation and available space and the need for environmental, economic and social sustainability.

It is believed that a framework can be provided for these new realities through the way in which spaces are designed, transforming the structures of subdivided spaces to promote areas which serve as intersections and meeting places within dwellings.

Living areas, leisure and communications

The room known as the living room is usually the area devoted to relaxing/socialising, receiving visitors and adult work/recreation. Nowadays, for social reasons relating to the characteristics of present-day families and for technological reasons, the living room is also a recreation area for children and young people. This is essentially due to the existence of various kinds of electronic leisure equipment enjoyed by both children and adults, which also functions as social entertainment. Examples include home cinema projectors that provide for both a family evening spent watching films or a lively gathering over a football match, and games consoles such as the Wii that provide games for children, young people and adults and even the chance to attend gym classes.

In addition to the large, diverse range of audiovisual materials offered by manufacturers, there is a rising demand for sophisticated sound systems. A distributed sound system can be centralised in the living room and relayed to the rest of the house.

Numerous activities take place in the living room including family gatherings, work and study and the aforementioned leisure activities and entertainments (parties and gatherings of friends, television, music, reading, etc.).

The contemporary age is characterised by a proliferation of images and audiovisual content. In the street, as well as on television, via the Internet, in cinemas and newspapers, we are consecutively presented with images and sounds seeking to inform us of events, products, brands, places, etc. Conventional reading, although still the most common form of reading, is starting to be rejected, mainly by the younger generations, in favour of the digital book, read or listened to on the computer, an activity already practised by many people. The options for digital reading range from a conventional fixed computer to lighter and more portable equipment such as the e-book or i-pad which have the same physical impact as a book but include a wide variety of extra functions. Both options have different spatial impacts which, in certain cases, may be further removed from the experience of conventional reading or, in other cases, closer to it.

The traditional CRT television, which is big and inconvenient, has been largely replaced in various households by lighter equipment that uses a much larger screen. Fixed large-scale equipment (LCD, plasma screens, LED, 2D/3D) is also being replaced by roll-up screens that can be concealed (Figure 113). These screens, which are attached to a free wall or suspended from the ceiling, are part of current home cinema systems, together with a projector (possibly suspended from the ceiling) (Figure 112), speakers in various locations, a data transmitter (computer, i-pad, TV device, or telecommunications operator box) and domotic cenarios for lights among others (Figure 114).

This has an effect on spatial organisation in the living room, where, due to its size, the television or concealed or visible projection system requires more free space. For this reason, leisure areas in the home must provide space for large (fixed or roll-up) screens in a place that offers good viewing conditions (e.g. without direct overhead light) and sufficient distance from the screen (Figures 115).

In specific cases when there are no constraints on availability of space, it is possible to allocate one room to serve solely as a home cinema. In this case, the sound and lighting should be arranged specifically for this purpose, and the screen and projector, together with the sofas, should be arranged in the best (or most appropriate) place.

Despite these activities, the living room has lost its role as the place which brings the family together and the place for meeting and socialising. The proliferation of interface and leisure equipment in various areas in the home has meant that this has been removed from the living room or, in the majority of cases, has multiplied in other areas, thus decentralising the home. Leisure activities associated with viewing audiovisual content, formerly based in the living room (and until a few years ago centred on the television set), nowadays take place in the kitchen and the bedrooms of adults and teenage children. It is no longer the television set that occupies this new place, but the fixed computer, laptop or tablet with an Internet connection.

Despite the proliferation of technological equipment in the various rooms in dwellings, in reality these devices are becoming smaller and more mobile, operating through wireless networks. Examples include portable computers and tablets, which can now carry out all the functions of fixed computers but allow for mobility, are small and light, use wireless networks, can be stored anywhere, and packed away.

In addition to domestic automation, which is proposed as part of this thesis, other kinds of technology which interact with residents are also possible nowadays. In these cases, interactivity is achieved through the use of large surfaces onto which images are projected. These may even include dividing walls, which can display information or remain opaque or even translucent. According to Tramontano and Requena (2005: 657) this form of interactivity between home and resident turns the house into an interface and an intermediary in itself, rather than simply a space fitted with equipment.

In the living room, as in other areas where people congregate, it is important to provide control interfaces for all the domotic systems in the dwelling.

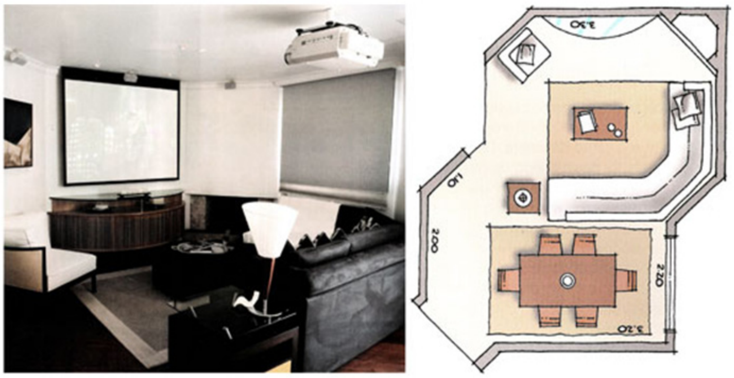


Figure 112 (top left) – Home cinema projector (source: www.home-cinema-installers-london.co.uk/)

Figure 113 (top middle) – Projection screen (source: www.krunker.com/)

Figure 114 (top right) – Touch screen for controlling DVD, iPod, television and domotic functions (source: www.home-cinema-installers-london.co.uk/)

Figures 115 (bottom) – Living room with interior design plan offering good conditions for home cinema. (source: www.interiores-pt.com/)

Working at home

Nowadays e-work is one of the most common forms of working from home. The use of ICT has enabled many people to work from home in the same way as in an office.

The re-integration of work within the housing function, with added new characteristics, requires a different approach to the concept of the home and a new design which accommodates the existence of a work space.

There may be different ways of working from home, ranging from using the house as an extension of the workplace to making the home the main workplace. In the case of the former, the dwelling acts as a support for work that is mainly carried out elsewhere and does not have a great impact on the dwelling. The area in the house used for work can therefore also be used for other functions, which may be the main or secondary functions in that area, e.g. as a dining room or living room that includes a workspace. In the latter case, the full transfer of work-related activities to the home leads to major changes in the way in which space is occupied and used.

E-working from home implies an analysis of the everyday routines of those working from home, others who live but do not work in the house and the extent to which the house can accommodate these differences. The appropriation and experience of domestic space will be different for the two groups and both must be reconciled in order to meet work-related demands whilst maintaining the requirements for habitability and normality within the family nucleus. The private space which is the home is reformulated to include the opposing concepts of private and public, permanence and mobility, traditional and modern, and appropriated and shared space.

Pelaéz (2003) states that in order to work from home, it is also necessary to escape from it. This suggests that e-work should take place in a specific, physically separate area within the dwelling, with a separate entrance and little contact with the interior of the house. This separation can be achieved by the use of doors, different floors or areas with different characteristics. A study by Crosbie and Moore (2004: 228) found that having a dedicated workspace was emphasised as a necessity by many of the professional homeworkers, whereas homeworkers in traditional homeworking occupations viewed it as desirable rather than essential. Some homeworkers moved their offices to an outside shed or to the attic to try and increase the boundary between home and work. (Crosbie and Moore, 2004: 228)

The working area should be provided with sound insulation, and have good natural and artificial lighting, good natural ventilation, thermal control equipment and suitable communications infrastructures.

Personal hygiene

Bathrooms have developed, been modified and increased in number within dwellings. These changes are the result of new hygiene habits that emerged during the 20th century, as well as a growing interest in "*beauty and leisure*" (Guerra, 2000: 184). Recent social thinking has introduced new criteria for the design of areas dedicated to hygiene. In this new context, the number of bathrooms per dwelling has increased and they are carefully designed to take functional advantage of what is usually a very small area but represents a major proportion of building costs.

The equipment in bathrooms has changed greatly in terms of design and it may be said that nowadays these areas, like kitchens, are composed of design items that resemble furniture. New equipment has appeared on the market, including saunas, hydromassage baths, multipurpose shower units, electronic scales with countless functions and mirrors with built-in screens. This equipment has emerged as a consequence of the interest in beauty and leisure and has turned the bathroom into a wider area devoted to physical and mental wellbeing which has acquired a new configuration and status within the home (Guerra, 2000: 184).

Figure 116 – ITC and other technologies in the bathroom (source: www.prlog.org /10153141)

Figures 117 – Mirror with built-in screen and clock. (source: http://www.philips.pt/)

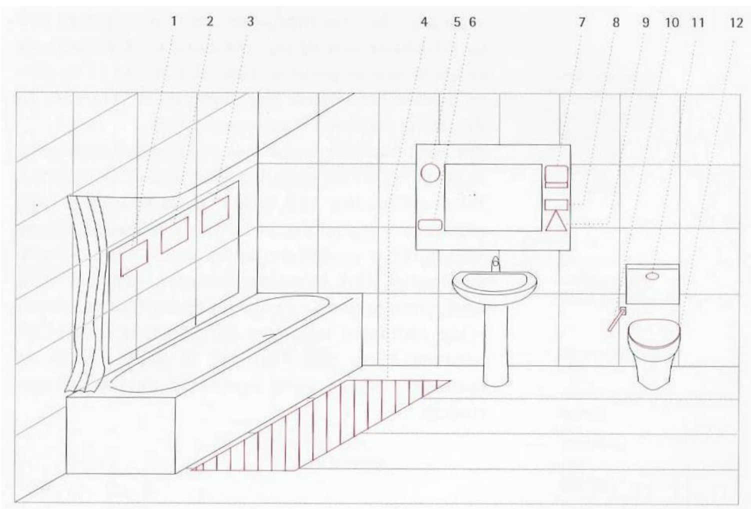
In fact, the current trend in new buildings is to provide better-equipped bathrooms that respond to the requirements of society. Although bathrooms are designed for small areas, there is a tendency in the real estate sector to provide a larger bathroom in the double suite, often containing a bath and shower or just a hydromassage bath, two washbasins, ample shelf space and large mirrors.

According to international studies, an increasing number of residents are using digital equipment in bathrooms, such as portable music players, equipment to access the Internet and other wireless devices, essentially for entertainment (Ideal Standard International 2008). In future these spaces will include digital technologies that monitor health and physical well-being (including weight, blood pressure, and blood, see Figure 118) offer relaxation (sauna, and hydromassage, amongst others) and provide access to ICT (Internet, television, radio, mobile phones) (Figure 116 and Figures 117).

Staying in good health is a present-day concern for citizens. With the aim of offering preventive health control, sensors can be included in bathrooms to analyse the state of health of residents. These procedures reflect a line of research that has been studied in depth, particularly in the United Kingdom, and has already resulted in practical applications in the field of telecare. In the near future it is envisaged that domestic equipment will be used to control health, involving simple, non-invasive instruments to analyse blood, urine, certain physiological functions, and cholesterol levels, and to control weight, among others (Figure 118). If there is a need for medical intervention, the bathroom is prepared with a monitor and speaker to allow for a conversation in real time with a doctor.

With regard to domotic equipment in bathrooms, devices to detect flooding, presence, temperature, humidity, light and air quality may be installed. The “bathroom environment” must be controlled independently of the other zones, particularly in terms of ambient temperature and personal safety. It may be provided with a separate power supply from the rest of the house, equipped with highly sensitive trip switches.

In terms of number, in addition to aiming for fully equipped bathrooms, the intention is also to promote privacy amongst members of the family. It is therefore recommended that there should be a bathroom for the couple or single adult and one for the children (this number may be increased if there are more than three children).



1 – Breast exam (sensor or infra-red)
2 – Full body scanning (biophysical exam)
3 – General exam and bone test (video or laser)
4 – Weight
5 – Eye test
- retina
- ocular pressure
6 – Hearing test
7 – Monitor for medical consultation
8 – Sound scan and analysis of respiration
9 – Language unit
- identification of patient
- consultation
10 – “Health arm rest”
- measurement of blood pressure
- pulse rate
- body temperature
11 – Temperature sensor
12 – Analysis of urine, analysis of biogas (sensors)

Figure 118 – The bathroom of the future. Source: (Daniels, 2000: 195)

Domestic tasks

Domestic tasks include activities such as preparing meals, cleaning and caring for clothes. The use of new domestic appliances and external services has reduced but not eliminated some of this work.

The kitchen, formerly a service area only, is nowadays a social area and a meeting place for the family. Due to the fact that all members of the family spend less time at home (due to long working hours, school, and outside activities), the food preparation and eating area, whether it is the kitchen or a dining area, has acquired the status of a family meeting place. It is therefore emerging as a key element in the overall structure of the dwelling, with aesthetic significance and high performance technology. Kitchens are multifunctional areas and meeting places. It is therefore important to allow space not only for preparing food but also for eating everyday meals.

The technology found in kitchens is often the most highly developed in the home and is not based solely on equipment for preparing meals. The kitchen may also contain equipment for connecting to the Internet, managing and maintaining appliances, ordering products and fostering communications between residents, thus acting as an interface (Figure 121 to Figure 124).

Electronic equipment used to prepare meals quickly, such as microwaves and freezers, and the possibility of remote control enable different household timetables to be managed.

In small households composed essentially of young people, the use of outside services to prepare meals is a factor which leads to this area of the home being undervalued.

It has become a habit in many families to install a television in the kitchen, regardless of whether this is the place where meals are eaten or not. However, this takes up space if placed on a work surface, and systems for fixing sets to walls or furniture have therefore emerged, in addition to flat screens or screens incorporated into other equipment which also provides Internet access (Figure 122 and Figure 123).

In order to meet information and communications access requirements, several electric plugs and Internet access points should be installed in the kitchen (Internet, TV, telephone and internal IT network to enable peripherals installed in other areas of the home to be used).

Figure 119 – Equipment for ironing shirts. Kasa do Futuro, Ericeira (photo: SE 2009)

Figure 120 – Equipment for drying clothes using jets of hot air. Kasa do Futuro, Ericeira (photo: SE 2009)

Figure 121 – The "electronic larder" with bar code reader to detect stock shortages. Kasa do Futuro, Ericeira (photo: SE 2009)

Domotics functions in the kitchen may include detectors and technical alarms (devices to detect gas leaks, temperature/fire and flooding) and sensors to detect intruders. Interfaces for manually regulated air conditioning and lighting systems, in addition to audio outputs should also be considered. Domestic appliances should be powered by an independent circuit, in order to prevent accidents involving other equipment in the event of a short circuit.

The laundry cycle is a very neglected function in present day housing. The cycle includes the storage of dirty linen, washing, drying, storage of dry laundry and ironing (new solutions on Figure 119 and Figure 120).

Washing and, in particular, drying laundry are, without doubt, the tasks that are least valued or ignored in present day housing, given that they require physical space with specific features that are often not provided. Efficient household laundering (of clothing, bed linen, kitchen linen, curtains, etc.) requires a tank and a washing machine and often, due to space restrictions, room is only provided for the machine. The current use of outside services for to collect and deliver laundry to the house, makes the current option of only providing space for a washing machine feasible.

Laundry can be dried using private lines (inside the dwelling, outside/attached to the façade or outdoors/on a balcony), communal lines (indoors or outside/on a terrace annexed to the building), or a drier. The introduction of equipment such as driers has reduced the traditional amount of space required for this purpose. However, drying laundry is a domestic task that cannot be reduced simply to the use of a drier. The ban on hanging out washing on the exterior of many residential buildings nowadays is frequently combined with a lack of equivalent indoor space for drying laundry on lines, creating two types of situations: breaking the rules by putting washing out and/or cramping indoor space with lines. Although this encourages the use of driers, in actual fact kitchens only provide space for two machines (a washing machine and dishwasher) rather than three (washing machine, dishwasher and drier).

Figure 122 – IceBox with TV and Internet access installed on upper surface. (source: Stanley Rowin Photography http://rowinphoto.com/)

Figure 123 – Fridge with touch screen and Internet connection. (source: Stanley Rowin Photography http://rowinphoto.com/)

Figure 124 – Oven connected to Internet. During the day it serves as a fridge and is later activated by programming or remote control to heat up and cook meals. (source: Stanley Rowin Photography http://rowinphoto.com/)

STORAGE

There are two reasons why the need for storage space within dwellings has increased: on the one hand, changes in consumer habits and the democratisation of commodities has led to an exponential increase in the amount of objects in homes, combined with the tendency for households to buy food and consumable goods in bulk. Storage areas within dwellings therefore need to be reconsidered and enlarged.

The option of online management of the amount of products stored allows for automatic management, using Internet trading companies which offer household deliveries. Even if this system is not fully used and is still quite rare amongst consumers, the ease and speed of ordering through the Internet is an attractive alternative to regular shopping expeditions. Given this scenario, it may be said that the structures assembled in dwellings for storing large amounts of food (e.g. chest freezers) may be replaced by smaller ones.

Conversely, we are also facing a reduced need for storage with regard to objects that are being replaced by digital formats. Shelves of CDs and DVDs, books, folders containing documents, etc, may be replaced nowadays by their digital equivalents which are only centimetres large. These digital formats will gradually replace physical devices and may not even be stored in the home but on external servers instead, making them accessible from anywhere in the world.

Circulation

The hall is a circulation area within the home and, in most cases, consists of an area isolated by means of doorways or a different geometry to the adjacent rooms.

The existence within the building of various filter areas and systems to control access (video surveillance, automatic locking), even before the entrance to an individual dwelling is reached, are factors that may alter the significance and function of the hall.

We are witnessing a reduction in the number of inconvenient and unscheduled visits to the home thanks to two current technological innovations: the use of distance communications (the Internet and mobile phone) to the detriment of physical encounters and the decentralisation of meters outside dwellings. The immediate consequences of this are less use of the hall as a filter area and the need to consider its significance in present day housing.

On the other hand, the current trend towards making purchases online, particularly ready meals delivered to the home, counters this theory that we are receiving fewer inconvenient visitors in the home. Supermarket purchases, books, music, films, flowers, newspapers, bread, etc are also delivered to the home, in addition to meals. These sporadic events signify the entry of strangers into the home and it therefore becomes logical to provide an entrance area that may be independent and offers no direct visual access to the rest of the house.

With regard to technological aspects, the main control panel for the entire system is usually located in the entrance area, where it can be checked and managed. The central control unit, the computer, may be installed in a normal electrical switchboard, if protection against electromagnetic interference is ensured.

Smoke, temperature and humidity sensors and presence detectors linked to the security and lighting system should also be installed in the hall, in addition to a video surveillance web camera that allows for remote viewing of the dwelling. In addition, the hall is also the main area for installing the interface for controlling lighting, heating/cooling and security systems.

Quality level

Two quality levels for the functional housing programme – minimum and recommended - have been defined for this study. The criteria and values presented are always the minimum acceptable for the situations in question.

The minimum level consists of the minimum habitability requirements and is adapted to low-income households. This level is reflected in both the size of the living space and the number of rooms.

The recommended level is destined for households with greater purchasing power but is also defined by the minimum criteria for this level. In households which include individuals with restricted mobility, the recommended quality level is the one that should be considered.

USE REQUIREMENTS

CAPACITY

			Number of inhabitants 1	2	3	4	5	6	7	8	9
Habitable rooms	Bedroom	Double		1 -	1	1	1	1	1	1	1
		Twin				1 -	1 -	2 -	2 -	3 -	3 -
		Single	- 1	- 2	1	- 2	1 3	- 4	1 5	- 6	1 7
	Living room	Combined living / dining room	1	1	1 -	1 -	1 -	1 -	1 -	1 -	1 -
		Dining room	-	-	- 1	- 1	- 1	- 1	- 1	- 1	- 1
		Living room	-	-	- 1	- 1	- 1	- 1	- 1	- 1	- 1
		Home office									
		Media room									
	Kitchen		- 1	- 1	- 1	1	1	1	1	1	1
Non- habitable rooms	Bathroom	Main	1	1	1	1	1	1	1	1	1
		Second					1	1	1	1	1
		Third							1	1	1
		Guest									
	Circulation	Hall	(shaded)								
		Corridors	(shaded)								
	Laundry		(shaded)								
	Storage		(shaded)								
	Closet		(shaded)								
Number of habitable rooms			1 3	2 4	3 5	4 6	5 7	5 8	6 9	6 10	7 11

(shaded) Other spaces required; X / Y: X Minimum level, Y Recommended level

Table 19 – Number of obligatory separate rooms per number of people in co-residing group, (adapted from (Pedro 1999a: 10, 54)) (on the basis that all co-residing groups containing more than 2 people may include a couple, these groups are therefore always allocated 1 double bedroom, which may be converted into a twin bedroom)

Housing capacity consists of the set of spaces and rooms included in a dwelling. Certain spaces are obligatory in order to guarantee the minimum level and others are optional and correspond to higher quality levels.

Private exterior spaces and spaces annexed to the dwelling were not considered in the definition of the functional programme, since in the buildings studied these areas were very small and offered limited possibilities for functional use. Given the small size of balconies in the building type studied, which made it impossible for them to be used for social and/or dining purposes for example, this space was not considered to supplement the area.

Table 19 shows the minimum rooms required according to the size of the household. Table 20 shows the number of bedrooms and other habitable rooms according to family size and characteristics.

Family		Number of bedrooms minimum[3]	Number of bedrooms recommended[2]	Number of living/dining/office rooms minimum[3]	Number of living/dining/office rooms recommended
1 person	Person living alone	0 / 1	1	1	1
2 people	Couple without children	1	1	1	1
	Couple likely to have children	1	2	1	1
	2 people co-residing	2	2	1	1
	Mother/father with 1 child	2	2	1	1
3 people	Couple with 1 child	2	2	1	2
	Couple with 1 other person	2	2	1	2
	Mother/father with 2 children	2[4]	3	1	2
	Mother/father with 1 child + 1 other person	3	3	1	2
	3 people co-residing	2	3	1	2
4 people	Couple with 2 children	2[4]	3	1[1]	2
	Couple with 2 other people	2[5]	3	2	2
	Mother/father with 3 children	3[4]	4	1	2
	Mother/father with 2 children + 1 other person	3[4]	4	2	2
	4 people co-residing	4	4	2	2
5 people	Couple with three children	3[4]	4	2	2[1]
	Couple with 3 other people	3[5]	4	2	2
	Mother/father with 4 children	3[4]	5	2	2
	Mother/father with 3 children + 1 other person	4[4]	5	2	2
	5 people co-residing	3	5	2	2
6 people[6]	Couple with 4 children	3[4]	5	2[1]	2[1]
	Couple with 4 other people	3[5]	5	2	3
	Mother/father with 5 children	4[4]	6	2	3
	Mother/father with 4 children + 1 other person	4[4]	6	2	3
	6 people co-residing	3	6	2	3

[1] In recomposed families (containing children from different marriages) it is recommended that one extra space should be added to the number of rooms allocated

[2] When any resident (with the exception of one member of the couple) occupies the dwelling for less than 50% of their time, the recommended level may opt for twin bedrooms rather than single bedrooms, thus reducing the number of bedrooms.

[3] If the family includes an individual with restricted mobility, the recommended level may opt for single bedrooms rather than twin bedrooms, thus increasing the number of bedrooms and increasing the number of rooms by 2.

[4] Only two siblings of the same sex may be considered to share a room. In the case of brothers and sisters, the number of bedrooms is increased by 1.

[5] Only two individuals of the same sex may be considered to share a room. In the case of single men and women, the number of bedrooms is increased by 1.

[6] Households comprising more than 6 people were not considered, as the national figures for these groups are very small (see *Part 1 – Chapter 4)*

Table 20 – Number of bedrooms and other habitable rooms according to family size and characteristics.

Housing capacity, as expressed by the number of rooms, varies from the minimum quality level, featuring only the essential rooms, to the recommended level, in which other rooms are added to provide greater flexibility of use.

In cases in which the functional programme is checked and validated by the family, it is possible to alter the preliminary ideal functional programme (output 1) by adding new spaces at the request of the families. In addition to defining new spaces, it is also necessary for the family to prioritise their additional requirements. This enables the most important requirements to be selected in the event that not all requirements can be met and also allows the solution to be assessed in terms of the final rehabilitation layout.

Spaciousness

The spaciousness of a dwelling enables residents to make use of equipment, furniture, circulation areas and space for carrying out activities within rooms. Rehabilitation work must ensure that residents can improve or maintain suitable conditions for carrying out user functions within dwellings. Spaciousness must be adapted to the total number of residents in the dwelling, as described in Table 21 (page 213).

In order to define the areas of rooms in dwellings, data from Pedro (1999a), Paiva *et al.* (2006) and the RGEU (General Regulations for Urban Buildings) were used. Two levels – minimum and recommended – were defined on the basis of this data. The minimum level was defined using RGEU figures, the figures given by Pedro (1999a: 58) for the minimum level and figures given by Paiva *et al.* (2006: 351) for housing rehabilitation. An area was added to these figures for homeworking and recreational activities using electronic equipment considered essential for any level of housing quality. The additional area was included in the home office and living areas.

In terms of the recommended level, the figures given by Pedro (1999a: 58) for the optimum level were considered, to which an area for homeworking, recreational activities using electronic equipment and home cinema in the media room space were added.

In rooms in which equipment/furniture are very important it is necessary to pay attention not only to floor space but also the linear dimensions of the free walls to which furniture can be attached, as well as the relationship between the length, width and floor-to-ceiling height of the room. From this perspective, in addition to the figures for the usable floor areas previously presented, other size criteria relating to rooms should not be disregarded (Pedro, 1999a: 67), namely:

- Bedrooms and isolated home office:
  - If the area is $9m^2$ or less, one of the dimensions should not be less than 2.1m;
  - If the area is $9.5m^2$ to $12m^2$ it should be possible to inscribe a circle with a diameter of no less than 2.4m, or, for the minimum level, 1.8m (Paiva *et al.*, 2006: 351);
  - If the area is more than $12m^2$, it should be possible to inscribe a circle with a diameter of no less than 2.7m, or, for the minimum level, 1.8m (Paiva *et al.*, 2006: 351);
  - The length of the room should not be more than twice its width, unless the position of the door or window openings ensures sufficient lighting for the use allocated to the room
- Living room, dining room and combined living/dining room:
  - In dining rooms
    - If the area is $9m^2$ or less, one of the dimensions should not be less than 2.1m;
    - If the area is $9.5m^2$ to $12m^2$, it should be possible to inscribe a circle with a diameter of not less than 2.4m;
    - If the area is more than $12m^2$, it should be possible to inscribe a circle with a diameter of not less than 2.7m;
    - There should be circulation space around the table;
  - In combined living/dining rooms and living rooms it should be possible to inscribe a circle with a diameter of not less than 3m for the minimum level and 3.5m for the maximum level;

- If a home cinema is allocated to the living room, it should be possible to inscribe a circle with a diameter of not less than 3.5 m;
- In the isolated media room, at least one of the dimensions should not be less than 3.5m;
- The length of the room should not be more than twice its width, unless the position of the door or window openings ensures sufficient lighting for the use allocated to the room;
- Rooms which have more than one access should be planned to avoid adverse effects on the functional arrangement of the furniture;

– Kitchen
    - Kitchens should contain enough space to install all electrical appliances, namely a large fridge, (electric or gas) cooker and oven, microwave oven, dishwasher, washing machine, smaller appliances (coffee machine, kettle, toaster, etc.) and the interface for the household domotics system, with Internet access;
    - In order to include a dishwasher, work surface and oven, the linear dimension for kitchens should not be less than 1.7m;
    - The distance between opposite workbenches or workbenches and the wall should be 1.1m or more, or 1.2m in the case of individuals with restricted mobility;
    - Kitchens with more than one access should be planned to avoid interruptions to the work space and obstacles to the installation of equipment;
    - Kitchens should include an area for everyday meals:
    - In the case of individuals with restricted mobility, all or part of the kitchen work surface should allow for height adjustments, to enable people to work from a sitting position. Assistive technologies are addressed in *Part 2 – Chapter 3.1.2*;
    - In the case of individuals with restricted mobility, after the kitchen equipment has been installed, it should be possible to inscribe a circle with a diameter of 1.5m and a height of 0.3m and another with a diameter of 1.3m and a height of 2m;

– Bathrooms
    - The interior dimensions should not be less than 1m (Paiva *et al.*, 2006: 351);
    - There should be at least one fully equipped bathroom of a size that ensures it can be used by individuals with restricted mobility. It should be accessible from at least one bedroom, living room, kitchen and entrance.
    - In the accessible bathroom it should be possible to inscribe a circle with a diameter of 1.5m and a height of 0.3m and another with a diameter of 1.3m and a height of 2m;

Number of bedrooms / number of residents

Rooms	T0	T1		T2			T3			T4			T5		
	1	1	2	2	3	4	4	5	6	5	6	7	7	8	9
Double bedroom			10,5 12		10,5 12	10,5 12	10,5 12	10,5 12	10,5 12	10,5 12	10,5 12	10,5 12	10,5 12	10,5 12	10,5 12
If reduced mobility			13 15		13 15	13 15	13 15	13 15	13 15	13 15	13 15	13 15	13 15	13 15	13 15
Twin bedroom [a]						10,5 14,5		10,5 14,5	10,5 14,5		10,5 14,5	10,5 14,5	10,5 14,5	10,5 14,5	10,5 14,5
If reduced mobility						13,5 16,5		13,5 16,5	13,5 16,5		13,5 16,5	13,5 16,5	13,5 16,5	13,5 16,5	13,5 16,5
Single bedroom [a]	5 [j] 5 [j]	8 8,5		8 [l] 8,5	8 8,5		8 [l] 8,5	8 8,5		8 [m] 8,5	8 [m] 8,5	8 [m] 8,5	8 [m] 8,5	8 [m] 8,5	8 [m] 8,5
If reduced mobility	6 [j] 6 [j]	9,5 12,5		9,5 12,5	9,5 12,5		9,5 12,5	9,5 12,5		9,5 12,5	9,5 12,5	9,5 12,5	9,5 12,5	9,5 12,5	9,5 12,5
Combined living/dining room	12 18,5	12 18,5	12 18,5	12 18,5	15 20,5	17,5 23,5	17,5 23,5	19 24,5	21 26,5	19 24,5	21 26,5	24 32,5	24 32,5	29 35,5	29 36
Living room			- 11,5	- 11,5	- 13	- 16	- 16	13 16	13 19,5	13 16	13 19,5	16 22,5	16 22,5	19,5 26	19,5 26
Dining room			- 7,5	- 7,5	- 8,5	- 9,5	- 9,5	7 10,5	8 11,5	7 10,5	8 11,5	9 12,5	9 12,5	10 13,5	11 14
Home Office [b]	1 2	1 2	1/2 3/4	1 3	1/2 3/4	1/2 3/4	1/2 3/4	1/2 3/4	1/2 3/4	1/2 3/4	1/2 3/4	1/2 3/4	1/2 3/4	1/2 3/4	1/2 3/4
Media room [c]	- 2	- 2	- 2	- 2	- 2	- 3/12	- 3/12	- 3/12	- 3/12	- 3/12	- 3/12	- 4/14	- 4/14	- 4/14	- 4/14
Kitchen [d]	4 6	4 6	6 9	6 9	6 9,5	6 10,5	6 10,5	6 11,5	6 12	6 11,5	6 12	6 13	6 13	6 13,5	6 14
If reduced mobility	5,5 6,5	5,5 6,5	6 9,5	6 9,5	6,5 11,5	7 12	7 12	7 12	7,5 13	7 12	7,5 13	8 13,5	8 13,5	8,5 14,5	9 15
Laundry [e]	2	2	2 3,5	2 3,5	2 3,5	2 3,5	2 3,5	2 3,5	2 4	2 3,5	2 4	2 4,5	2 4,5	2 4,5	2 4,5
Main bathroom [f]	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5	3,5 5
If reduced mobility	6 7	6 7	6 7	6 7	6 7	6 7	6 7	6 7	6 7	6 7	6 7	6 7	6 7	6 7	6 7
Second bathroom [g]						- 2	- 2	1 2	1 3	1 2	1 3	1 3	2,5 3	2,5 3	2,5 3
If reduced mobility						- 3	- 3	1,5 3	1,5 3,5	1,5 3	1,5 3,5	1,5 3,5	2,5 4	2,5 4	2,5 4
Third bathroom [g]												- 2	- 2	- 2	- 2
Guest bathroom						- 1	- 1	- 1	- 1	- 1	- 1	- 1	- 1	- 1	- 1
If reduced mobility						- 3	- 3	- 3	- 3	- 3	- 3	- 3	- 3	- 3	- 3
Storage(general) [h]	1,25	1,25	1,25	1,25	1,5	1,5	1,5	1,75	1,75	1,75	1,75	1,75	1,75	2	2,25
Storage(pantry) [h]	1	1	1,25	1,25	1,25	1,5	1,5	1,5	1,75	1,5	1,75	1,75	1,75	2	2
Storage(closet) [h]	0,75	0,75	0,75	1	1,25	1,5	1,5	1,75	2	2	2	2	2	2,5	2,75
Circulation [i]	16% of the total net area														
Dwelling net floor area	35 50,5	38,9 54,5	44,4 66,4	49,9 71,3	58 81,2	62,6 96,9	69,6 99,7	75,4 112	79,5 127	81,5 115	86,4 130	93,4 147	102 150	110 164	113 172
If reduced mobility	39,5 54	44,4 61	49,4 71,9	53,9 77,8	63,5 88,2	69,6 106,4	77,1 109,2	81,4 119,5	87 133,5	88 123,5	92,4 138,5	98,9 154,5	109 158	117,5 173	121 181

a _ bedrooms include study and recreational area for young people (minimum of 1m^2 for individual study, minimum level, 2m^2 for individual study, recommended level, 1,5m^2 for twin study, minimum level, 3,5m^2 for twin study, recommended level)

b _ if included/demarcated space (home office will only be isolated at the request of residents, in which case it will be the same size as an individual bedroom). The defined area assumes two working-age adults and will be increased by 1m^2 for each additional working-age adult.

10	Minimum area, minimum level
12	Minimum area, recommended level
(grey)	Included

c _ included/isolated (media room will only be isolated at the request of residents)
d _ preparation of meals (eating area for everyday meals included in recommended level)
e _ washing machine and natural drying of clothes
f _ full bathroom facilities: basin, bath, toilet and bidet
g _ partial bathroom facilities: basin and toilet, shower (or bath, in T5 dwellings)
h _ storage spaces for recommended level only
i _ average circulation area in relation to floor space in "rabo-de-bacalhau" dwellings
j _ extra area to be included in combined living/dining room
l _ one of the individual bedrooms may be $7m^2$
m _ two of the individual bedrooms may be $7m^2$

Demarcated

Isolated

Table 21 – Minimum floor space for dwelling. Adapted from (Pedro, 1999a: 60, 61), (Pedro, 1999b: 154), (Pedro, 2002), (Paiva *et al.*, 2006: 351).

– Circulation areas
  - Horizontal circulation areas should be not less than 0.9m wide (Paiva *et al.*, 2006b: 351), or 1.1m in sections extending 1.5m or less (in sections with no access to the doors of rooms, the width should be 0.9m or more) in the case of individuals with restricted mobility;
  - It is recommended that the main entrance/exit areas, doors to rooms and doors to storage areas should not overlap;
  - The doorways for the main entrance to the dwelling and to rooms should be at least 0.77m wide, to provide access for wheelchair users;
  - In the case of individuals with restricted mobility, it should be possible to inscribe a circle with a diameter of 1.5m at the entrance to the dwelling.

If there is a need to reduce the ceiling height by installing false ceilings or raised floors, the following minimum values should be considered: not less than 2.4m for habitable rooms; not less than 2.2m for non-habitable rooms (Pedro, 1999a: 67).

Articulation

The links between different areas and rooms refer to the way in which one space is connected to other spaces. Spaces may have the following characteristics (Figure 125): inclusive, when various functions are accommodated within the same room; isolated, when the function carried out is the main or only one within the space in question; demarcated, when the physical separation between two spaces in which separate functions are carried out is less clearly defined.

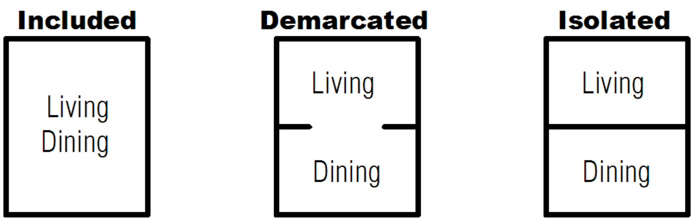


Figure 125 – Articulation between spaces. Adapted from (Duarte, 2007: 358)

In the universe analysed in this study, most areas are isolated given that the rooms are very small and cannot be used for a variety of functions. It was therefore usual for the function carried out in a room to be the main or only one. The most common case for an included space, in 5 of the 25 cases, was the combined living and dining room which combined the functions of socialising/receiving visitors and serving formal meals.

The characteristics of the articulation between rooms are shown in Table 21 for each type of space.

Topology

The topology defined for the functional programme includes all options for direct relationships between spaces (connections - door to, passage to, window to) and indirect relationships (close to, next to, far from, adjacent to, depth, integration, distributedness).

Space syntax theories are used to define the ideal topology for a given family and a given home capacity and spaciousness, focussing on the topology of the setting and the patterns created by relationships between spaces, but not on its size or shape (Ortega-Andeane *et al.*, 2005). The use of space syntax helps to define how spatial organisation promotes the use of dwelling space and its important effect on the way people move around the dwelling.

Space syntax provides an assortment of tools to analyse and describe the spatial configurations of settings. The integration measure is used to determine whether a space in the setting is segregated or integrated. Graph descriptions are also used which, according to Heitor (Heitor et.al, 2004), consider topological size (number of nodes), depth (number of levels) and topological types (see *Part 1: Chapter 3*).

Topological size is related, on the one hand to dwelling capacity and, on the other hand, to topological relationships between spaces. Depth depends on the accessibility of one space in relation to another and has different values according to whether the access is direct, or there is an intervening space between them. Topological types are classified by Hillier (2007: 250) as "a", "b", "c" and "d" according to the permeability between the different spaces, as described in *Part 2: Chapter 1.3.3*.

The topological relationships for the various spaces in the dwelling are presented in order of priority. In addition to the recommended topological relationships defined in the ideal functional programme, future residents may add new relationships between rooms and define the priorities for these relationships. The final ideal functional programme is defined on the basis of the topology proposed by the resident and the new spaces required.

Bedrooms	1. Should have individual access via a door connecting to the private circulation area → bedrooms should be topological type "a" as their priority is occupation; 2. Should be close to each other and accessed from the same private circulation area or another area connected to it; 3. Should have access to a private bathroom from one or more spaces in the private circulation area; 4. Bedrooms may have direct access to a private bathroom or a step-in closet → in this case bedrooms would be topological type "b"; 5. Bedrooms should be linked to the entrance to the dwelling via one circulation area (minimum level) or two isolated circulation areas (recommended level); 6. Bedrooms and private bathrooms should be the most segregated spaces in the dwelling; 7. In T3 or larger dwellings, one twin or single bedroom need not fulfil the above criteria; 8. T4 or larger dwellings may include one twin or single bedroom accessed only via the social area (living room, dining room, home office or media room).

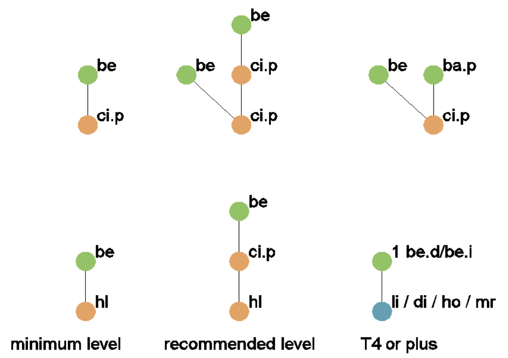


Figure 126 – Graphs illustrating possible solutions for bedrooms. The abbreviation "be" refers to one or more rooms with the same function when they are on the same level in the graph and linked in the same way to connecting rooms.

Living room

1. Should have individual access via a circulation area or, if this is not possible, access from a circulation area via another room (living or dining room);
2. A second access via another space in the social area (living or dining room) is recommended, and this should also be connected to circulation areas → living and dining rooms should be topological type "c" or "d" in order to foster movement as well as relationship and choice;
3. Should have access to the entrance to the dwelling via another room or one or two circulation areas → living rooms should be on level 2, 3 or 4 of the justified graph;
4. Should be adjacent to the dining room, to allow for enlargement of both areas
5. Should have access, via a circulation area, to a bathroom, preferably the guest bathroom.
6. The living room, and other spaces in the social area, should be well-integrated within the dwelling;
7. Should have a low proximity relationship as well as a low accessibility relationship to the bedrooms;

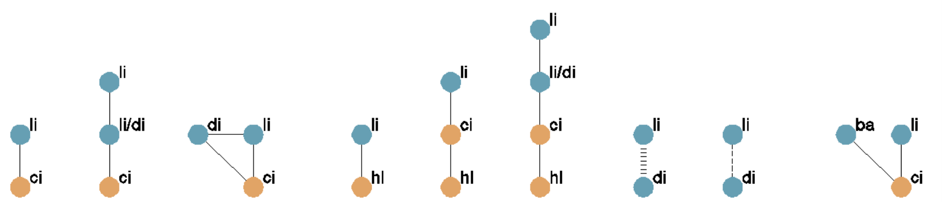


Figure 127 – Graphs illustrating possible solutions for living rooms. The abbreviations "li" and "li/di" refer to one or more rooms with the same function, when they are on the same level in the graph and linked in the same way to connecting rooms.

Dining room

1. Should have individual access via circulation area or, if this is not possible, access to a circulation area via the living room;
2. A second access via the living room is recommended, and this should also be connected to the circulation areas → living and dining rooms should be

topological type "c" or "d" in order to foster movement as well as relationship and choice;

3. Should have access to the entrance to the dwelling via anther room or one or two circulation areas → dining rooms should be on level 2, 3 or 4 of the justified graph;
4. Should be adjacent to the living room, to allow for the enlargement of both areas;
8. Should have access, via a circulation space, to a bathroom, preferably the guest bathroom.
5. May have direct access to the kitchen but should allow for protection from sight, noise and odours;
6. Should have a low proximity relationship as well as a low accessibility relationship with bedrooms;
7. Should have access, via a circulation area, to a bathroom.

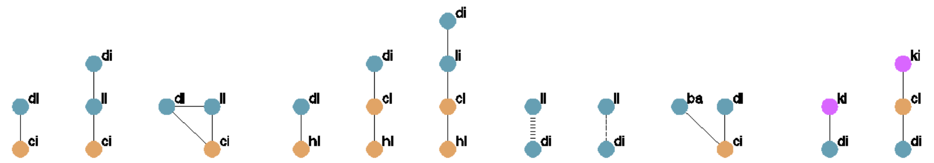


Figure 128 – Graphs illustrating possible solutions for dining rooms.

Home office

1. According to the residents' requests, the home office may be included (in a living room, dining room, media room or bedroom), demarcated (within all the above spaces or corridors) or isolated;
2. Must have access via a circulation space, living room or dining room;
3. Should have a close proximity relationship with, or be included in, the other spaces in the social area (li, di, mr);
4. May be located close to private spaces, connecting to a private circulation space, step-in closet or bedroom.

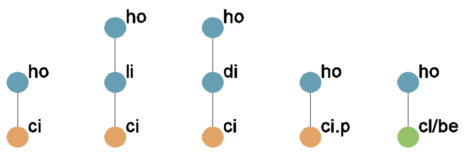


Figure 129 – Graphs illustrating possible solutions for home offices.

Media room

1. According to residents' requests, the media room may be included (in a living room), demarcated (within a living room, dining room or home office) or isolated;
2. If isolated, the media room should be topological type <u>a</u> in order to promote occupation rather than circulation or movement;
3. Must have access via a circulation space, living room or dining room;
4. Must be situated in the social area;

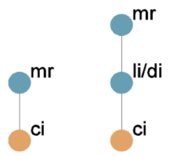


Figure 130 – Graphs illustrating possible solutions for media rooms.

Kitchen

1. Should have individual access via a circulation area;
2. If there are two access points, one may be via a room (combined living and dining room or dining room);
3. The kitchen may be linked to the main entrance via the circulation areas only;
4. The kitchen should have a short proximity relationship to the entrance of the dwelling → kitchens should be in a lower position - 2 or 3 of the justified graph;
5. There should be a direct connection to the area where everyday meals are served. If this is not possible, there should be a short distance between these two areas;
6. There should either be a direct connection or a connection via a circulation area to the room in which formal meals are served;
7. Should have access, via a circulation area, to a bathroom, preferably the guest bathroom.

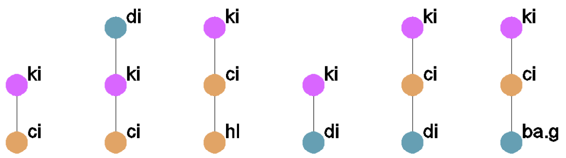


Figure 131 – Graphs illustrating possible solutions for kitchens.

Laundry

1. The laundry area should be demarcated or isolated and should not overlap into the kitchen or any other area.
2. There must be access to the kitchen from the laundry;
3. On the minimum level, the laundry may be included in the kitchen;

Figure 132 – Graphs illustrating possible solutions for laundries.

Bathrooms

1. Private bathrooms can only be accessed via private circulation areas, bedrooms or step-in closets → bathrooms should be topological type "a" in order to promote occupation;

2. Second private bathrooms may also be accessed via any of the circulation areas;
3. Guest bathrooms may be accessed via circulation areas (recommended level) or habitable spaces in the social area – the home office or media room – (minimum level);
4. Bathroom access should not be visible from the entrance.

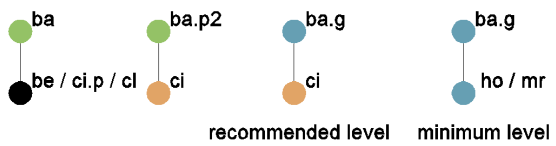


Figure 133 – Graphs illustrating possible solutions for bathrooms.

Circulation

1. The circulation area serving the private zone should be separated by a door leading to the circulation area which serves the social and service zone;
2. Circulation combined with other areas should create alternative paths within the dwelling → circulation spaces should be topological type "c" or "d" in order to foster movement as well as relationship and choice.

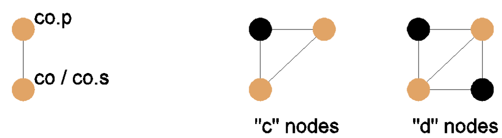


Figure 134 – Graphs illustrating possible solutions for circulation areas.

Hall

1. The hall should be directly linked to other (private and service) circulation areas in the dwelling;
2. The hall should be linked to the rooms in the social area (living room, dining room, home office, media room);

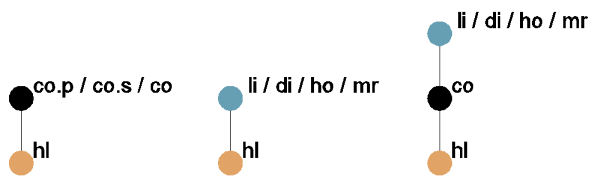


Figure 135 – Graphs illustrating solutions for the hall.

Storage (general storage, pantry, closet)

1. Storage space must be accessed via a corridor, the hall or a service corridor;
2. The pantry must be accessed via a service corridor, the kitchen or the laundry area;
3. The step-in closet must be accessed via a private corridor, a bedroom or the home office.

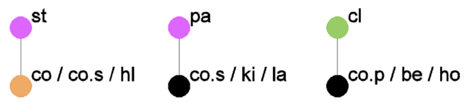


Figure 136 – Graphs illustrating possible solutions for storage.

Flexibility

The aim of promoting flexibility within dwellings is to respond to the way in which needs evolve over the useful life of a building. In fact, current needs may change within the space of a few years, and intervention work on buildings must therefore be as unintrusive as possible and any new elements introduced must allow for reversibility.

Nevertheless, it may be reasonable to introduce transformations before any actual need arises because they are cheaper when carried out as part of an overall refurbishment programme. Some of these, such as widening doors, may not be needed at present but would be more expensive to undertake at a later date as a one-off alteration (Bonnett, 1996).

An analysis of the current situation of "rabo-de-bacalhau" dwellings (see *Part 1 – Chapter 7*) reveals that identical rooms are used by different families in different ways. This clearly demonstrates that any transformations undertaken must allow for flexibility of use and be adaptable to the needs and desires of individual families.

It may therefore be stated that attributing a specific function to a room contradicts the need for adaptability. Despite this, it is felt that the transformations proposed for the dwellings need to be validated by an analysis which takes all habitability requirements into account and in doing so can define requirements for particular rooms and the connections between them.

The functional programme therefore consists of a set of spaces and functions defined in quantitative terms (X bedrooms, Y bathrooms, W rooms, etc) and in terms of the topological relationships between them. In order to take the need for flexibility into account, the definition of the functional areas and their connections aims to ensure, amongst other solutions, that they are well integrated by eliminating complex circulation areas and promoting alternative routes.

Achieving flexibility in dwellings through rehabilitation work cannot compromise the resistance capacity of the building or create functional or constructional incompatibilities between different floors.

Within this context, it is necessary to take the following criteria into account, which govern the intervention work in terms of promoting flexibility and the multiple use of spaces:

– A range of solutions for adapting a dwelling which follow similar criteria increase the diversity of offer for the building. It is possible to apply various transformation solutions to the same dwelling that are compatible from a constructional and functional point of view, taking the entire building into account;
– Constructional criteria
    - When new infrastructure networks need to be installed in the building (vertical sewage, ventilation and exhaust ducts, ICAT networks), they should conform to a location criterion that will enable them to be used on all floors, regardless of dwelling topology;
    - In terms of individual dwellings, the location and size of water, electricity and ICAT infrastructures determines future use and the expansion of the network should therefore be envisaged within the area reserved for this purpose;

  - Several power points and inputs for telecommunications networks should be provided in order to guarantee different types of use;
  - Any new walls should be built using "light" construction systems such as plasterboard with an interior cavity, in order to facilitate future alterations and allow domotics cables to be installed;
  - If during the course of the work an original doorway is no longer needed, it should be concealed rather than permanently sealed. It should be covered by easily removable panels, so that it will still be possible to connect the two rooms at a later date;
- Functional criteria
  - Neutrality of spaces should be encouraged, meaning that a room can potentially serve various alternative functions without the need for physical alterations. These rooms should be neutral in terms of access, doorways, minimum size and area;
  - It should be possible to alter relationships between spaces using reversible methods. The strategies required to accomplish this are the use of alternative connections, easily removable fittings and wide doorways between rooms;
  - In T3 or larger dwellings, one twin or single bedroom should be easily accessed from the entrance. This offers greater autonomy to an older child, an elderly person or guests and alternatively may be used to supplement the social area;
  - If there are two living rooms, they should be joined in particular circumstances; if two spaces are not available for a living room, it should be possible to add a bedroom to a living room to enlarge it;
  - There should be a connection between the kitchen and the area where everyday meals are served;
  - The existence of topological type "c" and "d" rooms means that there is a possibility of choosing routes within the dwelling and consequently altering the functions of the rooms;
  - In some current households, the introduction of an additional bathroom, changing the location of the kitchen or providing wheelchair-user bathroom space are not immediate priorities. In these cases, a future expansion stage may be cheaper, easier and less disruptive if certain important infrastructures are installed during the current rehabilitation work.
  - The widths for doorways and hallways should comply with the access standards stipulated in DL 163/2006. Although the programme does not include any proposals to widen hallways, due to the difficult nature of the work, widening doorways will allow for future flexibility.

ACCESSIBILITY

As previously stated, there is no obligation in dwelling rehabilitation projects to carry out barrier-free upgrades provided that this work does not create or increase non-compliance with standards (DL 163/2006). However, it is advisable to examine all the design components to determine whether an alternative design is feasible and would provide barrier-free access, thus offering additional convenience to all users.

Within dwellings, corridors, kitchens, bathrooms, stairs, ramps, fittings and doorways should conform to specific size criteria to ensure that they can be used by individuals with restricted mobility.

Any alterations carried out in a dwelling should address the need to ensure access for all. Rehabilitation work should take all the aspects of physical alterations into account that would be difficult for residents to undertake if they became necessary in the future. The dimensions of doorways and corridors, access to rooms and bathrooms should all be established during rehabilitation work, leaving the smaller-scale alterations for the time when they are actually needed.

Various access recommendations have been taken into account in this study. However, given that they do not fall within the scope of the research, the intervention work is governed by the principle of not worsening the existing situation and improving access only when the solution to the problem itself does not require constructional alterations to the dwelling.

If the access recommendations cannot be fully implemented, priority should be given to access to the living room, kitchen, one bathroom and one bedroom.

In cases involving only elderly people, individuals with restricted mobility or disabled people, an additional habitable room should be included in the dwelling which can be used as an occasional sleeping area for a nurse or carer. In these cases, all spaces should be accessible.

HABITABILITY REQUIREMENTS

Only habitability requirements which do not require unfeasible alterations to the building (e.g. changes to the façades) and which can be achieved by spatial-functional reorganisation are envisaged here.

The requirements listed below were adapted from Pedro (1999a: 34, 35) and should be incorporated into the housing programme.

Acoustic comfort

- A door should separate the private rest area (bedrooms) from the areas where daytime activities take place i.e. social and service areas;
- Social/meeting areas should not be adjacent to:
    - Sewage ducts and lifts or other shared facilities that create inconvenient noise;
    - Communal areas in the building;
- Rest areas should not be above or adjacent to:
    - Areas where daytime activities take place i.e. social and service areas in neighbouring dwellings;
    - Sewage ducts and lifts or other shared facilities that create inconvenient noise;
    - Communal areas in the building;

Visual comfort

- All habitable rooms (bedrooms, kitchens and living rooms) must have doors with glass windows or windows leading directly to the exterior to provide natural light and ventilation;
- In the case of kitchens, glassed verandas may replace door or window openings leading directly to the exterior;
- Habitable rooms, with the exception of the kitchen, must receive direct sunlight, at least in the NE-S-NW. Rooms dedicated to relaxing/socialising should face E-S-NW.

Security requirements

Fire safety

In the case of dwellings which cannot comply with all current fire safety regulations, the use of active detection and alarm systems may reduce the risks associated with fire (Paiva, 2006: 381).

The following are therefore recommended:

- Complete re-wiring;
- Repair, improvement or (total or partial) replacement of gas installations;
- Repair, improvement or (total or partial) replacement of heating system;
- Adoption of measures to facilitate evacuation: introduction of automatic detection and alarm systems (see *Part 2: Chapter 3.1)*;
- Installation of smoke detectors in the entrance hall in each dwelling to detect fire;
- Installation of temperature detectors in kitchens in each dwelling to detect fire.

Protection against intruders

With regard to protection against intruders, the proposals for the dwelling are based on adopting active control and detection systems (see *Part 2: Chapter 3.1*):

- Control of access to all entrances to the dwelling (doors and windows on ground floor and first floor and doors on the other floors);
- Remote control of presence by video surveillance in various areas of the dwelling;
- Intruder alarms.

Possible adjustments to the ideal default functional programme

The objective of this thesis is that the ideal functional programme should be defined automatically using the criteria defined in the previous sub-chapters with tables, flow charts and written recommendations. If the functional programme does not fully meet the needs of residents, they may add or change data, which may affect rooms and the relationship between them.

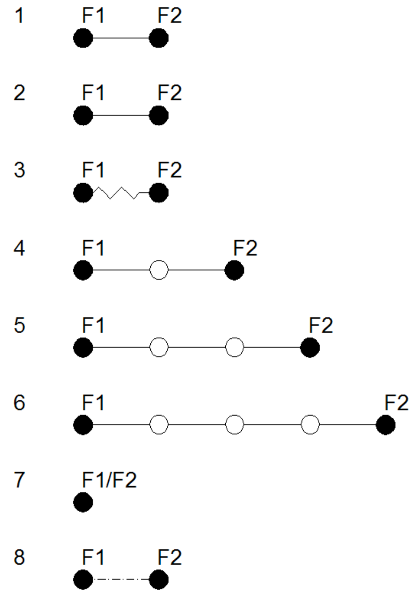
The following spaces may be added to rooms:

- Single bedroom (instead of a twin bedroom)
- Home office (isolated)
- Guest bathroom
- Private bathroom
- Media room
- Dining room (isolated)
- Storage area

The set of rooms that may be added to the initial definition of the functional programme was designed on the basis of knowledge of the study universe. In this way, only rooms that have proved feasible on the basis of the experiments performed are suggested. The demand for extra rooms must be met by prioritising so that, if it is impossible to meet all requirements, these will be incorporated in accordance with the residents' priorities.

In terms of topology, it is possible to define the relationships between each room included in the ideal functional programme and any additional rooms. These relationships should be expressed as follows:

1. Door to (has an arc between the two nodes)
2. Passage to (has an arc between the two nodes)
3. Window to (has an arc between the two nodes)
4. Next to (a third node connects the two nodes)
5. Close to (two nodes stands between the two original nodes)
6. Far from (more than two nodes stands between the two original nodes)
7. Merged with (two functional spaces are combined)
8. Adjacent to (the two rooms share a wall)



Topological relationships should also be ordered in terms of priority.

The second stage in the definition of the ideal functional programme enables the final programme to be personalised according to family needs.

2.3 THE ADAPTED FUNCTIONAL PROGRAMME FOR THE DWELLING

In order to satisfy the requirements contained in the ideal functional programme defined in the previous chapter, varying degrees of intervention work must be carried out in the dwellings.

In rehabilitation work, whether involving dwellings or other buildings, attention must be paid both to the morphology and the construction system to enable buildings to develop when the work is finished, whilst respecting the potential they offer, in terms of various combinations of functional use rather than only one standard solution.

The capacity of a dwelling to meet current requirements is not classified according to the age of the building. The idea that older buildings must have less housing quality than contemporary buildings is, in itself, erroneous. It results from the belief that current housing requirements involve various qualities that were not obligatory at the time when older buildings were constructed. These qualities are usually associated with different lifestyles, greater floor space, the inclusion of more domestic equipment and technology and better thermal performance (Lawrence, 1987: 242).

Although it is possible, through rehabilitation work, to provide older dwellings with the same standards of comfort as those found in contemporary dwellings, we should not forget that a range of aspects are involved in housing quality. Factors such as proximity to consolidated residential areas with a strong sense of community and proximity to services, amongst others, enhance housing quality and are major advantages when opting for rehabilitated dwellings.

Within the context of this research, as described in *Part 1: Chapter 7*, the study has focussed on "rabo-de-bacalhau" dwellings built between 1945 and 1960. In the proposed rehabilitation work, unlike buildings constructed from scratch, the functional programme for the dwelling is restricted by the existence of a specific building which, although designed for residential use, was planned for a different social, economic and constructional situation to ours. In addition to being organised in functional terms in a manner very typical of their time, the buildings in the study also have a constructional system that may restrict certain types of rehabilitation work. In fact, the existence of a dwelling with a very rigid morphology, as is the case with the "rabo-de-bacalhau" buildings, may restrict and alter the ideal functional organisation for a particular household. Therefore the adapted programme for the dwelling described in this chapter cross-references information from the ideal programme for the dwelling with the actual construction, with the aim of implementing the programme as far as possible within the constructional and function limitations of the existing dwelling.

"Rabo-de-bacalhau" dwellings differ in countless aspects, e.g. area and number of rooms, but retain the same *type* rules (Figure 137), as described in *Part 1: Chapter 7.3*. In fact, although the various dwellings presented are different, the spaces they contain are related in the same way in each of the dwellings, establishing a clear hierarchy in which certain sections must be omitted before others and certain sections can never be omitted. These differences are the *type* variations. The characterisation of *type* contained in *Part 1: Chapter 7.3* also enables the proposed adaptations to be categorised more specifically.

On the basis of type, the restrictions and potential of the "rabo-de-bacalhau" buildings were analysed in the light of current family needs and intervention work proposed for each conflict of use that are common to all types of building in the study and each particular building type.

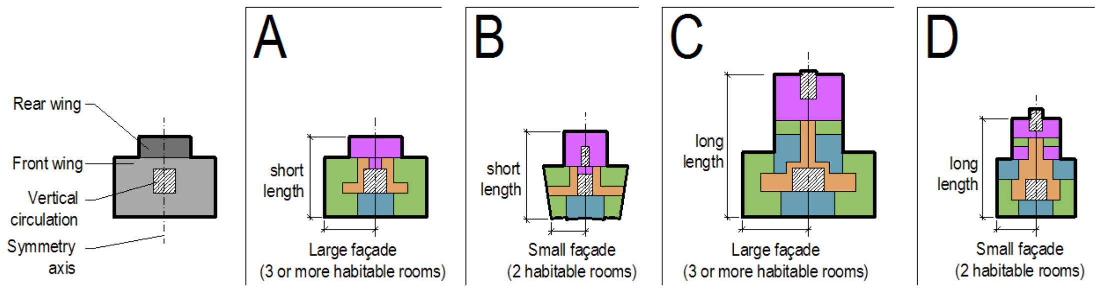


Figure 137 – Types of "rabo-de-bacalhau" dwellings

The buildings analysed in the sample, all over 50 years old, do not comply with current building legislation in terms of thermal, acoustic, structural and fire safety aspects, amongst others. In addition, with regard to the General Regulations for Urban Buildings, certain dwellings do not comply with provisions for natural light and ventilation in habitable rooms or other provisions. This research does not aim to resolve this non-compliance, but instead to adapt buildings to current lifestyles by integrating ICAT. Therefore, both the ideal and the adapted functional programme refer only to issues based on these adaptations.

The intervention work proposed in this chapter and adapted to current circumstances aims to accomplish the following:

- In functional terms
  - To redefine functional areas in accordance with present-day requirements;
  - To enable essential technological functions to be introduced;
  - To allow for reversibility in intervention work;

    - To allow for flexibility in intervention work.
- In constructional terms
    - The need for functional alterations should not exceed the existing constructional restrictions;
    - The layout of the interior should be altered by specific demolition of walls with no structural consequences;

As stated in *Part 2: Chapter 1.2*, this adapted functional programme corresponds to the pre-design phase, and occurs after the analysis, diagnosis and preliminary programme, at the time when it is necessary to assess the ideal functional programme options and adapt it to the existing situation. The information supplied in this chapter provides the knowledge required to fully inform the pre-design phase and produce unequivocal results without the need for a more extensive study, which is only undertaken in the more advanced phases of the project. This information will help architects adapt "rabo-de-bacalhau" buildings to new functional requirements in housing.

2.3.1 Choosing an appropriate dwelling

The first major decision in the rehabilitation process is to choose an appropriate dwelling for a given family. There are three possible market scenarios in which such a decision will have to be made: a family looking for a dwelling to rehabilitate, a family intending to rehabilitate its current dwelling, and a property developer intending to rehabilitate an existing dwelling for sale or for rent, in which case the future dwellers are unknown.

In any of these cases:

- if a family is seeking to buy a dwelling to rehabilitate, it is necessary to identify a set of dwellings of the type that can accommodate the family's functional programme; (Figure 138);
- if a family intends to rehabilitate its current dwelling, it is necessary to assess whether this dwelling would respond to the family's functional programme and, if not, to propose another dwelling (Figure 139);
- if a property developer intends to rehabilitate an existing dwelling for sale or for rent, it is necessary to carry out a market analysis to estimate the potential buyer or tenant family type. In this case, the future dwellers are anonymous (Figure 140).

The selection of an appropriate dwelling or the assessment of the appropriateness of an existing one is based on two criteria:

i) the correspondence between the type of dwelling and the family structure (Table 22);
ii) the correspondence between the area needed to accommodate the functional programme and the area of the dwelling (Table 23).

The area needed to accommodate the functional programme is an essential parameter that allows a dwelling type to be selected from among the ones included in the case study, labelled A to D. The data tables show that types A and C have larger areas and that types B and D are more appropriate for smaller families. Despite this, all types except type B can be subdivided using the third strategy.

When looking for an appropriate dwelling the following two scenarios are possible:

a) looking for an original dwelling;

b) looking for a dwelling that has been divided into two smaller ones, in which case the proposed dwelling has zero, one, or two bedrooms, i.e., it is T0, T1 or T2 accommodation, respectively.

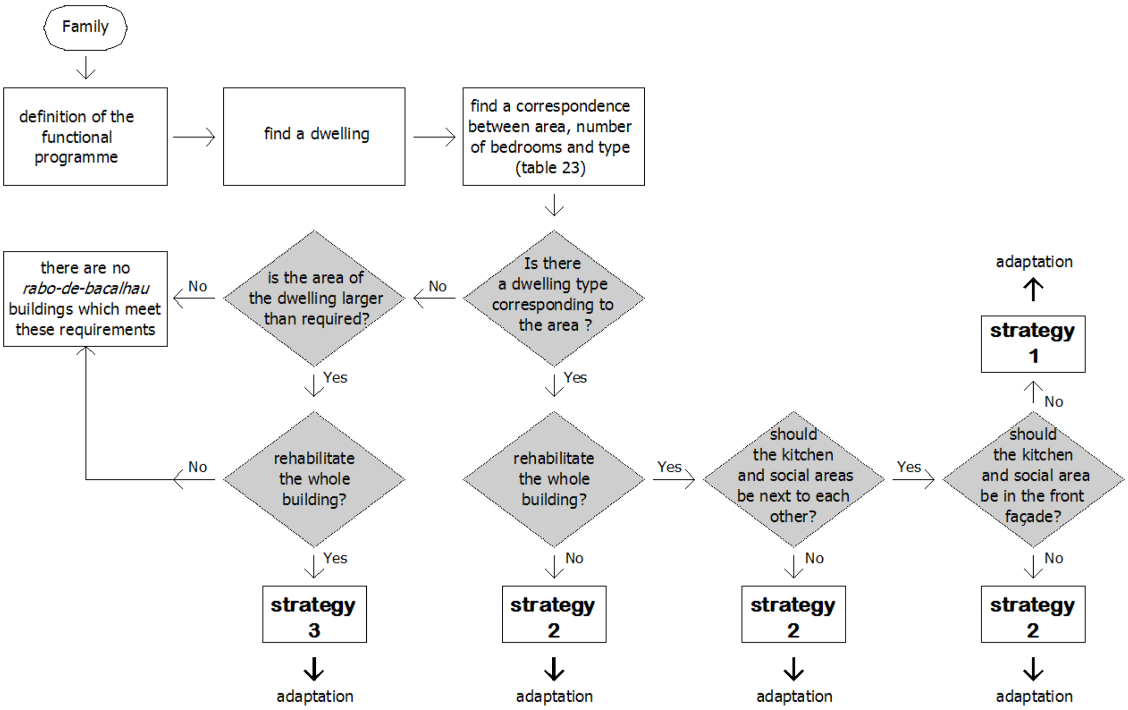


Figure 138 – Decision algorithm for the choice of a dwelling that can accommodate the family's functional programme.

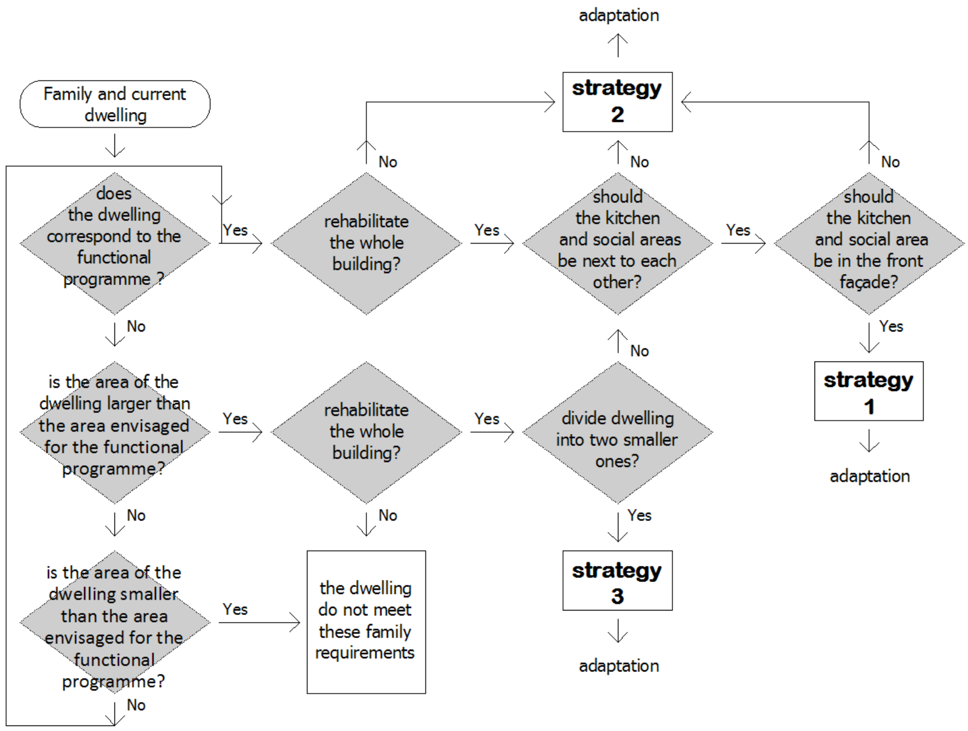


Figure 139 – Decision algorithm for the choice of a rehabilitation strategy when a family intends to rehabilitate their dwelling.

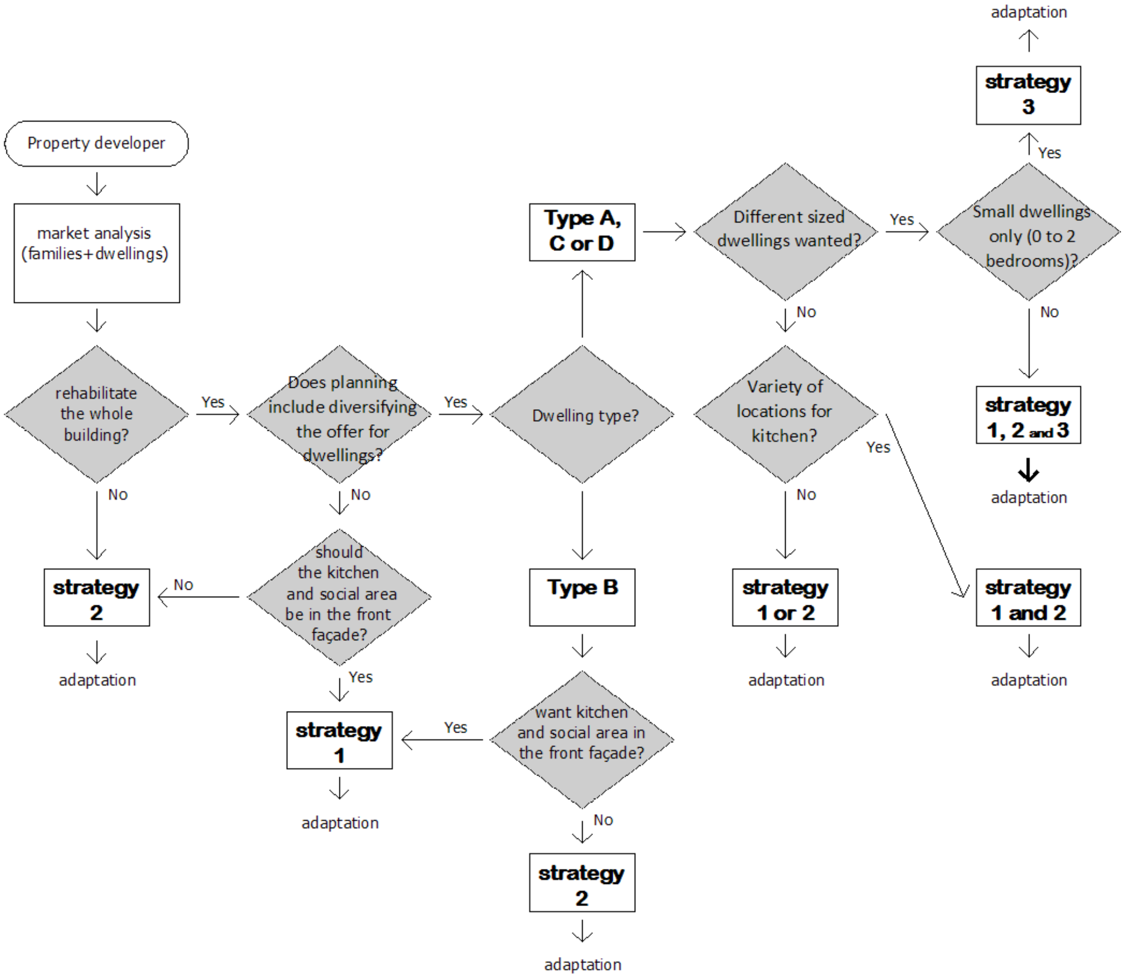


Figure 140 – Decision algorithm for a property developer who intends to rehabilitate an existing individual dwelling or the whole building.

Family		**Recommended number of bedrooms** (minimum)	***Rabo-de-bacalhau*** (types) **A**	**B**	**C**	**D**
1 person	Person living alone	0 / 1				
2 people	Couple without children	1				
	Couple who may have children in the future	1				
	2 people co-residing	2				
	Mother/Father with 1 child	2				
3 people	Couple with 1 child	2				
	Couple with 1 other person	2				
	Mother/Father with 2 children	2				
	Mother/Father with 1 child + 1 other person	3		*		
	3 people co-residing	3		*		
4 people	Couple with 2 children	2				
	Couple with 2 other people	3		*		
	Mother/Father with 3 children	3		*		
	Mother/Father with 2 children + 1 other person	3		*		
	4 people co-residing	4		*		
5 people	Couple with three children	3		*		
	Couple with other 3 people	4		*		
	Mother/Father with 4 children	3		*		
	Mother/Father with 1 child + 1 other person	4		*		
	5 people co-residing	5		*		*
6 people	Couple with 4 children	3		*		
	Couple with 4 other people	5		*		*
	Mother/Father with 5 children	4		*		
	Mother/Father with 4 children and 1 other person	4		*		
	6 people co-residing	6		*		*

Under-occupied   Ideal occupation   Over-occupied   Possible typologies, by room

Table 22 – Correspondence between number of people in household and types of "rabo-de-bacalhau" dwellings. Households of more than 6 people were not considered, as they are almost non-existent (see *Part 1 – Chapter 4*) * Types incompatible with household size.

Dwelling functional programme, area	**Number of bedrooms** 0	1	2	3	4	5	***Rabo-de-bacalhau*** (types) **A**	**B**	**C**	**D**
30 to 40 m^2	●									
40 to 50 m^2	●	●	●							
50 to 60 m^2		●	●							
60 to 70 m^2		●	●	●						
70 to 80 m^2			●	●	●					
80 to 90 m^2			●	●	●					
90 to 100 m^2				●	●					
100 to 110 m^2				●	●	●				
110 to 120 m^2				●	●	●				
120 to 130 m^2					●	●				
130 to 140 m^2					●	●				
140 to 150 m^2						●				
150 to 160 m^2						●				
160 to 170 m^2						●				
170 to 190 m^2										
190 to 210 m^2										

● Correspondence   Correspondence   No correspondence

Table 23 – Number of bedrooms and types according to areas required to implement the functional programme.

2.3.2 Three rehabilitation strategies

The process of inferring transformation rules from the experiments carried out enabled two possible methods of transforming the dwellings to be identified. In addition, a third method of transforming the dwellings was explored in order to create smaller dwellings for households consisting of one or two people.

Each of these three rehabilitation strategies has its own advantages and disadvantages in terms of functional and constructional aspects, and they can be combined within the same building to generate a wider market offer.

As mentioned in *Part 1: Chapter 7*, the buildings in the case study have 6 to 9 floors with a left-right symmetrical layout and 2 dwellings on each floor. This arrangement is repeated on all floors. The differences in the resulting transformations lie in the number of dwellings on each floor and the position of the kitchen in each dwelling.

The three strategies are as follows:

1. Maintaining two dwellings on each floor and moving the kitchen from its original position in the rear wing of the building to the front of the building.

   The aim is to strengthen the relationship between the social and service areas and to segregate the private area from the rest of the dwelling.

2. Maintaining two dwellings on each floor and the position of the kitchen.

   The aim is to keep construction transformations to a minimum without compromising the use requirements established in the functional programme. This strategy can be used to rehabilitate just one dwelling in the entire building.

3. Dividing one dwelling into two smaller ones and creating a kitchen in one of the new dwellings.

   The aim is to obtain smaller dwellings and a variety of dwelling types within the building.

Figure 141 shows the simplified derivation and decision tree for the three rehabilitation strategies described above, which is reflected in the structure of the grammar described in *Part 2: Chapter 4*.

For reasons of space and clarity of information, the decision tree shows only some of the transformation options for each strategy. The first transformation step shown is the choice of strategy, according to the resident/developer’s objectives. It then shows the option of defining the social area for strategies 1 and 2 and their basic variations. For strategy 3, the second step consists of choosing between the three methods of dividing up the dwelling to create different types of housing. The third step shows the definition of private space, which may have various configurations. The tree aims only to simulate the derivation by considering the main functional areas and not the specific rooms, with the exception of the kitchen, which is the major defining space in the service area.

The graphs which accompany the tree in Figure 141 are simplified and provide a general view of the situations illustrated.

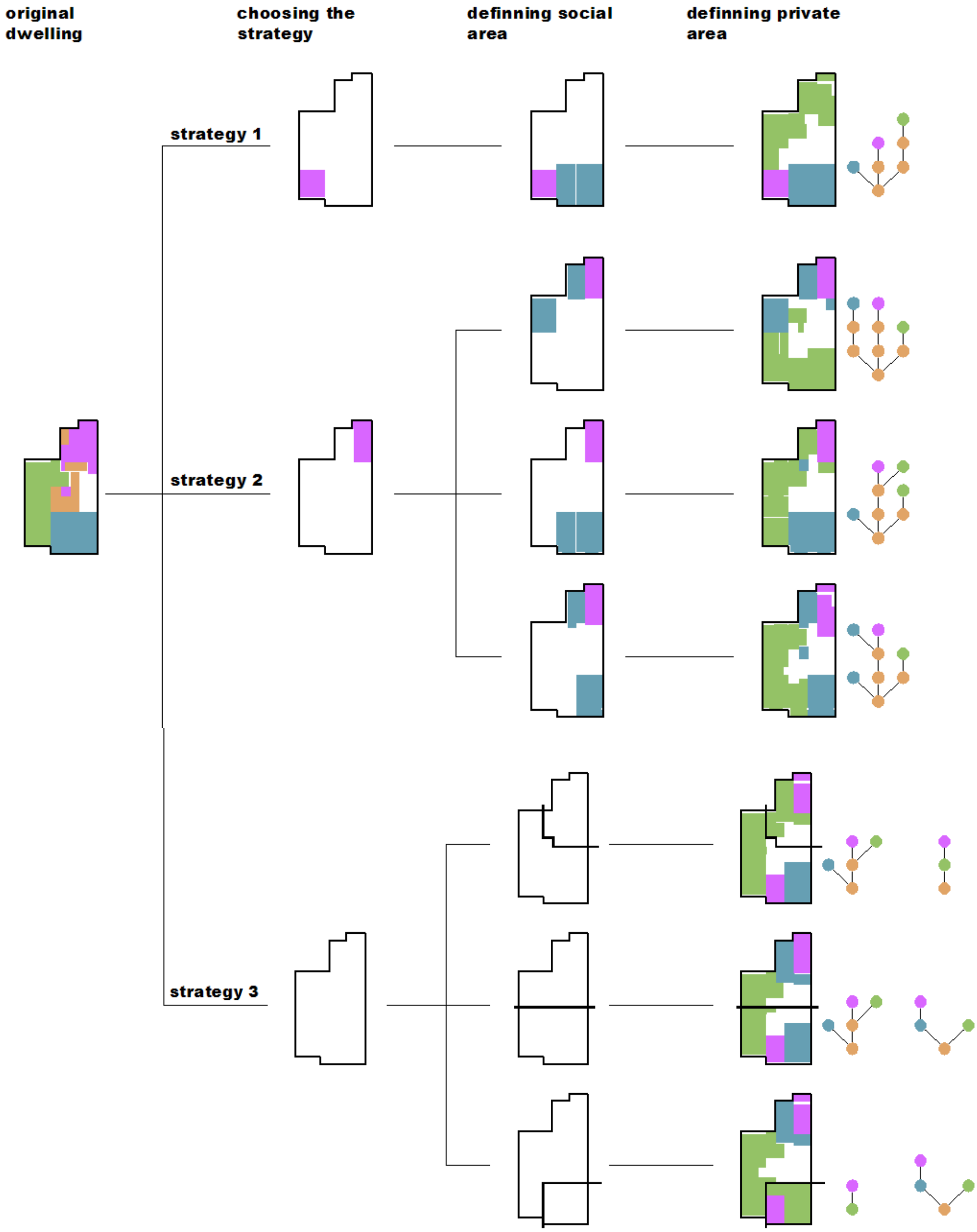


Figure 141 – Simplified derivation tree for the different rehabilitation strategies.

STRATEGY 1

In the first rehabilitation hypothesis the aim was to functionally reorganise the dwelling so that it would respond better to present day lifestyles. The kitchen is therefore situated next to the main façade so that it is conveniently linked to the main entrance and social areas, in particular the dining room. In this solution, the private areas are essentially located in the rear wing and are well segregated in relation to the remaining areas of the dwelling.

In this proposal the circulation areas in the rear wing are maintained, since they provide access to the bedrooms and bathrooms.

In experiments involving transformations of the dwellings exemplified in *Appendix 3* and Figure 142, all the examples produced by experimenter 2c followed this hypothesis.

The advantages and disadvantages of this strategy in terms of rehabilitating the dwelling and/or building are presented in Table 24.

Advantages	**Disadvantages**
– Good location for social area, with direct access to the main entrance and connection to kitchen	– Changing the location of the kitchen has a major constructional impact, requiring new infrastructures
– Location of kitchen/ social area improved, with direct access to the main entrance and connection to social area	– As it is located in the rear façade of the building, the drying area for laundry is included in the private area rather than the service area
– Private area better segregated, offering greater privacy	– This strategy in isolation does not increase the range of typologies within the building

Table 24 – Advantages and disadvantages of Strategy 1.

This strategy will produce different results, according to the type of dwelling (Figure 142):

- In types B and D, the front wing will be exclusively dedicated to service and social areas and the rear wing to private areas.
- In types A and C, the front wing will include part of the private area as well as the social and service areas.

The strategy 1 proceeds by:

a. Converting the smallest room at the front of the dwelling into the new kitchen;
b. Assigning social spaces (living and dining rooms, home office, guest bathroom) to rooms adjacent to the kitchen;
c. Occupying the rear wing with private areas (bedrooms and private bathrooms).

An analysis of the transformations tested in Step 2 of the experiments performed (see *Part 2: Chapter 1.4.2*) shows that the application of Strategy 1 produces dwellings with less depth and greater integration. Nevertheless the main room in the service area – the kitchen – generally acquires greater depth and less integration.

Moving from a general analysis to a specific analysis of each building type, the following may be noted:

- In types A, C and D, Strategy 1 produces transformations in which the dwellings acquire less depth and greater overall integration;
- In type B, the use of Strategy 1 leads to transformations in which dwellings acquire greater depth and less overall integration, which would indicate that this is not the best solution for this type of dwelling;
- Only in type C (the larger dwellings), does Strategy 1 manage to produce less depth and greater integration for the kitchen (originally a very segregated area of the dwelling)

Transformation using Strategy 1

Figure 142 – Transformation of a dwelling based on all 4 types, using Strategy 1

The fact that the drying area for laundry remains at the rear façade of the building means that, in terms of the service area, this strategy has some disadvantages.

Another interesting aspect is the comparison between integration measures in terms of the social area in the original and transformed dwellings. If the data contained in Table 14 (page 154) is analysed, it can be seen that this area was better integrated in the original dwellings than after transformation. In addition, an analysis of the transformations for each type confirms this. It is believed that this unexpected result is due to the fact that, in most cases, there was only one social area in the original dwellings, located near the entrance. In the rehabilitated dwellings, the fact that there are two or more social areas (living and dining room, home office, guest bathroom) means that, on average, the integration value for the social area is lower. This conclusion justifies the importance of considering the number of rooms and their function in any general analysis. Overall, the dwellings transformed using Strategy 1 acquired greater integration in comparison with the original solutions.

STRATEGY 2

The second hypothesis was developed with the intention of producing a less intrusive proposal in both functional and constructional terms. From this perspective, the aim was to maintain the wet zones as far as possible and only add one or two bathrooms when necessary.

The option of keeping the kitchen in its original location led to three options for the social area:

- Relocating the entire social area (or its main rooms) to the rear, providing a link between the service and social areas with the frequent disadvantage that the rooms were not very large and had a linear arrangement (Figure 143, type C);
- Keeping the social area in the front wing, linked to the main façade of the building and, consequently, away from the service area (Figure 143, type B and type D);
- Dividing the social area between the dining area (in the rear, near the kitchen) and the living room area in the front wing, linked to the main façade of the building, which has the disadvantage of separating the living/dining room areas (Figure 143, type A).

In this rehabilitation hypothesis, the premise of keeping the kitchen in its original position made it unfeasible, in most cases, to comply with all the functional requirements for connections between the different functional areas. The advantages of this strategy are presented in Table 25.

An analysis of the transformations tested in Step 2 of the experiments performed (see *Part 2: Chapter 1.4.2*) shows that Strategy 2, like Strategy 1, produces dwellings with less depth and greater integration.

Moving from a general analysis to an analysis of each building type, the following may be noted:

- In "rabo-de-bacalhau" types A, C and D, Strategy 2 produces transformations in which the dwellings acquire less depth and greater overall integration;
- In type B, Strategy 2 leads to transformations in which dwellings acquire greater depth and less overall integration, which would indicate that this is not the best solution for this type of dwelling;
- Only in types C and D does Strategy 2 manage to produce less depth and greater integration for the kitchen (originally a very segregated area of the dwelling)

Transformations using Strategy 2

Figure 143 – Transformation of a dwelling based on all 4 types, using Strategy 2

Advantages	Disadvantages
– Few constructional impacts – Few changes to the original morphology of the dwelling	– Poor results in terms of relationship between social and service areas – Private area generally very exposed – This strategy in isolation does not increase the range of typologies within the building

Table 25 – Advantages and disadvantages of strategy 2.

As was the case with Strategy 1, in the transformation sequence for Strategy 2 the social area as a whole does not become better integrated (Table 14). It is believed that this is due to the fact that, in most cases, there was only one social area in the original dwellings, located near the entrance. In the case of dwellings rehabilitated using Strategy 2, the existence of two or more social areas, sometimes separated from each other, means that on average the integration value for the social area is lower than in the original dwellings. For Strategy 2 as well, this conclusion justifies the importance of considering the number of rooms and their function in any general analysis. In general, disregarding the functional areas, the dwellings transformed using Strategy 2 acquired greater integration in comparison with the original solutions.

STRATEGY 3

The third rehabilitation strategy was explored with the aim of creating a more diverse offer within the building. The possibility of combining T0, T1 and T2 dwellings with other larger types such as T3s or T4s within the same building allows for greater social diversity and increases the real estate value of the building.

In addition, certain studies show that the demand for rehabilitated dwellings comes mainly from young families consisting of 1 or 2 individuals and that the desired types are T0, T1 and T2 (Caria, 2004: 163). "Rabo-de-bacalhau" buildings can therefore only be adapted to meet this demand by dividing one dwelling into two smaller ones.

It is interesting to note that, although divided, one of the new dwellings (the one in the rear) will always have areas with greater depth or segregation, given that the building is organised in terms of a long passage from the front wing to the rear. This occurs essentially in types C and D. In types A and B, in which the main nucleus for vertical access within the building offers two possible entrances to the dwellings, this can be inverted (Figure 144).

Advantages	Disadvantages
– Creates a range of typologies within the building – Offer meets demand – Makes building more profitable by providing accommodation for a larger number of families	– The addition of a kitchen has major constructional impacts, requiring new infrastructures – The dwelling which only opens onto the main façade has no outdoor area for drying laundry – In some cases dividing the dwelling involves removing space from the original hall to accommodate the two new entrances.

Table 26 – Advantages and disadvantages of strategy 3.

Transformations using Strategy 3

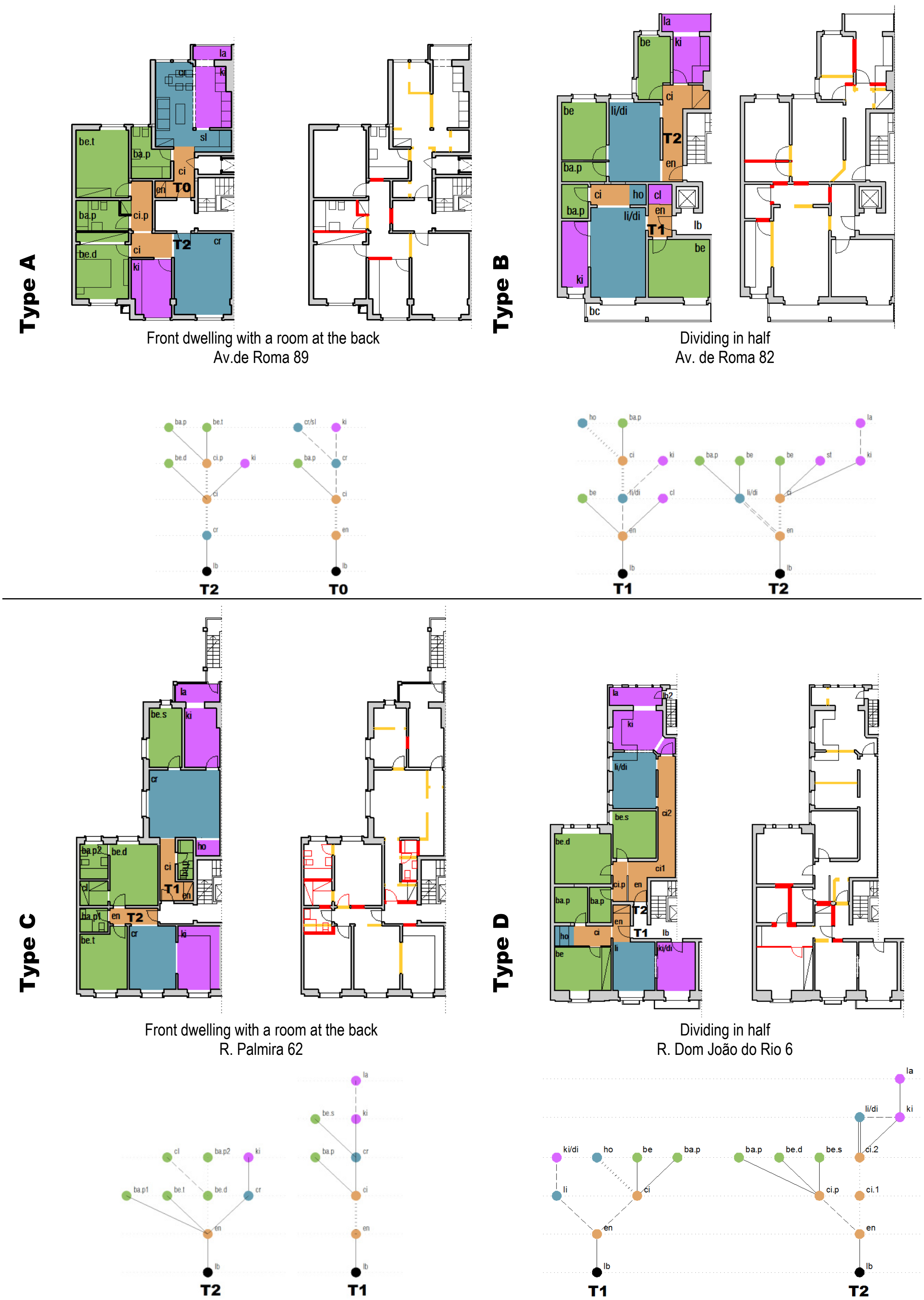


Figure 144 – Transformation of dwellings based on all 4 types, using Strategy 3

This strategy proceeds by:

a. Dividing the dwelling into two autonomous spaces as illustrated in Figure 145 according to the desired final dimensions for the dwellings / building type;

b. If there are two identical entrances to the dwelling (and the possibility of using the same vertical access) they should be used as the new entrances for the new dwellings (Figure 144, Type B). If not, part of the hall area should be used to supplement the public circulation area in the building in order to accommodate the two entrances to the new dwellings (Figure 144, Type A, C and D).

c. In the rear dwelling, the social area will preferably be adjacent to the existing kitchen;

d. In the front dwelling, the new kitchen will be located in the smallest room at the front of the building (as in the 1st strategy) and the social area will preferably be adjacent to the kitchen.

The dwellings can be divided in three different ways: by dividing the dwelling in half; by dividing the dwelling in half but ensuring that the rear dwelling has one habitable room at the front of the building; by dividing the dwelling in half but ensuring that the front dwelling has one habitable room in the rear (Figure 145). The combination of different types of rooms on floors creates different typologies within the same building, thus creating greater diversity. In each of the new dwellings, the aim was to ensure that the new infrastructures required for the bathrooms and kitchen were planned around the same duct (see *Part 2: Chapter 2.3.3*).

In all the transformations carried out using Strategy 3, the service and social areas have less depth and only the private area becomes more segregated within the dwelling as a whole.

This rehabilitation strategy was not compared with the previous ones in terms of syntactical measures, since the resulting dwellings are not comparable in terms of final size and spaces.

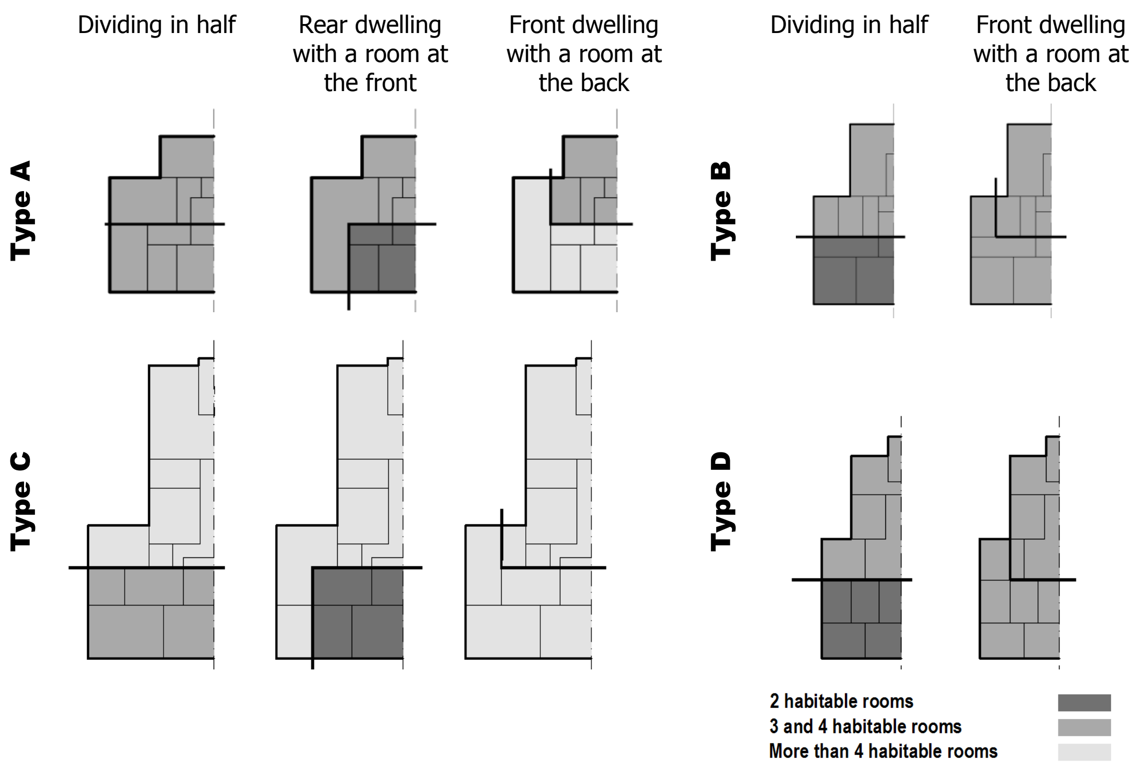


Figure 145 – Alternative ways of dividing dwellings, according to type.

COMBINING THE THREE REHABILITATION STRATEGIES

It is possible to combine all three rehabilitation strategies within the same building. Strategies 1 and 3 have a greater constructional impact and require new infrastructures for the position of the new kitchen. These include a new vertical drainpipe as well as a chimney. The new bathrooms proposed in all three strategies need new vertical infrastructures or macerating pumping systems units as discussed in *Part 2: Chapter 2.3.3* (space strategies) and *Chapter 2.3.4* (construction strategies). The combination of Strategies 1 and 2 would have a major constructional impact because of Strategy 1 and would not generate new dwelling types within the building, thereby leading to a narrower market offer. The combination of Strategies 1 and 3 would also have a major construction impact but would generate new dwelling types.

If only one or a small number of dwellings in the same building are rehabilitated, the second strategy is recommended, since this does not require new vertical ducts for the infrastructures. If the decision is made later to rehabilitate the entire building, Strategy 2 can be combined with the other two strategies.

	Original dwelling			1st Strategy			2nd strategy		
	i	TDN	Topological size*	i	TDN	Topological size*	i	TDN	Topological size*
Mean values for all types of dwelling									
Min	1.78	34.00		2.03	30.50		1.97	29.36	
Mean	3.14	48.74	15.3	3.29	45.48	15.1	3.34	43.97	14.9
Max	5.18	69.60		5.78	61.10		5.99	60.29	
Private area	2.55	53.84	3.8	2.82	48.81	5.5	2.59	47.44	4.8
Social area	3.10	47.23	2.2	2.75	49.15	3.7	2.94	44.39	3.4
Service area	2.48	55.40	4.8	2.52	52.20	1.6	2.53	51.29	2.6
Circulation area	4.36	38.21	4.5	4.75	34.95	4.3	4.84	34.07	3.9
Type A									
Mean	3.11	51.98	16	3.39	45.82	15.3	3.43	47.33	15.3
Type B									
Mean	3.32	29.86	12	3.16	32.58	12.5	3.24	34.83	13
Type C									
Mean	3.01	72.60	19	3.38	66.74	19	3.43	59.74	18
Type D									
Mean	3.12	42.18	14.3	3.23	39.55	14	3.21	38.60	14.3

Table 27 – Integration values (i), total depth for current node (TDN) and number of nodes in original dwelling and the three rehabilitation strategies (all calculations performed using AGRAPH software). The values were calculated on the basis of the 10 case studies analysed in the second experimental phase and the solutions presented by the experimental subjects. * Number of nodes

The integration (I) and depth (TDN) values of the layouts studied in the second step of the experiments (see *Part* 2 – *Chapter 1.4.2*) are shown in Table 27. By comparing the original dwellings with the rehabilitated ones the following may be concluded:

_ The first strategy produces layouts in which the private area is better integrated than those produced using the second strategy or in the original layout. The circulation and service areas will also be better integrated and have less depth than in the original layout;

- The second strategy produces layouts in which all the areas have less depth and the service and circulation areas are better integrated than in the original dwelling or if the first strategy is used;
- With regard to the overall figures, the results obtained by applying Strategy 2 produce better integration and less depth in comparison with the original dwelling;
- After transformation, regardless of the strategy used, the dwellings have a larger number of private areas (bathrooms and bedrooms) and social areas and fewer circulation and service areas;
- Types A, C and D acquire better integration and less depth through the use of any of the strategies;
- Type B reduces the integration values and increases depth through the use of any of the strategies.
- Circulation plays a central role in the overall configuration of the houses, since the highest integration values tend to be concentrated in the circulation areas in all 4 types of dwelling and in the 2 rehabilitation strategies.

As the third strategy generates considerably smaller dwellings, no comparison was made between their syntactic properties and those of the dwellings produced by Strategies 1 and 2.

As previously noted, in all the cases studied syntactic properties differ according to the rehabilitation strategy chosen. These properties also differ according to the original dwelling types. These results suggest that the "rabo-de-bacalhau" dwelling types A to D have particular characteristics which enable specific rehabilitation strategies to be carried out. This observation leads to the conclusion that a combination of rehabilitation strategies and dwelling types enables designs to be produced for various life-styles, therefore meeting current market demands.

Hillier (2007: 247) defines functionality as the ability of a spatial configuration to accommodate functions in general and therefore potentially a range of different functions, rather than any one specific function. This means that deep tree-like forms (with great depth) are inflexible and not adaptable to different functional patterns, whilst depth-minimizing forms are flexible and suited to a large number of possible functions.

As previously stated (*Part 1 – Chapter 3.5*), Hillier uses four topological types – a, b, c and d – to define how spaces meet the requirements of occupation and movement. Type "a" is a terminal space, reached only by one arc and its priority is occupation, type "b" is a space reached by two or more arcs and its priority is circulation, type "c" is a space reached by two or more arcs and is connected in a ring shape, inducing movement and providing controlled access, and type "d" is a space reached by two arcs connected by more than two rings, inducing movement, relationship and choice (Heitor *et al.*, 2004).

In accordance with these criteria and on the basis of the transformations produced in Experiment 2 and the data contained in Table 28, the following may be concluded:

- In all types, there were more "a" topological spaces (rooms in which the main household activities take place) than "b", "c" and "d" spaces, both in the original versions and the transformations;
- In types A and B, the "b" spaces rank second which, together with the previous point, produces "not distributed" spatial configurations, since there is only one hypothesis for reaching most of the rooms within the dwelling;
- Type C offers the greatest number of "distributed spaces" - "c" and "d" – in the original layout, but this number is almost halved after transformation;

- The values for distributedness for types A and B are lower than those for types C and D, both in the original and the transformed dwellings, indicating that the former are less flexible and adaptable than the latter;
- Although , due to the morphology of the building, types C and D appear to have greater segregation potential, they in fact have a greater percentage of "c" and "d" spaces, leading to less depth;
- In the original dwellings, "c" and "d" topological spaces occur between private and circulation areas as well as between the dining room and the circulation area;
- In the transformed dwellings, "c" and "d" topological spaces occur between social areas and circulation areas. Private areas are less distributed and belong essentially to type "a" topological spaces.

	Original dwelling		1st strategy		2nd strategy	
	Topological size**	%	Topological size**	%	Topological size**	%
Mean values for all types of dwelling						
a	6.7	44%	7	46%	6.9	47%
b	4.5	29%	4.7	31%	4.4	30%
c	3.4	22%	2.6	17%	3	20%
d	0.7	5%	0.8	5%	0.5	4%
Distributedness*	0.37		0.29		0.31	
Type A						
A	7.33	46%	7.33	48%	7.8	51%
B	6	38%	5.23	34%	4.4	29%
C	2.67	17%	1.87	12%	3	20%
D	0	0%	0.93	6%	0	0%
Distributedness*	0.2		0.22		0.29	
Type B						
A	7	58%	7.5	60%	6.5	50%
B	3	25%	3	24%	5	38%
C	2	17%	2	16%	1.5	12%
D	0	0%	0	0%	0	0%
Distributedness*	0.2		0.19		0.13	
Type C						
A	6.5	34%	8	42%	8	46%
B	4.5	24%	7	37%	4	23%
C	6	32%	3	16%	4.5	26%
D	2	11%	1	5%	1	6%
Distributedness*	0.73		0.26		0.46	
Type D						
A	6	42%	6.33	45%	5.67	39%
B	4	28%	3.67	26%	4.33	30%
C	3.33	23%	3.33	24%	3	20%
D	1	7%	0.67	5%	1.67	11%
Distributedness*	0.43		0.4		0.47	

Table 28 – Values for topological space types a to d. The values were calculated on the basis of the 10 case studies analysed in the second experimental phase and the solutions presented by the experimental subjects. *Distributedness was calculated according to Hanson (1998) (c+d)/(a+b). ** Number of nodes

2.3.3 Conflicts in current dwelling use and proposed solutions

The organisation of domestic space is the cause of conflicts of use when it is not suited to or easily adapted to the circumstances of a particular group of residents.

To support the analysis of conflicts of use *Part 1: Chapters 5* and *Part 2 – Chapter 2.1* explored housing requirements and *Part 1: Chapter 7* the study universe, using a survey to identify the main problems associated with spatial organisation in "rabo-de-bacalhau" buildings.

This chapter presents an approach to conflicts of use in these buildings, and proposals to correct them. Although the scope of this thesis concerns adaptations to dwellings, an analysis of the main spatial conflicts associated with the actual building, albeit brief, must also be included.

Various strategies are proposed for overcoming these problems and the conflicts involving the use of space and should be followed in order to adapt the ideal functional programme defined in the previous phase (*Part 2 – Chapter 2.2*) to the actual construction of the dwelling that is to be rehabilitated.

THE BUILDING

As mentioned in the analysis of the study universe in 3.6.6, in terms of the physical building itself, the main conflicts of use are:

1. Small lifts;
2. The lack of communal service areas;
3. The need to put meters on the ground floor or the shared landings on each floor;
4. The need for a permanent but restricted access area in the building or in individual dwellings for short-term storage of deliveries.

COMMUNAL AREAS

The communal areas in the building are the stairway, the landings on each floor, the main entrance to the building and, sometimes, a small room used to deposit rubbish. In addition, 72% of the buildings include a caretaker's dwelling.

Nowadays there is felt to be a lack of isolated larger communal areas which provide the proper conditions for storing rubbish, cleaning materials, the archives for the building and the video surveillance systems, amongst other items. The existence of a recreation room, where condominium meetings and other activities can be held, is also a current requirement.

The gradual disappearance of the figure of the caretaker has meant that many buildings can now make use of the caretaker's dwelling to address the need for communal space. Moreover, the caretaker has been replaced by other more efficient and specific service providers. This raises two questions: on the one hand, the release of space which constitutes property shared by the condominium residents and, on the other hand, the possible need for space for the services of contract cleaners or a security company and for automatic systems to control access.

The caretaker's dwelling, which usually consists of a bathroom and one or two rooms (living room/kitchen and bedroom, or only one room for all three functions), may be destined for condominium use (as a storeroom, workshop, bike shed, etc.) and/or services and technical areas. It is possible to adopt a strategy for the same end which involves extending the communal or technical areas (installing a lift or duct) by reducing the area of the dwellings.

Individual water, energy, and gas meters

Ideally, water, gas and electricity consumption should be read remotely. Although this technology is already being used in Portugal it has not yet been fully adopted. In any case, it is also necessary to provide an accessible place to house meters. The legal requirement to place individual meters on the ground floor or, as a last resort, on communal landings, has had spatial repercussions for buildings.

In fact, the shortage of communal space in most cases has made it difficult to provide a space to house all the meters which is easily accessible but also offers protection from everyday circulation within the building (for functional reasons relating to security and aesthetics).

If the caretaker's dwelling is on the ground floor, part of it can be used to accommodate a technical area for the building where meters and other necessary equipment such as video surveillance can be installed.

In cases where the caretaker's dwelling is on the top floor, two other methods can be used to accommodate meters:

- Using space taken from part of the ground floor – either from a dwelling or a shop. In the case of a dwelling, this may be converted into smaller accommodation for which, as previously stated, there is a large demand in the current market (Figure 146);
- Placing individual meters on landings accessible from outside dwellings (Figure 147).

Figure 146 (left) – Set of meters in a ground floor room of a building (source: www.epul.pt)

Figure 147 (right) – Individual meters removed from inside dwellings and installed on landings (photo: AC 2008)

Telecommunications networks

Ducts for new telecommunications infrastructure cabling should be accessible from a communal circulation area and located in technical areas or enclosed spaces using removable components (e.g. screw-in panels).

Storage units for individual use

The increasingly common practice of making purchases via the Internet has created a need for a permanently accessible but controlled area outside the dwelling.

There are two hypotheses for this: a room for each dwelling, or one or two rooms for collective use by all residents (previously agreed). Due to lack of space for the first option, the second is more favourable for the building type being studied. To ensure that this space is easily accessible both by residents and delivery staff, it is proposed that it should be located on the ground floor. As in the case of meters, this will require the use of part of the private area of one of the properties on the ground floor (a shop, caretaker's home or condominium dwelling). If one or more of this type of room exists on the ground floor they may be used alternately by condominium dwellers by means of an automatic locking system activated by a reconfigurable code that can be given to delivery staff.

DIVERSITY / FLEXIBILITY

Given that diversity of housing should be promoted within the same building, three rehabilitation strategies are proposed in *Part 2 – Chapter 2.3.2* for diversifying the layout and final size of dwellings. This criterion aims to provide freedom of choice and enable the building to be occupied by households which differ in terms of size, gender and age.

Although they contain identical dwellings on all floors, "rabo-de-bacalhau" buildings generally retain one or two smaller dwellings on the ground and top floor. The dwellings on the top and bottom floors have particular characteristics that make them more suitable for certain types of people. In fact, it has been proved that the upper floors offer "*good views and privacy in terms of the exterior, isolation, in terms of neighbours, difficult access to the exterior and isolation from social and neighbourhood life*" (Pedro, 1999c: 19) meaning that these dwellings may be suitable for groups with less need for contact with neighbours: single people, young people without children, or individuals who spend a lot of time outside the home. Conversely, the lower floors, which offer more contact with the street and the outdoors and consequently more control, are better suited to families with small children and elderly people or individuals with restricted mobility. On the lower floors residents can make more intensive use of the exterior and tend to feel part of the outdoor world.

In addition to the different rehabilitation strategies for dwellings, the incorporation of other activities within the building is another possibility that can be explored. We are currently witnessing the need to incorporate work spaces into areas annexed to housing, which may be inside dwellings, in the building or in the local neighbourhood. The existence of communal or individual work areas within the building is a good response to the increasing practice of working from home, since they allow both for proximity to, and at the same time a certain distance from, the home, as required for work. This hypothesis may be incorporated into certain "rabo-de-bacalhau" buildings e.g. by converting the caretaker's home (a communal space within the condominium) or commercial areas on the ground floor.

THE DWELLING

As mentioned in the analysis of the study universe in *Part 1 – Chapter 7.4.3*, the main conflicts associated with spatial organisation in "rabo-de-bacalhau" dwellings essentially concern the following:

- The discrepancy between habitable and non habitable areas;
- The repetition of identical dwellings throughout the building;
- The existence of inner yards;
- Segregated service areas;
- The existence of over-sized service zones but small kitchens;
- Small living rooms;
- The existence of interior rooms;
- Few bathrooms;
- Two close accesses for each dwelling (originally one for the family and one for the servants);
- The excessive length of the circulation areas;
- Small habitable areas;
- The lack of storage areas;

- Over rigid partitioning.

Reducing the discrepancy between habitable and non habitable areas

With the exception of type B, the dwellings in the study invariably present net floor areas which are disproportionate in terms of habitable and non-habitable areas.

This discrepancy is essentially due to two factors – narrow façades and deep wings – and the consequence of this – large circulation areas. The existence of inner side passages in the rear increases the number of rooms with natural ventilation and sunlight (although they are small), but also increases the size of the circulation areas, which represent around 17.4% of the floor area in the type of dwellings in the study.

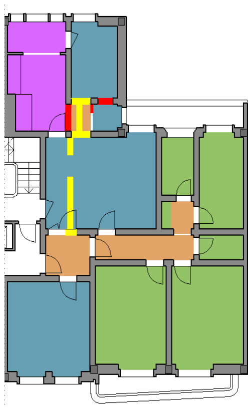
These characteristics mean that the dwellings have a large amount of non-habitable area. In fact, only 68% of the usable floor area of the dwellings (measured in terms of the original rooms) can be considered habitable area[57]. The remaining 32% of the area is reserved for circulation (17.4%), bathrooms (7.3%), interior rooms (bedrooms, dressing rooms and sitting rooms) (3%), storage areas, the pantry and glassed veranda.

In addition, many of the dwellings are sublet[58], indicating the need to subdivide them into smaller units thus enabling more people and/or different households to live in the building.

The excessive size of the dwellings is the result of this discrepancy between areas differs according to the building type. The larger dwellings are types *A* and *C*, whereas type *B* has smaller areas and consequently a better ratio of habitable to non-habitable areas.

The following strategies may be used to counter this:

- If the same dwellings are kept on each floor (Strategies 1 or 2), the discrepancy can be minimised if the circulation areas are annexed to the social areas to create larger rooms (Figure 148).
- If the dwellings are to be divided (Strategy 3), the ratio between the habitable and non-habitable areas will tend to decrease (Figure 149).



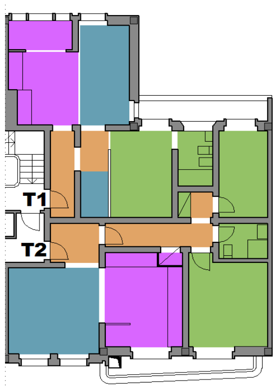


Figure 148 (left) – Joining circulation areas to social areas to enlarge the latter (new walls shown in red, demolished walls shown n yellow). Strategy 2.

Figure 149 (right) – Original dwelling divided into two separate dwellings. Strategy 3.

Creating diversity in dwelling typology in the building

The buildings in the study have symmetrical dwellings on each floor which are also identical on the various floors, with the exception of the top floor which has a mansard roof and smaller dwellings. As a consequence, there is little typological variety in the building, leading to social homogeneity in terms of residents. The dwellings available in each building are almost exclusively destined for the same type of family and are therefore either large or small, according to the household in question.

This factor, combined with the other conflicts of use discussed in this chapter (such as oversized service and circulation areas and small social areas) results, in most cases, in dwellings that are not considered suited to present-day lifestyles.

Whilst, on the one hand some families seek larger dwellings with ample rooms, we are also witnessing a rise in the number of small families comprising only one or two individuals. These needs relate to the elderly, single people (nowadays many elderly people live alone), newly married couples and/or couples with only one child.

These types of household, which differ greatly in terms of numbers, do not have to be an obstacle to reusing "rabo-de-bacalhau" dwellings. According to data obtained from the survey, 46% of these dwellings are being sublet (to 1 or 2 individuals), which leads to the conclusion that the dwellings are too large by current standards.

The proposed strategy to counter this is therefore to divide the dwellings into smaller units using Strategy 3, resulting in a larger number of available dwellings and greater variety in terms of types of housing within the building (see example in Figure 149). According to Paiva (2006b: 346) this strategy represents a traditional and very common means of transforming and increasing the number of dwellings which, if a cautious approach is taken towards the building's capacity to respond to the new residential structure, can be advantageous. The combination of strategies proposed in *Part 2 – Chapter 2.3.2* can be used to rehabilitate dwellings in the same building in order to diversify the offer.

This strategy implies substantial intervention work, since it involves constructing new infrastructures for the kitchen and bathrooms that require new supply and discharge ducts (for sewage, ventilation and exhaust), in addition to restructuring all the interior networks.

Enlarging the habitable areas

In accordance with the analysis presented in *Part 1: Chapter 7.2.2*, the habitable rooms, living rooms and bedroom are generally small by today's standards. The living rooms have an average of 13.32m^2 of usable floor area and bedrooms an average of 12.4m^2. The bedrooms areas are particularly small bearing in mind that there are few storage areas in the dwellings and these therefore have to be included in bedrooms.

Although the bedrooms may be considered relatively small, they still comply with the parameters specified in *Part 2: Chapter 2.2.2*, and this is not therefore considered a conflict of use that needs to be resolved.

The following strategies are proposed to increase habitable areas:

- Reducing the number of residents initially envisaged to 1 person per bedroom (with the exception of the double bedroom). The functional programme must therefore preferably include single bedrooms rather than twin bedrooms.
- Enlarging the social areas as described in the previous section.

The reduction in the number of residents means that, for example, a dwelling with three bedrooms and one sitting room cannot be occupied by a family of 6 (e.g. a couple and four children), but instead by a family of 3 or 4 (e.g. a couple and one or two children). In this case, two rooms can be allocated to the social area and two can serve as bedrooms (one double bedroom and one single or twin bedroom). Alternatively, one room can be allocated to the social area and three may serve as bedrooms (one double bedroom and two single bedrooms which include a recreational/work/social area).

Enlarging living room areas

The size of the original living room is very far from satisfying present-day demands, even in smaller households. Nowadays, the aim is for social areas to include new recreational equipment such as home cinema, games consoles and the space needed to enjoy these activities.

As previously stated, the average area of the rooms destined to serve as living rooms in the original plans was 13.32m^2, which is considerably smaller than present-day requirements.

The solution to this conflict must involve allocating two or more rooms to meet relaxation/social and formal dining functions in any dwelling that has more than 1 bedroom. To ensure that the social areas remain close to the entrance to the dwelling and/or the kitchen, the following hypotheses are recommended for the location of the social areas illustrated in Figure 150:

1. Use of the space closest to the entrance facing the main façade and another space close to the kitchen (Cases a1, b1, c1 and d1 in Figure 150);
2. Use of two rooms next to the rear wing (Cases a2, b2, c2 and d2 in Figure 150);
3. Use of the two rooms closest to the entrance facing the main façade (Cases a3, b3, c3 and d3 in Figure 150);

The connections between the different rooms in the social area – living room, dining room, home office and media room – must be clear, allowing for combined use, but not involve demolishing entire walls which would compromise the resistance capacity of the building (see *Part 2: Chapter 2.3.4*). Therefore, hypotheses 2 and 3 create a better relationship between the rooms in the social area.

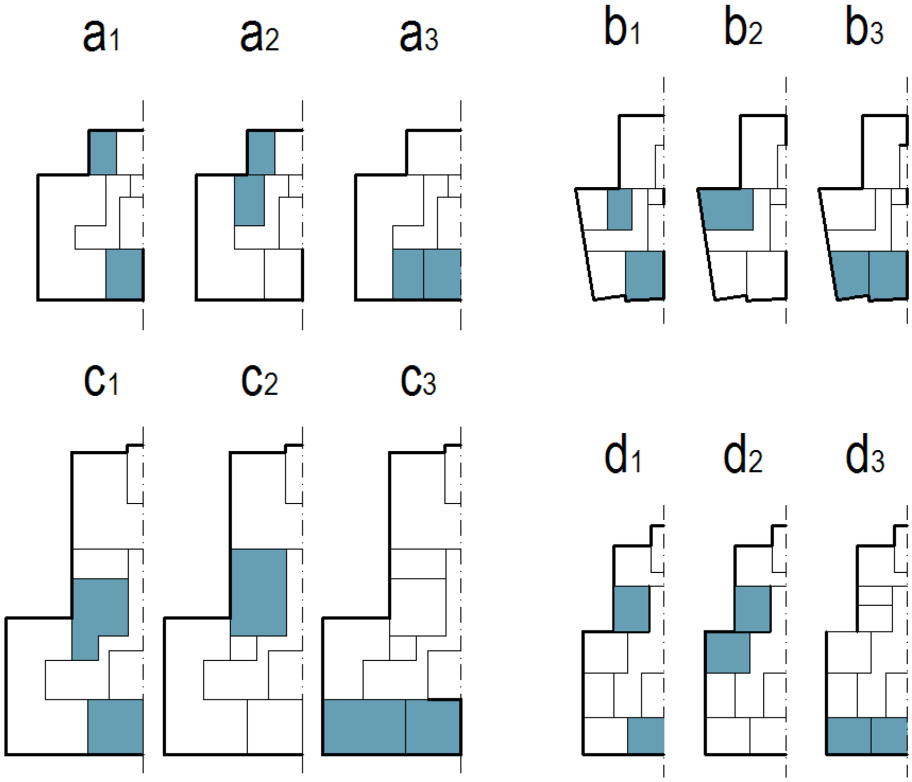


Figure 150 – Possible locations for living rooms, according to different types of building

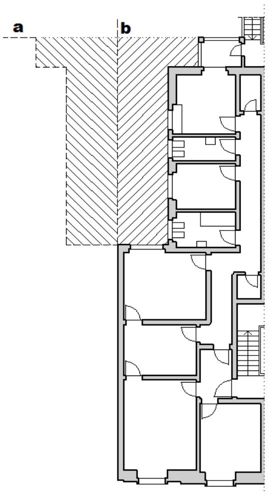
In addition to meeting the area criteria described in Table 21 (page 213), the spaciousness of the dwelling may be increased by taking various strategies into consideration during rehabilitation work (Pedro, 1999a: 55):

- A visual opening between rooms in the dwelling, provided by directly connecting or glassed doorways;
- A reduction in the areas reserved for circulation;
- The existence of at least one room, preferably the living room, with an area of 25m^2 or more;

INNER YARDS

The existence of inner yards looking onto the rear façades of buildings affects the natural ventilation and light in the adjacent rooms (Figure 151 and Figure 152). Although these inner yards exist in all the buildings studied, in the more recent buildings the interior windows are restricted to the section of the rear façade parallel to the main façade (Figure 152). Type C and D dwellings, which have a larger rear wing, always have windows on the side façade of the inner hallway, specifically to provide light and ventilation for the bedrooms.

Although these inner yards are not permitted under current building regulations (in force since 1951), their size does not invalidate natural light or ventilation. Therefore, within the scope of this study, inner yards are not identified as a problem that needs to be resolved.



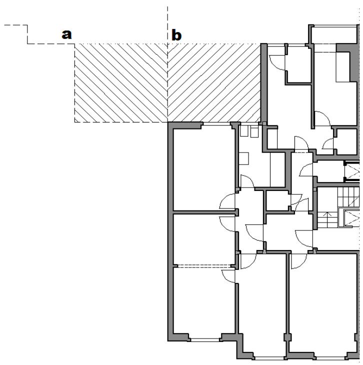


Figure 151 (left) –Type D dwelling, with inner yard and windows along rear and lateral façades of rear wing.

Figure 152 (right) – Type A, dwelling with inner yard and windows only along rear façades.

a and **b** represent possible profiles for the façade of the neighbouring building, showing different levels of sunlight and ventilation

TRANSFORMING THE SERVICE AREAS IN LESS SEGREGATED SPACES

The service areas, located in the rear wing of the building, are the most segregated spaces in the dwelling, as the analysis in *Part 1 – Chapter 7.2.2* reveals. This one of the most striking characteristics of the "rabo-de-bacalhau" building type and their transformation, in addition to significantly altering the compositional logic, has a major constructional impact on the building.

This original structure of the dwelling, although perfectly adapted to 1950s lifestyles, creates a series of conflicts of use in modern everyday life, in which the kitchen is a family meeting point and should therefore have a central position in the dwelling.

The segregation of the service area differs according to the building type and is most marked in types *C* and *D* and almost non-existent in type *B*.

Figure 153 – Strategies for overcoming the problem of segregated service areas

The proposals for changing this are as follows, in order of the advantages they offer in terms of integrating the kitchen (Figure 153):

intervention a) Transferring the kitchen to a smaller room on the main façade of the building, making it more central within the dwelling and providing a direct connection to the social area – using the 1st rehabilitation strategy;

intervention b) Keeping the kitchen in its original location and transferring all or part of the social area next to it;

intervention c) Keeping the kitchen away from the social area;

intervention d) If dwellings are to be divided, creating well integrated kitchens.

Whilst intervention b) has a very low constructional impact, intervention a) has a major constructional impact, since it involves constructing a vertical duct for sewage and ventilation. On the other hand, option a) also involves the use of one window on the main façade to serve the kitchen and creates a problem with regard to drying laundry. This domestic task has to take place inside the new kitchen or existing glassed veranda, which remains facing the rear façade and has to be accessed via a bedroom.

REDUCING THE SERVICE AREAS

The service area in "rabo-de-bacalhau" dwellings consists of the kitchen, laundry area, service bedroom and bathroom. The service support area, which consists of a service bedroom and bathroom, was designed for a social context in which it was common to have a live-in maid. Nowadays this area is not used for this purpose but, in functional terms, due to its relative segregation in relation to the rest of the dwelling, it is difficult to integrate it into either the social area or the private area.

In addition, the room allocated to the kitchen, which has an average area of $9.49m^2$, is considered small by present-day standards since it is difficult for it to accommodate a space for everyday meals (see minimum net floor area in *Part 2: Chapter 2.2.2*).

The solution to the excessive rooms within the service area and the lack of usable floor space in the kitchen may include the following strategies:

- Using the service area to supplement the social area, including a space within it for formal meals and/or guest bathroom (Figure 153, cases 2, 4, 10);
- Using the service area to supplement the kitchen and including a space within it for informal meals (Figure 153, cases 3, 6, 7, 10);
- Using part of the service area as a bedroom, in cases where the aim is to separate members of the household to provide greater autonomy or privacy (e. g. in the case of adult children, elderly relatives or members of the household who are not relatives) (Figure 153, case 11) or transferring the entire private area to the rear wing (Figure 153, cases 1, 5, 9, 13).

TAKING ADVANTAGE OF INTERIOR ROOMS

Type B and D buildings have façades which are narrow in proportion to their depth. The consequence of this is the existence in certain dwellings in the sample of interior rooms which, at the time they were built, were considered habitable.

The solution to this conflict is to use these interior spaces to extend the living room, as work areas, storage areas or bathrooms (Figure 154).

The environmental and hygienic conditions in these areas may be partly resolved by the following:

- In the case of an interior room destined to serve as a bathroom, using mechanical ventilation systems and artificial lighting. This solution involves the installation of a duct connected to the exterior (which may require a false ceiling) or the installation of a ventilation duct covering the entire building (Figure 154.4);
- In the case of a interior room destined to serve as a work space or to supplement the living room, altering or partially demolishing the interior walls of the rooms to provide visual permeability in relation to the adjacent illuminated rooms (Figure 154.3);
- Using the space as a step-in closet or dividing it to join it to adjacent rooms, e.g. by creating closet or storage areas (Figure 154.1).

These solutions have constructional impacts, involve careful analysis of the building that is to be rehabilitated and specialised planning to ensure the stability of the building and the viability of the alterations (Paiva *et al.*, 2006: 399).

The use of these interior rooms may involve dividing them into smaller units which can serve as bathrooms, storage areas or extensions to the social area.

Original dwelling with interior room	Interior room used for closet	Interior room used as an extension of the living area	Interior room used for a private bathroom

Figure 154 – Strategies for making use of interior rooms

INCREASING THE NUMBER OF BATHROOMS

The dwellings have a small number of bathrooms in relation to their total area and intended number of occupants. Given its location, the existence of a service bathroom, generally very segregated from the rest of the dwelling, does not resolve the need for this type of room.

The solution is to add another private bathroom to dwellings occupied by 4 or more people (recommended level) or 5 or more people (minimum level) and convert or change the location of the service bathroom to make it closer to the social area.

The proposed location for new bathrooms is shown in Figure 155 and consists of demarcating a section in the centre of the front wing for the new bathroom and for storage areas.

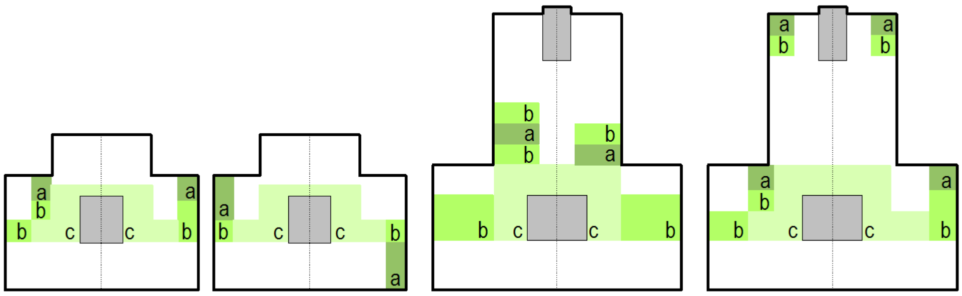


Figure 155 – Original bathroom (a), new priority locations for bathrooms (b), alternative new locations for bathrooms (c)

In locating private bathrooms, the following should be given priority:

1. Maintaining the original bathrooms;
2. Locating the new bathrooms in areas without windows so as not to occupy a habitable room;
3. Locating the new bathrooms in the sections shown in Figure 155.

Taking advantage of the two accesses to the dwelling

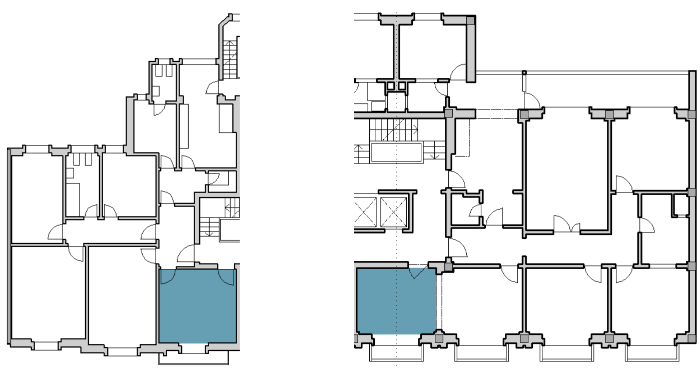
Most of the dwellings, even the smaller ones, have 2 entrances, one for the family and another which is a service entrance, arranged as follows: two entrances to the dwelling which are far apart to allow for more efficient evacuation in the case of fire, or two located only a few metres away from each other, making them redundant in terms of present-day lifestyles.

Keeping the two entrances can be a formal issue (when they provided access to the same vertical nuclei) or a functional issue (when they provide access to different vertical nuclei). The existence of two entrances is optimised if it is proposed to divide the dwelling into two smaller separate dwellings (see *Part 2: Chapter 2.3.2* and Figure 153, cases 4 and 8)

Introducing a home office for permanent or non-permanent work

As previously stated, there can be different forms of working from home, ranging from a home which has an extension that serves as a workplace to using the home as the main workplace.

In cases in which the home is the main workplace it is necessary to design an area that provides the independence needed for work.



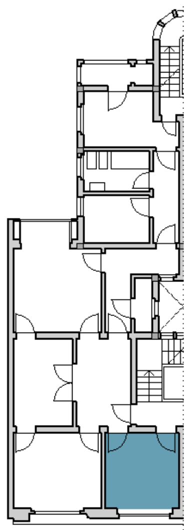


Figure 156 – Dwellings with a room providing direct access to the lift area/stairs. (Av. Afrânio Peixoto 13, Av. da Igreja 63, R. Actor Isidoro 11)

In 16% of the buildings studied there is an interior room and in 16% there is a room in the dwellings with a second or third connecting door leading directly to the landing, which avoids the need to enter via the interior (see the examples in Figure 156). Fifty years ago, this access was justified by the fact that the room was used as a small office or guest bedroom. Nowadays the space can be used as a small office that is sufficiently isolated from the rest of the home to enable it to be used for work.

In several of the remaining dwellings it is possible and viable to put in a door connecting to the lift or stair lobby to provide independent access and this would have no negative effect on the appearance of the building.

Designing a workspace as an extension to the workplace is not difficult and it is usually inserted into another functional space in the social or private areas of the dwelling.

Taking advantage of the wide circulation areas

The circulation areas are very extensive and often accentuate the segregated nature of the service area in the dwellings. In most cases, areas within the dwelling dedicated exclusively to service have their own separate circulation areas, in addition to the other areas in which the family moved around using their own circulation areas.

The solution to this waste of space may include incorporating part of the circulation area into the functional zones. However, this is not an easy strategy to accomplish, since it involves demolishing large sections of wall, counter to the intended rehabilitation principles (see *Part 2: Chapter 2.3.4*). One example of this hypothesis is illustrated in Figure 148, in which the aim is to extend the dining area by joining a habitable area to the circulation area. Although possible with structural reinforcements, this intervention represents the limit of the constructional viability for the proposal presented.

Enlarging the storage areas

A lack of general storage space was noted in the original dwellings analysed in the study. Although 84% of the cases included a larder (near or in the kitchen) and 24% had a step-in closet (in the circulation area), there was little provision for storing clothes and for general storage and this is inadequate by today's standards.

The proposed solution involves enlarging the storage area in the kitchen by using more functional cupboards and including cupboards in the private areas.

Altering the original layout

The layout of the original rooms in the dwellings is not very adaptable and is difficult to alter. This is due, on the one hand, to the morphology of the dwellings and also to the constructional system used, in which the interior walls are part of the load bearing structure.

The morphological structure of the dwelling is affected by the existence of a circulation area which lacks natural light and ventilation and runs longitudinally throughout the entire dwelling alongside the vertical access nuclei (Figure 157).

With regard to the constructional system for the buildings defined in *Part 1: Chapter 7*, it may be stated that the alterations to be made to the interior walls should be specific, avoiding demolition of lengthy sections of wall. Thus, alterations based the demolition of constructional components should be severely restricted and should comply with the building requirements described in *Part 2: Chapter 2.3.4.*

Figure 157 – Developing circulation areas in the 4 different types of building.

To prevent introducing alterations that would make the dwelling more rigidly compartmentalised, it is proposed that all new walls should be constructed using light systems that can be dismantled (see *Part 2: Chapter 2.3.4*).

Dividing existing rooms

Given that the case study is characterised by small rooms, this strategy is limited to the creation of bathrooms and storage areas in interior spaces or those with inadequate light and/or ventilation, already referred to in "*Taking advantage of interior rooms*".

In the case study, splitting rooms is only recommended for the central area of the main wing, as indicated in Figure 155 for the inclusion of bathrooms.

Linking or joining existing rooms

The smallness of most of the habitable rooms in the study creates the need to link or join adjacent rooms with the aim of increasing space, mainly in the social area. This strategy also allows rooms with inadequate light and/or ventilation to be integrated into habitable rooms. In the previous points this strategy was cited as capable of achieving the following: diminishing the discrepancy between habitable and non-habitable areas; enlarging habitable areas; enlarging living room areas; reducing service areas; taking advantage of indoor rooms; taking advantage of wide circulation areas.

This type of intervention always involves the need for a structural evaluation of the building in order to assess the structural function of the construction component proposed for demolition. The existence of brick load bearing interior walls in the dividing walls requires careful decisions concerning demolition. In fact, the demolition, whether partial or total, of interior walls may put the structural stability of the building at risk and compromise safety in the event of an earthquake.

Recommendations for linking rooms by means of the total or partial demolition of walls must therefore be subject to size restrictions.

In the case of this study, the possibility of demolition, as contained in the transformation grammar defined in *Part 2 – Chapter 4*, is restricted to the following conditions:

- Only construction components not built from reinforced concrete can be demolished;
- Only a maximum of 2m per brick wall can be demolished;
- A 2-3m brick wall can be demolished if there is a parallel wall not more than 1.5m away from it;

- The proposed project must take into consideration the fact that for each section demolished it will be necessary to install a lintel with a metal or concrete beam as a reinforcement and possibly concrete pillars on each side – this will be assessed in the stability plan containing the overall structural calculation for the structural safety of the building.

Regardless of the length of wall to be demolished and even when a beam is installed, in terms of the building demolition represents a loss of rigidity and resistance to seismic activity and should therefore always be avoided.

This strategy is mainly used in the following circumstances:

- To link the living room to the dining room, keeping them differentiated but connected;
- To link the home office and living room;
- To link the area for everyday meals and the kitchen.

ENSURING FLEXIBILITY

In order to ensure the flexibility of the dwellings with regard to the evolution of the household or future occupation by different households, in addition to the criteria established in the ideal functional programme, other aspects should also be taken into account when adapting the functional programme to present-day circumstances.

- If there is an original connection between a bedroom and living room this should not be removed in the proposed rehabilitation, even if this makes the bedroom appear more exposed. The two rooms can be linked by removable panels which partly conceal the link but ensure it can be used whenever desired,
- Maintaining the two entrances to the dwelling, using this dual option to create greater autonomy and flexibility in terms of use of space;
- If there is an original connection between two rooms this should not be removed unless another is created in the same wall or if this obstructs functional areas in rooms. Maintaining the original links allows for alternative routes around the dwelling to be created and, consequently, flexibility of use.

2.3.4 Constructional strategies to implement morphological adaptations in rehabilitation work

Rehabilitating housing and buildings is a strategy for sustainability. The continued use of existing buildings promotes ecological, economic and social sustainability. The reasons for adopting rehabilitation measures will emerge again in the near or distant future due to new demands for comfort and space, technical progress and changing legislation and standards.

To minimise the difficulties that current rehabilitation measures may generate in future interventions, it is important to follow certain principles:

- Major interventions to the original construction should be avoided, especially to structural components, since these are irreversible;
- New constructional components such as walls and ceilings should be designed to be easily removable later;
- New infrastructures should be designed to be easily accessed, maintained and updated.

In fact, solutions that result in irreversible changes to the building should be avoided. Accordingly, the new solutions adopted must implemented using materials and processes that ensure reversibility or a return to original solutions.

During the planning process it is necessary to establish which part of the fabric of the building will be retained and which can be demolished. The basis for this decision rests firstly on the question: where does the intervention take place? The questions differ according to whether the rehabilitation concerns only one dwelling or the whole building.

After identifying the goal of the intervention several aspects have to be examined in order to determine the extent of the rehabilitation work:

- Which building components are load bearing?
- Is it worth retaining the existing structure?
- How do we value the existing structure?
- How intrusive do we want to be in terms of construction?
- What is the client's budget for rehabilitation work?
- Does the existing structure conflict with new spatial and technological demands?

This knowledge will lead to a sensible demolition plan. It is very important to understand that every demolition process represents an intervention in the load bearing structure of the building due to the change in load, the temporary storage of debris in the building and vibrations during the work (Giebler, 2009: 30). All this can damage existing components even if only non-load bearing components are demolished.

For reasons of structural safety, the fewest possible demolitions should be carried out. Demolitions should not affect structural components and should be restricted to the interventions that are strictly necessary.

New components such as partition walls, ceilings and finishings, should be constructed from light materials to avoid overloading floor slabs.

We will now turn to rehabilitation measures on non-structural components as a means of finding solutions to space conflicts – e.g. the need for an extra bathroom, enlarging a bedroom or merging two spaces. Rehabilitation measures to ensure the dwelling is equipped with ICAT infrastructures will be addressed in *Part 2: Chapter 3*.

WALLS, FLOORS AND CEILINGS

According to Paricio (2001), partitions are only included in housing for reasons of privacy. If it were not for privacy and the need to hide service areas, partitions would not be desired and wider spaces would be preferred. In addition, in old buildings, internal walls were also built to support the building.

In order to allow for intimacy without making flexibility impracticable, several options for internal partitions have been studied for decades. Solutions often adopted in office and commercial buildings, such as movable, sliding or folding partitions and plasterboard walls, have been imported into the housing sector. However, most of these solutions were designed essentially for new buildings in which internal walls do not contribute towards the stability of the building.

As mentioned in *Part 1: Chapter 7.2.3*, there are four different types of exterior and internal walls in the buildings in the case study. Different rehabilitation approaches are proposed for each type:

- Exterior load bearing masonry walls _ no transformations to the morphology of these walls are proposed, since they represent an essential component of the load bearing capacity of buildings, as well as an important part of their aesthetic image. An exception is the proposal contained in the 1st strategy, involving the addition of a new infrastructure column attached to the façade (if the intervention does not affect the whole building) (Figure 169).

- Side walls _ no transformations are proposed for these walls, since they also represent an essential component of the load bearing capacity of the building. Interventions must be confined to upgrading thermal and acoustic performance, when needed, and renewing infrastructures;
- Party walls and staircase walls _ interventions in these walls are justifiable only if the intention is to upgrade the infrastructures of the building (water, gas, electricity, ICAT), elevators or other rehabilitation measures that benefit all residents;
- Internal walls / partitions
  - Original walls _ hollow brick walls with a plaster finish. Some of these original walls contribute towards the structural stability of the building, supporting loads from upper floors. A common rule has been established for these internal walls which applies to the entire sample and is used in the transformation grammar presented in *Part 2: Chapter 4* and explained below.
  - Existing walls (constructed during the lifetime of the building) _ Hollow brick walls or light frame walls with gypsum boards. These walls may be demolished without any negative impact on the stability of the building.

When rehabilitating a dwelling the following criteria for internal walls should be obeyed:

- Making the most of existing partition walls;
- Demolishing small sections of wall;
- Vertically overlapping new walls on different floors to avoid introducing load to less resistant parts of slab.

The demolition of existing internal walls must be restricted to the cases in which this is genuinely necessary. Demolishing a wall does not necessarily mean demolishing the entire wall. An opening can be made to connect two previously separate rooms or a small section of wall can be demolished to allow access to a closet, for example. Demolishing an entire wall which separates two rooms is not always advisable and the benefits are usually not very different from those achieved by making a large opening in the wall.

As shown in *Part 1: Chapter 7.4*, the most common intervention in the buildings studied was to merge two adjacent rooms to create a bigger living space. This was frequently carried out by tenants by demolishing the entire wall between the two rooms.

In order to restrict the demolition of internal walls, and because a stability study is not presented for each of the dwellings studied, demolition is restricted to the following:

- The maximum length of internal wall that can be demolished is 2m;
- A 2 and 3m section can be demolished if there is a parallel wall not more than 1.5m away from it;
- If a wall is longer than 4m and shorter than 6m, half the wall length can be demolished.

These restraints will be used to implement the construction requirements in the transformation grammar (*Part 2: Chapter 4.3*) in order to parameterise demolition work.

Figure 158 (top left) - Strengthening a lintel with a steel beam after demolishing part of the wall. Av. de Roma, 89. (Photo: AC 2008)

Figure 159 (top right) - Strengthening a lintel with a concrete beam after changing the door position (demolishing part of the wall and adding another part). (Photo: AC 2007)

Figure 160 (bottom left) – Steel distended mesh fixed to existing wall for reinforcement (Photo: AC 2007).

Figure 161 (bottom right) – Movable wall allowing one bedroom to be enlarged and the adjacent one made smaller. The wall is made of three movable parts that slide along groves in the ceiling (Photo: SE 2002)

Due to their expected load bearing characteristics, when creating an opening in an existing wall strengthening the lintel with a steel or concrete beam should be considered (Figure 158 and Figure 159). In this case it may also be necessary to build concrete columns on both sides of the beam.

As previously explained, whatever the width of the opening and even when a beam is placed over the new opening, this demolition represents a loss of rigidity and the resistant capacity of the building to seismic action. Therefore, non-essential demolition must always be avoided.

According to Appleton (Millier, 2007), any transformation will have repercussions on a building because all the walls contribute towards its stability. Therefore, when rehabilitation is badly planned it will lead to construction pathologies in the dwelling and in neighbouring dwellings. Even if the rehabilitation work is well planned and executed, intervention weakens the building in the event of an earthquake.

In addition to strengthening the lintel, it is sometimes necessary to reinforce adjacent walls or other less resistant walls. In these cases, a common solution is to use a distended steel mesh reinforcement (Figure 160). Although this solution has advantages in terms of stability, steel mesh blocks radio-frequency transmission making the use of wireless transmission within different areas of the house almost impractical.

High-performance fibres (FRP - fibre-reinforced plastic) are being widely researched with regard to repair and rehabilitation work and can be used as an alternative to steel mesh (Cóias, 2007: 171) (Gilstrap and Dolan, 1998). Reinforcing masonry structures with these fibres has many potential benefits and does not block wireless transmission.

New internal walls should be built using a drywall construction system with light frame structures. These structures offer the necessary variability required for changing the housing layout and to maintain and upgrade infrastructures. In addition to offering variability and the possibility of removal, these systems do not overload the slab below them.

A drywall or wallboard system consists of a light structure, usually made of galvanized steel, to which plasterboard[59] is screwed on both sides of the structure. Sound insulation material in the form of boards or quilts can be layered between frames to improve acoustic performance. Drywalls can also be built using a timber frame and other types of lining can be applied, such as wooden boards or plywood. Unlike the traditional plaster finish techniques, which involve applying base, scratch and finish coats in successive layers all by hand, plasterboard requires hand finishing only at the fastenings and joints with joint compound.

The existence of vertical and horizontal frames and panels on both sides of partitions enables pipes and cables to be laid inside the wall. This and other possibilities for laying cables and pipes are studied in *Part 2: Chapter 3.2.2*.

Partitions made from light frame structures are assembled on site and can be easily modified either during or after construction. These walls are fixed to the floor but can be easily dismantled in order to change the housing layout. They can also be built as movable partitions, as shown in Figure 161.

In addition, different materials can be used in partitions to promote privacy and visibility whenever desired. New technologies for glass or new uses for glass offer new possibilities for glazed panels. Certain types of smart glass[60] can be changed from transparent to translucent, partially or totally blocking light, changing the levels of opacity and providing privacy at the turn of a switch (Figures 162). Electricity is required to change the level of opacity, but once this change has been made, no electricity is needed to maintain the current setting. Nowadays it is also possible to view selected images or information on a wall (Figures 163).

Figures 162 – Door with glass that changes from transparent to translucent at the turn of a switch. Millenium House, London (photo: SE 2003).

Figures 163 – Partition wall made of a metal frame structure supporting glass panels onto which images can be projected when the panels became translucent. (photo: SE 2009)

Floors in “rabo-de-bacalhau” buildings are frequently composed of narrow slabs (e.g. 10cm) and thin floor finishes. When necessary, the load bearing capacity of floors must be upgraded. New floor finishes must be restricted to the existing thickness of finishes, unless the decision is made to raise the floor level. This measure would increase the load on floors as well as create a step inside the dwelling. Floor rehabilitation usually involves upgrading acoustic performance by installing impact sound insulation for the first time, since this did not feature in the original construction (Figure 165). Within the context of this study, no alterations are envisaged to floor slabs or finishings as a result of functional changes. Changes in this area take place through the introduction of ICAT and are addressed in *Part 2: Chapter 3.2.2.*

Suspended ceilings may be used both for laying cables and pipes and for concealing beams and defining the boundaries for the different areas (Figure 164). The use of concrete columns and lintels to support new openings in walls may be disguised by suspended ceilings at different heights.

Suspended ceilings are also used to improve the acoustic performance of buildings with the addition of insulation known as Sound Attenuation Batts (SABs) (e.g. fibre glass) above the panels to help deaden sounds and keep adjacent rooms quieter.

There are two generic types of suspended ceiling: the fixed suspended ceiling and the accessible suspended ceiling. The fixed ceiling consists of a continuous plastered surface and is used where no immediate access to the ceiling void below is required. These suspended ceilings are built with plasterboard sheets which are supported from the underside of the concrete slab above either by wires or galvanized steel strips (Watts, 2001: 262). Accessible ceilings are usually used in office and commercial buildings and are made of modular panels which enable permanent access.

The existing ceilings in the buildings in this study are not decorative or particularly elaborate so there is no particular interest in retaining them. However, given that suspended ceilings are heavy and the existing floor slabs are not very strong, suspended ceilings are only recommended in circulation and service areas where it is necessary to conceal infrastructures. In countries where earthquakes are frequent (e.g. California) diagonal wire stays are often required in order to ensure the ceiling grid will not sway laterally during an earthquake, which can lead to the partial or total collapse of the ceiling grid during a severe tremor. As an additional measure, compression posts can be added to prevent the ceiling from bouncing vertically during an earthquake.[61]

Suspended ceilings may be installed in other areas if this facilitates the laying of cables. The dwellings in the case study have a floor-to-ceiling height of approximately 2.8m, which allows for a ceiling suspended up to 0.40m away from the existing ceiling or even 0.60m in circulation areas[62]. One disadvantage of using suspended ceilings is that they reduce room height.

Figure 164 – Suspended ceiling in rehabilitated dwelling to hide cables, pipes and beam and to define a circulation area inside a living room. (photo: AC 2008)

Figure 165 – Acoustic insulation over floor finishes. (photo: AC 2008)

Energy efficiency and acoustic upgrades

Upgrading thermal performance by passive measures is a priority in rehabilitation. Improving thermal performance and the energy efficiency of buildings mainly involves work on the external envelope. Thermal insulation in external walls may be improved by providing a new exterior covering, applying external thermal insulation or renewing the rendering. Applying internal insulation to an existing external wall is also a possibility and is sometimes the only viable solution when the exterior façade has many prominent elements. Internal insulation in exterior walls may also benefit the ICAT infrastructure cabling needed for the home automation network. To accomplish this, it is recommended that the insulation material is set behind a lightweight wall structure (e.g. plasterboard panels fixed to metal or timber battens screwed to the inner façade). Part of the space between the existing wall and the new lightweight wall, mostly filled with insulation, can be used to lay cables (Figure 166). This situation and others that facilitate cabling within the dwelling will be addressed in *Part 2: Chapter 3.2.2*.

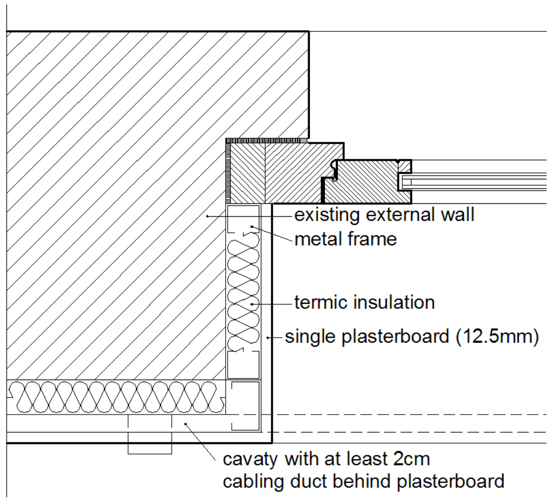


Figure 166 – Insulation attached to the interior panel of the façade allowing cables to be laid behind the plasterboard wall.

In addition it is important to improve the thermal performance of existing single-glazed windows by the addition of further glazing or the replacement of existing glazing.

An exterior or internal sunscreen, shutters, screens or curtains can be used to promote better insulation and ventilation and may be activated automatically by a domotic system, as discussed in *Part 2: Chapter 3*.

Rehabilitation of the building envelope must also include other measures such as the replacement of the covering on pitch roofs above or floors below habitable rooms and the renewal of flat roofs. These features are not discussed in this research, since ICAT cannot contribute directly to their performance or *vice versa*.

Technical infrastructures

Nowadays the performance demanded of technical infra-structures is largely higher than it was 50 years ago when the buildings in the study were built. The increasing and often simultaneous use of electrical and electronic equipment in homes has also increased the requirements for these facilities.

The electrical and telecommunications infrastructures in some buildings from the 1940s to 60s were upgraded some years later, but most of the intervention work took place in individual dwellings which were far apart. In addition, the enlargements or upgrades did not comply with existing regulations (Paiva *et al.*, 2006: 731).

All interventions involving technical infrastructures (e.g. water, gas, electricity, telecommunications and domotics, among others) and measures to integrate them into rehabilitation work will be addressed in *Part 2: Chapter 3.2.2.*

BATHROOMS

The functional rehabilitation of bathrooms usually involves new sanitation equipment, new finishings and upgrading the (water, sewage and domotics) infrastructures. If the position of the original bathroom is to be maintained after rehabilitation work, only the abovementioned tasks are necessary.

If a new bathroom has to be built, special measures must be envisaged. There are two possible proposed situations for new bathrooms which include several construction possibilities:

- Replacing an existing bathroom: demolishing part of the existing bathroom and constructing a new one adjacent to it. In this case the existing plumbing (after upgrading in accordance with current legislation), with an extension, may be used to the new bathroom.
- Constructing an additional bathroom: in this situation there are two hypothesis
    - If the rehabilitation work covers the entire building it is possible to add a new duct for sewage and ventilation in the positions proposed in Figure 155 (b area) and Figure 169 a). Therefore new bathroom(s) can use the new building infrastructures.
    - If the rehabilitation work does not cover the entire building or one entire side of it, macerating pumping units can be used (Figure 168).

Alternately a prefabricated bathroom can be installed (Figure 167), which is assembled on site and fits into small spaces with or without pre-existing plumbing. These bathrooms often offer water-wise technologies such as recycling hand basin waste water to the toilet cistern. Special prefabricated units can be easily dismantled for refurbishment. In these units, panels have been developed in a modular format that can be configured to produce flat-pack kits. Following a detailed site survey, these kits are pre-assembled in the factory, dismantled and delivered to the site. The panel sizes are carefully selected to ensure full access even via standard door openings and stairways[63].

Figure 167 - Prefabricated bathroom in refurbished house (source: http://www.europeanensuites.co.uk/)

Figure 168 - New bathroom located in an existing closet. Installation of a macerating pumping unit inside the wall, accessible for maintenance via a removable panel (source:. http://www.tubolandia.net/agua_gas.htm)

KITCHENS

The functional rehabilitation of the kitchen in this type of building usually involves enlarging the kitchen area by merging it with an adjacent area. In addition to enlarging the kitchen, new electrical appliances, cabinets and finishings as well as new infrastructures (water, sewage, electrical, gas, domotics) are installed.

In addition to upgrading the kitchen, the proposed methodology also envisages the construction of a new kitchen in the dwelling. This may occur in two situations: rehabilitation work carried out using the 1st strategy and rehabilitation work carried out according to the 3rd strategy. In both situations the kitchen will be positioned in the front façade of the building, which implies two different approaches (see Figure 169):

- If the intention is not to perform any major rehabilitation work within the building, a new technical duct may be attached to the façade. In this case, a prefabricated plumbing casing would be built onto the outside of the building's façade to accommodate the water supply, sewage and mechanical ventilation for kitchens. This solution is suitable for rehabilitation projects but involves substantially altering the appearance of the exterior of the building;
- If the intention is to carry out major rehabilitation work within the entire building, the solution for incorporating a new kitchen may be to build a new duct the same height as the building to accommodate sewage and exhaustion plumbing.

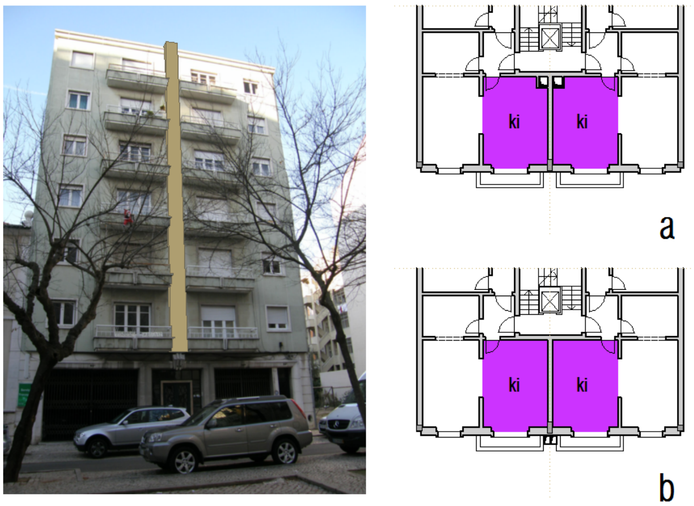


Figure 169 – Simulation of the two hypothesis for constructing a kitchen in the front façade: a) introducing a new duct; photo and b) attaching plumbing casing to the façade. (photo: SE 2010)

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57 Only habitable divisions were considered in this calculation – bedrooms, living rooms and kitchen – with an area of more than 6.5m2 and direct lighting and ventilation.

58 The average number of residents per dwelling (according to the replies to the questionnaire) is 2.43. In the 25 completed questionnaires, 7 dwellings were occupied by only 1 person and 10 dwellings by 2 people.

59 Plasterboards are also known as gypsum boards, wallboard or placoplatre. (Source: http://en.wikipedia.org/wiki/Drywall)

60 Electronic Smart Glasses. (Source:URL:http://www.glassonweb.com/articles/article/192)

61 Suspended ceilings. (Source:http://en.wikipedia.org/wiki/Dropped_ceiling)

62 Portuguese legislation allows a minimum floor-to-ceiling height for housing of 2.40m and exceptionally, in circulation areas, bathrooms and storage areas, 2.2m.

63 European ensuites. Prefabricated bathroom pods specialists. (Source: http://www.europeanensuites.co.uk/)

3 INTEGRATING ICAT INTO THE DWELLING

This chapter aims to define appropriate ICAT packs to incorporate into the dwelling in order to ensure environmental sustainability and social integration, adapting them to each household according to present and future needs. The ICAT packs can be installed when rehabilitating existing residential stock as well as constructing new buildings.

The chapter is divided into two major sections. In the first section (the 2nd step of the rehabilitation methodology), household profiles are used to determine the ideal pack of ICAT functions for the dwelling (Figure 170). The pack of ICAT functions in this case is a description of an ideal set of domotics systems and functions for the family which is not restricted by any existing morphological or constructional structure.

In the second section (the 3rd step of the rehabilitation methodology) the existing dwelling and the ideal pack of ICAT functions are used to derive a description of a compromise or adapted solution based on the existing dwelling (Figure 170). Since the solution is influenced by the existing morphological structure and construction of "rabo-de-bacalhau" buildings, the description of the ideal solution must be transformed into a description of an adapted solution.

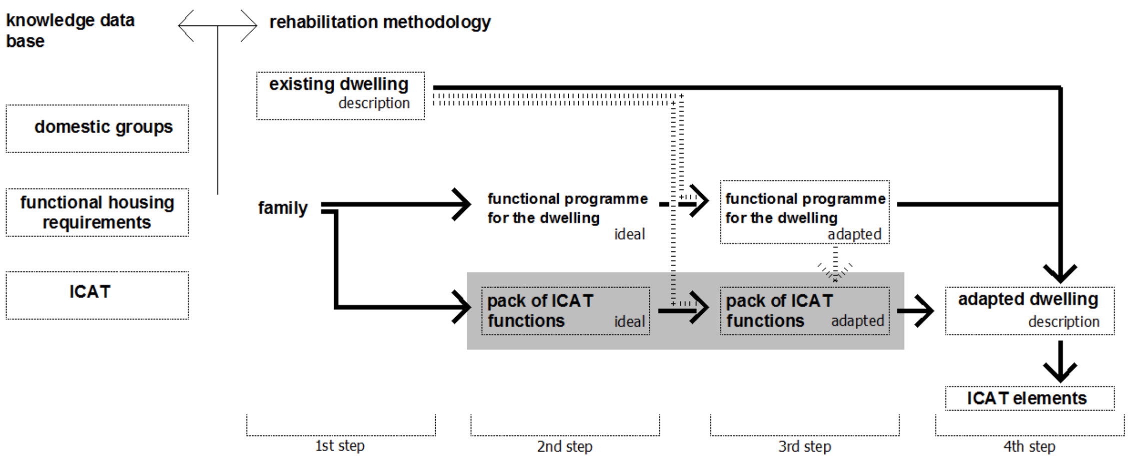

Figure 170 – Rehabilitation methodology. The steps defined in this chapter are highlighted in grey.

The proposed methodology aims to define the appropriate set of ICAT functions and their integration by following the four steps described earlier and illustrated in Figure 165.

Before developing Sections One and Two, it was considered necessary to define certain premises for the definition of the ICAT packs in advance. These premises concern the definition of family profiles, the real needs of individuals and technology generation, all of which influence the choice of domotics options.

An indication of some likely future developments in domotics is provided at the end of the chapter. Although under investigation at the moment, these will only be integrated into the domestic environment several years hence.

Currently there are several possibilities for home automation, ranging from isolated applications to fully integrated solutions with numerous functions, as described in *Part 1: Chapter 1*. Bearing in mind the objective of this work and the socio-economic situation, the proposals presented here are destined for various types of private (middle to upper class) residences and public residences (for a public developer wishing to rehabilitate for re-housing/low rents, etc).

Focussing on the functionality available to the user, Aldrich proposes five hierarchical classes of smart homes (Aldrich, 2003):

1. Homes which contain intelligent equipment - homes containing single, stand-alone applications and equipment which function in an intelligent manner;
2. Homes which contain intelligent communicating equipment - homes containing equipment which functions intelligently in its own right and also allows information to be exchanged between individual items to enhance functionality;
3. **Connected homes** - homes with internal and external networks allowing for interactive and remote control of systems, as well as access to services and information both within and outside the home;
4. Learning homes – homes where patterns of activity are recorded and the accumulated data is used to anticipate users' needs and control the technology accordingly;
5. Attentive homes - the activity and location of people and objects within the homes are constantly registered and this information is used to control technology in anticipation of the occupants' needs.

The growing widespread use of broadband is creating a trend away from homes which contain intelligent, communicating equipment to connected homes. According to Bierhoff and Berlo (2007: 46), a home must at least be classified as a connected home in order to transform it into a smart home environment to provide better quality of living.

According to Aldrich (2003), the 4th and 5th classes of smart homes - learning and attentive homes - only exist in demonstration settings, since the technology used is in most instances still experimental.

This study aims to provide methods for integrating ICAT into dwellings with the aim of rapidly transforming them into connected homes, allowing for future expansion to include other functions that have meanwhile become accessible on a domestic level.

FAMILY PROFILES

Smart homes should address residents' demands and needs. However there is frequently a gap between the technology implemented and the user's real needs. This happens because the implementation of home automation is usually undertaken without the previous knowledge of the end-users (e.g. in multi-family residential buildings) or without understanding the exact needs of residents. It is important that every stakeholder within the building process, in particular the architects and clients, have enough knowledge of ICAT to allow the pack of technologies chosen to be useful to the end-user.

In order to define the ideal pack of ICAT functions, several types of households were considered based on previous works on the user-centred approach: (i) Meyer and Schulze (1996), on the uptake of technology based on household characteristics; (ii) Bierhoff and Berlo (2007), on technology preferences based on lifestyles; (iii) Van de Goor and Becker (2000), on technology generation.

Like Bierhoff and Berlo (2007), the process began by considering several attempts to classify residents into target groups for ICAT packs. The initial criteria were the technology generation to which residents belonged, family composition, the lifestyle of residents and their involvement in processes.

The technology generation enables the definition of the selected technology to be based on the residents' skills and knowledge of technology. The use of this criterion seemed to be very limited and not helpful to our goal since it would differentiate only three essential groups (the electro-mechanical, display and menu generations). However this criterion was used when assigning ICAT packs to groups which included elderly residents.

Family composition consists of knowing the number, age and kinship of the residents as well as other characteristics that are important in defining the ICAT pack, e.g. the existence of a disabled member of the family.

The use of resident participation introduces the problem of residents having to decide on an unfamiliar subject with only limited information on the possibilities and benefits (Bierhoff and Berlo, 2007: 49).

The final goal was to make sure that the proposed domotics functions met most of the wishes and desires of the residents.

The criterion chosen was to classify families based on kinship, age and number (see *Part 1: Chapter 4*). It was chosen for two reasons: (i) it was the criterion used in defining the functional programme for the dwelling and its reuse avoided difficulties in correlating the functional programme to the pack of ICAT functions; (ii) it is a criterion that has been tested and is directly related to the family, which allows for assertiveness. A category was introduced for elderly and disabled people which can be added to each of the categories defined if a household contains a disabled person, in order to incorporate assistive technologies. Resident participation is also part of the solution to the problem, since residents have the chance to intervene in the acceptance or modification of the ideal pack of ICT functions.

WHAT ARE REAL INDIVIDUAL NEEDS?

Nowadays we are witnessing an increasing dependence on technology in our everyday individual and collective lives. Although domotics clearly offers advantages in many areas, given that it promotes sustainability, social inclusion, support for the elderly and individuals with restricted mobility and improvements to the quality, comfort and adaptability of dwellings, it should be noted that, in addition to being planned in advance, it should essentially aim to meet the real needs of users.

Virilio comments on the need to ensure that domotics does not affect human mobility:

> "*The ergonomic aspect of the body must be taken into account in the habitat. However, with the new technologies, we do not need to move to carry out routine domestic tasks. With domotics, you do not simply press buttons to change television channels, but to operate lights, heating, doors and windows as well. You do not go over to the window to open it, you just press a button. Hence there is a kind of allusion to a disabled rather than an active body. The active individual who is over-supplied with domotics, the person living in an automated home, is equivalent to a well-equipped invalid*." (Virilio, 2000: 70)

For Virilio it is important to question the excessive use of technology, the objective of which seems to be limited to providing a level of comfort beyond that which is really necessary and risks turning human beings into "*well-equipped invalids".*

However, the intrusion of technology into the lives of residents who consider it an integral part of their existence forces us to acknowledge unreservedly that we are witnessing growing forms of dependence on technology in our everyday individual and collective lives.

Although still questioned by some, the importance of integrating domotics into various aspects of housing has been demonstrated. As previously stated in *Part 1: Chapter 1* the benefits of domotics in promoting social inclusion, support for the elderly and those with restricted mobility and the reduction of energy consumption is unequivocal.

Domotics must be understood as a means of providing better quality of life for residents, by meeting their real needs. The systems and functions available must be used as an aid to human activities and not as a replacement for them or the solution for all everyday tasks.

The needs of residents may be divided into two groups, in line with Cabrita (1987): genuine and artificial. Genuine needs include satisfying basic human survival needs (physical, intellectual and spiritual, moral and cultural). Artificial needs are characterised by the acceptance of needs contrary to the physical and psychological balance and cultural and moral self-enhancement. In this case, human beings are subjecting themselves to a process of standardisation of needs (Cabrita, 1987: 35).

In the light of these concepts, the application of ICAT to housing must be carefully considered from the outset in accordance with the genuine needs of residents. It may be said, in this context, that the so-called information society bears its share of responsibility for the growth of the consumer society since, on a technological level (essentially ICT), there is a great deal of pressure on the socio-economic system for the acquisition of goods.

It is considered here that ICAT is partly concerned with basic needs and also with artificial needs. In fact, as previously discussed in detail, for some of the more vulnerable social groups certain ICAT functions represent basic needs. The creation of government programmes to promote broadband Internet access, for example, and the use of tele-alarms are proof of this.

Therefore, the proposal in this thesis for ICAT packs adapted to different family profiles includes 3 levels of integration, ranging from systems/functions that are proven to be basic needs to the more superfluous technologies in the 3rd level whose integration depends on the families concerned and may correspond, in certain cases, to so-called artificial needs (see *Part 2: Chapter 3.1.1*).

However, this proposal meets the requirement for housing to be 'lifecycle-proof", which is accomplished when the technical infrastructure can adjust to the changing desires and wishes of the residents and to state-of-the-art technology (Bierhoff and Berlo, 2007: 65). This requirement demands more than the basic technology included in the first level of integration.

THE HUMAN REACTION TO TECHNOLOGY

The human reaction to domotics and technology as a whole has to do with different aspects such as age, technology generation, physical and mental capacities, social and cultural levels. The "technology generation" to which the residents belong is defined on the basis of the type of technology that was available in the formative stages of their life (between the age of 10 to 25) (Rama, 2001) (Sackmann and Weymann, 1994)[64].

Rama (2001: 18) distinguishes three different technology generations: the electro-mechanical generation (born 1930-1960, now aged of 50 to 80), the display generation (born 1960-1970, now aged 40 to 60) and the menu generation (born after 1970, now under 40). The last two technology generations (display and menu) are then combined by Rama into a single one called the software generation.

It is important to note that the categories were based on different geographical contexts to Portugal and there may therefore be a time difference between these generations and the Portuguese generations.

Due to these differences in technological skills, people who are not part of the software generation will hesitate to buy new technology because of the problems they expect to encounter when operating the equipment (Bierhoff and Berlo, 2007: 49).

Nevertheless, the technological difficulty that adults of 30 years ago experienced in using the technology is rapidly being overcome by the new generations of children, who use the available technologies almost spontaneously.

Technological literacy is expanding as one generation succeeds the next and, parallel to this, technology has been acquiring more user-friendly interfaces.

The research carried out by Rama (2001) concluded that the learning performance of an individual using a new device with a given complex user interface, is a function of (1) age, referring to the user's cognitive abilities, which are susceptible to change with age and (2) technology generation, referring to the user's skills.

3.1 THE IDEAL ICAT PACK

In this chapter household profiles are used to determine the ideal pack of ICAT functions for the dwelling. The pack of ICAT functions in this case is a description of an ideal set of domotics systems and functions for the family, which is not restricted by any existing morphological or constructional structure. Several types of households were considered in order to define the ideal pack of ICAT functions and, based on their characteristics and anticipated needs and activities within the home, a set of essential domotics functions were established.

The ICAT pack for a particular family was defined in accordance with a methodology based on previous works on: i) the user-centred approach, by Meyer and Schulze (1996) on the uptake of technology based on household characteristics, by Bierhoff and Berlo (2007) on technology preferences based on lifestyles, and by Van de Goor and Becker (2000) on technology generation; ii) the approach focussing on activities which take place in the home by Mateas *et al*. (1996), iii) hierarchical classes of smart home by Aldrich (2003). This methodology encompasses several steps during which the future residents are asked questions in order to define the contents in terms of the domotics systems and functions required by a particular household.

Following the same principles used to define the ideal functional programme for the dwelling (see *Part 2: Chapter 2.2*), this process of defining an ideal ICAT pack in accordance with the characteristics of a particular household may be undertaken as follows:

3. Using computer software designed for this purpose;
4. Using tables and flow charts which cross-reference data and supply values for it, thus establishing a sequence of actions to be followed in order to obtain the ICAT pack.

The first procedure would be the more productive one but software development was not a goal of this thesis. The second procedure for defining the ideal ICAT pack was therefore chosen for this study and the steps leading to definition are identified in this chapter. Table 29 shows the sequence for the list of data that must be introduced (inputs) and how the programme definition is obtained (outputs).

In order to define the ideal ICAT pack three levels of integration were taken into consideration, the first being the basic level that should exist from the outset and the others depending on the family's wishes and available budget.

This methodology enables the designer to use tables and flow charts (and, in a future development of this research, digital simulation) to assess the real basic needs of each household without spending undue amounts of time and eventually supplement this choice with extra requirements requested by residents. The availability of countless domotics systems and functions and the lack of in-depth knowledge of these systems on the part of designers and residents mean that choices made without guidance may be prejudicial to residents. In this situation, it is likely that residents will be presented with too much choice that exceeds their basic needs and includes superfluous elements in addition to the essentials. Consequently, either due to price or the final dimensions of the system, this may deter them from opting for domotics (Kasier, 2008c).

Input	**7**	Define desired quality level	Basic, Medium, Optimum (choose from *Part 2: Chapter 3.1.1)*
Output	**5**	Preliminary ideal ICAT pack	List of systems and particular functions (choose from *Part 2: Chapter* 3.1.2, Table 20Table 39, page 270 to 284)
Input	**8**	Define additional ICAT functions	List of systems and particular functions (choose from *Part 2: Chapter* 3.1.2, Table 20Table 39, page 270 to 284)
Output	**6**	Final ideal ICAT pack	List of systems and particular functions

Table 29 – List of questions to ask future residents (input) and definition of the ideal ICAT pack (output).

Bearing in mind that the scope of this thesis is housing rehabilitation undertaken either by residents themselves or by developers with the aim of placing dwellings on the market, it was also considered necessary to include an ICAT pack for a non-characterised family profile which can be integrated if a property developer intends to do so. In this case, the proposed methodology also enables designers and developers to choose an appropriate ICAT pack for each dwelling even if the future residents are not known at the outset. In this context, the dwelling should, from the outset, offer all the potential to meet the requirements of any household that may eventually live in it.

The definition of three levels of ICAT integration offers great advantages since it requires the basic infrastructure to take future extensions of the installation into account, thus not hampering the development of the system and the introduction of new functions and equipment from the outset. Residents can be informed of the potential for extending the installation, which can be decided in the future.

In addition, the system and functions must be clearly designated and what they may or may not contain must be accurately specified, to enable the user to make an informed choice. This clarification will, on the one hand, provide for security during the transition from the design to the construction phase and also ensure the final budget and customer satisfaction.

This chapter is divided into three parts:

- the first part defines the levels of ICAT to be used;
- the second part assigns ICAT systems and functions to each family profile;
- the third part takes a different approach to defining ICAT functions according to accommodation and new housing functions;
- Finally, the physical impact of ICAT integration is addressed in terms of domotics elements.

3.1.1 ICAT levels

As previously stated, it was necessary to define three levels of ICAT integration that would meet the real needs of residents, taking into account the evolution of residents' requirements and hence the need to upgrade infrastructure.

If they do not meet the current or future needs of residents, ICAT elements will involve substantial additional costs in the future. In practice, these costs will be approximately four times higher than they would have been if the resident's needs had been taken into account initially (ISSO, 2004).

Three levels of ICAT packs were defined for each family profile, which can be chosen according to the family's income. The minimum proposed level of ICAT is recommended for every new or rehabilitated house or dwelling. The medium level is an upgrade of the lower level and requires a greater financial investment. The optimum level of ICAT integrates a complete set of technologies to meet prospective family needs, without becoming unreasonable.

BASIC LEVEL (1ST LEVEL)

The basic level includes wired infrastructures, basic security systems and access to ICT, and the exact definition of these features varies slightly according to the different family profiles. This basic level contains all the cable infrastructures required to enable the system to be upgraded to the optimum level. This level is suitable for low-budget households and property developers who want to make a small investment without compromising the upgradability of the system.

MEDIUM LEVEL (2ND LEVEL)

The medium level includes automation technologies that extend beyond the basic setup. This level includes a larger group of systems and functions that could be integrated into the initial ICAT pack in the following situations:

i) Increased family needs and requirements (e.g. larger number of residents and/or advancing age);

ii) An increase in family disposable income.

OPTIMUM LEVEL (3RD LEVEL)

The optimum or 3rd. level includes a vast range of current domotics systems and functions that can be integrated into a dwelling in accordance with the household for which they are destined. This ICAT pack does not comprise the entire domotics range currently on offer but instead all the elements which have been considered throughout this study to promote better quality of life.

3.1.2 ICAT systems and functions according to family profiles

As previously stated, 3 levels of domestic ICAT integration will be defined for each household defined in *Part 1: Chapter 4*. These categories are therefore be used to allocate an ICAT pack to each household which is adapted to its real needs and allows for future developments by progressing to the next level.

It was decided that the ICAT pack for the "other types of family" group, which consists of two or three nuclei with or without children and with or without other individuals, would be supplemented by additional individual packs that the group would require. As an example, a family consisting of a couple with children with 2 adult relatives and one set of grandparents will need the "couples with children and other individuals" pack plus the "elderly couple" pack.

Although it was decided to define ICAT packs according to family profiles as the best option to respond to real family needs, there are some situations that do not meet this criterion:

– Some functions depend more on the lifestyle of the residents than on the composition of the family;
– In some cases the property developer may not be aware of the residents' profiles and may prefer to choose a basic ICAT set to incorporate into a predefined dwelling. In this case the "Couples with independent children/adults" was considered the "default family type" because this group does not include any special age or mobility needs (e.g. children and the elderly) and incorporates different generations (independent children/adults and adults).

In this section the different rooms within the dwelling are considered and the systems and functions relevant to the functional performance of the accommodation are assigned.

In order to define the ideal ICT and domotics packs, decision-making tables and flow charts were used, indicating the decision-making process.

In addition to listing the systems, functions and equipment required, this chapter also includes a brief consideration of the options for positioning equipment.

SAFETY

The domotic functions regarding safety are described in Table 30 and Table 31 which allow the decision-making process to assign domotic functions to specific profiles of family.

	Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
1. Safety	Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
1.1 Detection of fire																	
a. Detection of smoke	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
b. Detection of temperature	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
c. Electrically operated valve to switch off power and gas	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
d. Remote alarm (interaction: if 2.1.a is activated remote alarm is sent)	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
e. Local alarm	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
f. Interaction with 3.2 (e.g. emergency lighting switched on in the event of fire)	Medium	Medium	Medium	Optimal	Optimal	Optimal	Basic	Optimal	Medium	Medium	Optimal	Optimal	Basic	Medium	Medium	Basic	Basic
g. Interaction with 3.3 (e.g. all controled blinds opened before power is cut off, in the event if fire)	Medium	Medium	Medium	Medium	Medium	Medium	Basic	Medium	Medium	Medium	Medium	Medium	Basic	Medium	Medium	Basic	Basic
h. Interaction with 3.4 (e.g. exits opened in the event of an emergency)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Basic	Optimal	Medium	Medium	Optimal	Optimal	Basic	Basic	Basic	Basic	Basic

* If a member of the household needs electrically operated health care equipment, these functions are included in the basic level.

Basic level — Medium level — Optimal level

Table 30 – Cross-referencing of households and safety systems

	Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
1. Safety	Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
1.2 Detection of gas leaks																	
a. Detection of gas	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
b. Electrically operated valve to switch off power and gas	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
c. Interaction with 3.4 (e.g. windows opened to provide ventilation)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Basic	Optimal	Medium	Medium	Optimal	Optimal	Basic	Medium	Medium	Basic	Basic
d. Interaction with 3.4 (e.g. emergency exits opened)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Medium	Medium
e. Interaction with 3.2 (e.g. emergency lighting switched on in the event of a gas leak)	Medium	Medium	Medium	Optimal	Optimal	Optimal	Basic	Optimal	Medium	Medium	Optimal	Optimal	Basic	Medium	Medium	Basic	Basic
f. Remote alarm (interaction: if 2.1.a is activated, remote alarm is sent)	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
g. Local alarm	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
1.3 Detection of flooding																	
a. Detection of flooding	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
b. Electrically operated valve to switch off water	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
c. Power to equipment located near flooded area cut off	Medium	Medium	Medium	Medium	Medium	Medium	Basic	Medium	Medium	Medium	Medium	Medium	Basic	Medium	Medium	Basic	Basic
d. Remote alarm (interaction: if 2.1.a is activated, remote alarm is sent)	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
e. Local alarm	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
1.4 Detection of power failures																	
a. Detection of power failure *	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Medium	Medium
b. Remote alarm (interaction: if 2.1.a is activated, remote alarm is sent)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Medium	Medium
c. Local alarm	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Medium	Medium
d. Emergency socket powered by generator *	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Medium	Medium
1.5 Power supply																	
a. Controlled sockets																	
1.6 Personal support																	
Monitoring of more vulnerable individuals included in Assistive Technologies – 7.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a. SOS / Panic function	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Medium	Medium
b. Video monitoring of particular areas (e.g. baby monitoring) (may interact with 2.2b)	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal

* If a member of the household needs electrically operated health care equipment, these functions are included in the basic level.

Basic level | Medium level | Optimal level

Table 31 – (continuation of Table 30) Cross-referencing of households and safety systems

With regard to the fire detection system, it is also necessary to take the following aspects into consideration:

- Smoke detection implies fitting smoke sensors to the circulation areas near the entrances to the dwelling (to detect fire in other dwellings or in communal areas of the building) and near the kitchen (to detect fire in the kitchen);
- Smoke sensors should not be installed in the kitchen;
- The temperature sensor should be installed in the kitchen next to the oven;

With regard to the gas leak detection system, it is necessary to take the following aspects into consideration:

- Gas detectors should be installed next to equipment with gas outlets – gas oven, gas ring, heater, boiler, etc (at the correct distances and positions defined for the equipment).
- If the domotics system incorporates automated opening and closing of window/windows to provide ventilation, the window with the opening motor should be located in the room that contains the gas appliances – the kitchen. It is recommended that a second window on the opposite facade is also fitted with a motor to create transversal ventilation to remove the gas more efficiently.

With regard to the flood detection system, it is also necessary to take the following aspects into consideration:

- The flood sensors should be installed near the floor in rooms containing water outlets and near appliances that may cause flooding – i.e. the kitchen, bathrooms and electrical equipment such as washing machines and dishwashers;
- The flood sensors should be installed in visible locations to control their efficiency and prevent them from being obstructed by rubbish;

Controlled sockets allow the power supply to be cut off in certain areas. This allows certain appliances to be disabled and, in addition, reduces the likelihood of accidents involving small children (under national legislation it is compulsory to install protected sockets in new buildings or for new electrical installations).

With regard to personal alarms and monitoring systems the following aspects should also be taken into consideration:

- Personal alarms may take the form of a portable trigger or wall-mounted switch usually fitted in bathrooms and/or bedrooms next to the bed;
- The use of a personal alarm linked to a care centre presupposes the existence of a telephone line with an alarm unit feature and one or more portable triggers. The communications unit should provide for two-way speech and may be activated by speaking into the portable trigger;
- Video monitoring of a particular space into order to supervise children implies the existence of a camera in the room linked to the home video distribution system to enable viewing from any screen.

With regard to the access control system the following aspects should be taken into consideration:

- On the basic level, the video caretaker system is located in the hall at the entrance to the dwelling;
- There may be other fixed video caretaker interfaces next to the second entrance to the dwelling or the night-time area of the home (if the dwelling has two defined areas – day-time and night-time).

With regard to the detection of intrusion system (Table 32), the following aspects should be taken into consideration:

- The movement detectors should be installed in all rooms, taking the related domotics functions into consideration. A basic installation should reserve cabling in the wall near the ceiling or in a false ceiling for the future installation of these sensors. To detect intruders it is necessary to install sensors that can scan the entrance door(s) to the dwelling and any windows that provide access to the dwelling on the ground floor or on another floor that can be accessed from the exterior (see the decision-making process to introduce movement detectors in page 295);
- Magnetic detection of the opening of doors and windows should follow the same criteria applied to movement detectors. In addition to detection of intruders, this function can also control access to the dwelling, namely the uncontrolled exit of children and elderly people;
- If the topology of the dwelling allows for an isolated night-time zone to be defined, consisting of all the bedrooms and related bathrooms, 2 zones should be defined: a day-time and a night-time zone. This option implies one or more control panels for the system so that it can be switched on or off in the zone that is not being covered;
- With regard to video surveillance, it is necessary to choose from the following options: use of specific CCVT cameras (black and white or colour, positioning, enlargement, sensitivity, possibility of controllable dome pan & tilt); choice of areas requiring coverage/definition of number of cameras; period and autonomy of functioning; monitors and recording devices (type of recording, remote or local viewing, networked cameras recording to another area of the building, transmission of images via GPRS to a mobile phone in the event of an alarm). Initially, in the buildings studied the areas that may require video surveillance were the access hall(s) to the dwelling (one camera installed in the hall) and the ground floor dwellings or those on other floors that can be easily accessed (cameras installed in circulation areas).

Presence simulation uses equipment from other systems like lights and blinds which are not specified here.

SECURITY

The domotic functions regarding security are described in Table 32 which allows the decision-making process to assign domotic functions to specific profiles of family.

	Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
2. Security	Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
2.1 Control of access																	
a. Video caretaker control of access																	
b. Video caretaker linked to various points in the home (TVs, PCs)																	
c. Remote attendance by video caretaker *																	
2.2 Detection of intruders																	
a. Detection of movement (e.g. interacting with the sensors in 3.2)																	
b. Magnetic detection of opening of doors and windows (may also serve as a control for children/elderly people exiting to the exterior)																	
c. Alarm to the exterior (by telephone)																	
d. Local alarm																	
e. Interaction with 3.2 (e.g. flashing lights switched on in the event of intrusion, complementing 1.1.f and 1.2.e)																	
f. Definition of multiple zones for different activation periods (e.g. night-time and day-time or other zones)	This function does not correspond directly to a particular household, but to whether the topology of the dwelling allows for division into zones.																
g. Video surveillance with recording and remote viewing of intrusion	This function does not correspond directly to a particular household but to the location of the dwelling within the building (e g. on the ground floor) and the characteristics of the urban area in which it is situated.																
2.3 Presence simulation																	
a. Interaction with 3.2 (e.g. activation of pre-programmed daily routines such as lighting, combined and apparently random activation)	This function does not correspond directly to a particular household, but to the lifestyle of the residents (e.g. amount of time spent outside the home), the location of the dwelling within the building (e g. on the ground floor) and the characteristics of the urban area in which it is situated.																
b. Interaction with 3.3 (e.g. activation of pre-programmed daily routines for raising/lowering blinds, combined and apparently random activation)	=																
c. Interaction with 3.5 (e.g. activation of pre-programmed daily routines for watering, combined and apparently random activation)	=																

* This function will be used more by people who spend many hours absent from the home (the working population) and need to receive mail or other home services.

Basic level | Medium level | Optimal level

Table 32 – Cross-referencing of households and security systems

COMFORT

The domotic functions regarding comfort are described in Table 33 and Table 34 which allow the decision-making process to assign domotic functions to specific profiles of family.

	Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
3. Comfort	Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
3.1 Control of HVAC																	
a. On/off control for all units in various places	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
b. Individual control in each room	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
c. General on/off control to activate exit from building (Interacts with 4)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
d. Remote control via telephone	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
e. Remote control via Internet	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
f. Control of maximum and minimum temperature required*	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Medium
g. Remote monitoring of air conditioning system	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Medium
h. Activation/deactivation by presence	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
i. Lowering of temperature when room is unoccupied	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
j. Activation/deactivation by detection of open doors/windows	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
3.2 Control of lighting																	
a. Automated lighting controlled by movement sensors in hall – safe entry to home (Interacts with 1.1 and 1.2)	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
b. Automated lighting controlled by movement /presence sensors on bedroom/bathroom route and in these rooms (Interacts with 3.6), with dimmer function	Medium	Medium	Medium	Medium	Medium	Medium	Basic	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Basic	Basic
c. Automated lighting controlled by remote control in living room/home cinema (Interacts with 6.1)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
d. Automated lighting in all rooms controlled by presence sensors	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
e. Automated lighting in all rooms and interior lighting levels in accordance with natural outdoor light (twilight and light sensors)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
f. On/off control of all automated lighting units in various points	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
g. On/off control of all controlled sockets	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
h. Control by remote controls	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Medium
i. Control with varying intensity (Interacts with 4.)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
j. Remote monitoring of lighting system	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Medium

* This function warns of hypothermia and dehydration in dependant individuals

Basic level   Medium level   Optimal level

Table 33 – Cross-referencing of households and comfort systems – control of air conditioning and lighting

With regard to the centralised air conditioning system (e.g. gas or electric boilers, heat pump/air conditioning, under-floor heater) (Table 33), the following aspects should be taken into consideration:

– Control of air conditioning involves the existence of HVAC equipment in all the habitable rooms linked to the domotics system. It also presupposes the existence of the following (according to the functions desired): interior and exterior temperature sensors or a weather station; presence detector; magnetic contacts on windows (optional).
– Remote control (by telephone or Internet) is essentially designed for households who are regularly absent from the home for several days and therefore does not depend on a particular family profile;
– Difficulties or anomalies in use frequently associated with central air conditioning systems are due to inadequate control systems which lead to low energy efficiency and compromise comfort. One example of this is centralised control which does not allow for individual regulation of the temperature in each area, either causing overheating (and consequently high energy expenditure) or insufficient heating in order to control expenditure.

With regard to the lighting control system (Table 33), the following aspects should be taken into consideration:

– This system presupposes the existence of lighting equipment (moveable lights which can be plugged in and fixed lighting) linked to a domotics system;
– In addition to this equipment, the following are also required: interior and exterior light sensor, motion sensor, presence sensor.

With regard to the control system for blinds and screens (Table 34) the following aspects should be taken into consideration:

– Control of the raising/lowering of blinds and screens presupposes the existence of the necessary electrical equipment (requiring the replacement of the original blinds) in all habitable or most frequently used rooms (e.g. bedrooms). It also presupposes the existence of the following equipment (according to the functions desired): interior and exterior temperature sensors, wind sensor, light sensor or weather station.
– If there are electrical blinds controlled by a domotics system, SOS systems should be installed to allow for manual opening in the event of a power failure. This is particularly important should any emergency occur, e.g. fire. In this case, the use of electric blinds may compromise rescue measures. There should be not less than two mechanical SOS systems for the manual opening of blinds, which should be installed in opposite facades of the dwelling and in habitable rooms;
– The command to activate the blinds or screens should be installed in each room by the entrance and, in the case of bedrooms, via a multifunction control next to the bed.

The automation of doors and windows (Table 34) presupposes the existence of the following:

– New frames that can support a motor installed in the existing window space;
– A motor may be added to the existing doors or they may have to be replaced with new doors;
– A presence sensor which detects whether a door can be closed safely can be installed to prevent accidental closing of doors.

Automation of watering implies the existence of a watering network linked to the domotics system and activated by hourly scheduling or through the use of humidity detectors, rain detectors or a weather station.

		Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
3.	**Comfort**	Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
3.3	**Control of motors (blinds and screens)**																	
a.	Automated blinds in all rooms	Medium	Optimal	Medium	Optimal	Optimal	Medium	Basic	Medium	Medium	Medium	Optimal	Medium	Basic	Optimal	Medium	Basic	Basic
b.	General open/close control on main panel	Medium	Optimal	Medium	Optimal	Optimal	Medium	Basic	Medium	Medium	Medium	Optimal	Medium	Basic	Optimal	Medium	Basic	Basic
c.	Individual open/close control in each room	Medium	Optimal	Medium	Optimal	Optimal	Medium	Basic	Medium	Medium	Medium	Optimal	Medium	Basic	Optimal	Medium	Basic	Basic
d.	Centralised control from various points in the home	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
e.	Control by measuring atmospheric conditions (wind, intensity of light, rain)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
f.	Control by hourly scheduling	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
g.	Remote control	Medium	Optimal	Medium	Optimal	Optimal	Medium	Basic	Medium	Medium	Medium	Optimal	Medium	Basic	Optimal	Medium	Basic	Basic
h.	Remote control via telephone or Internet	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
i.	Control of blinds and screens to reduce or increase light (interacts with 3.2 and 4.)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
3.4	**Control of motors (doors and windows)**																	
a.	Entrance door with open/close motor (Interacts with 1.1, 1.2 and 1.6)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium	Medium
b.	Doors to main rooms with open/close motor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	* (Basic)
c.	Presence sensor (to prevent accidental closing)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium
d.	Specific opening and closing of windows linked to air conditioning/ventilation system (interacts with 2.1 and 3)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
3.5	**Control of watering ***																	
a.	Control by pre-established schedule (hourly, seasonal)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
b.	Control by humidity and temperature sensors	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal

* In the event of physical disability which prevents user from opening doors

Basic level | Medium level | Optimal level

Table 34 – Cross-referencing of households and comfort systems – control of blinds, opening and closing doors and windows and watering

ENERGY MANAGEMENT

The domotic functions regarding energy management are described in Table 35 which allows the decision-making process to assign domotic functions to specific profiles of family.

		Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
4.	**Energy / water management**	Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
4.1	**Control and distribution of energy**																	
a.	Monitoring of energy use	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
b.	Management of renewable / non-renewable energy resources (as appropriate)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
d.	Control of energy distribution / prevention of energy peaks (Interacts with 3.1, 3.2, 4.2, 6, 7)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
e.	Cutting off electricity to non-priority sockets during the night	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
4.2	**Management of electrical domestic appliances**																	
a.	Use of day/night tariff to activate appliances during off-peak hours (manual or automated)	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
b.	Remote control of dishwashers, washing machines and driers	Medium	Medium	Optimal	Optimal	Medium	Optimal	Optimal	Optimal	Medium	Medium	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
c.	Management of appliances, phasing to prevent overloading	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
4.2	**Management of water resources**																	
a.	Use of efficient taps and commands via IR detectors (Interacts with 7.1, 7.2)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Medium
b.	Control of bath/basin water levels (Interacts with 7.1, 7.2)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
4.3	**Coordination with air conditioning and ventilation (Interacts with 3.1)**																	
	Air conditioning management functions (3.1b, 3.1f, 3.1h, 3.1i, 3.1j)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.4	**Coordination with lighting (Interacts with 3.2)**																	
	Other lighting management functions (3.2a, 3.2b, 3.2d, 3.2e)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a.	Low cost lighting	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
4.5	**Coordination with opening and closing of blinds (Interacts with 3.3)**																	
	Blind opening/closing functions (3.3e, 3.3i)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Basic level Medium level Optimal level

Table 35 – Cross-referencing of households and energy management

The possibility of monitoring energy use is a valid function when the vast majority of equipment (e.g. air conditioning, lighting, electrical domestic appliances) is automated. Other domotics functions which promote energy and water efficiency have been described previously in relation to the lighting, air conditioning, watering, opening/closing of blinds and control of electrical domestic appliances systems, in terms of providing greater comfort for residents. In addition to matters of comfort, control of these systems and the use of certain domotics functions can improve energy and water performance in buildings.

INFORMATION AND COMMUNICATION

The domotic functions regarding information and communication are described in Table 36 which allows the decision-making process to assign domotic functions to specific profiles of family.

		Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
		Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
5.	**Information and communication**																	
5.1	**Communication within the system and with the exterior**																	
a.	Alarms sent to the exterior via telephone																	
b.	Alarms sent and received via the Internet																	
c.	Personal alarms with two-way communication between resident and care centre																	
d.	Remote reception of system commands via telephone																	
e.	Remote reception of system commands via the Internet																	
5.2	**Local networks and Internet**																	
a.	Access to broadband Internet																	
b.	Telecommunications networks in compliance with ITED																	
c.	Telecare																	
d.	Telehealth							*						*			*	*
5.3	**Communications between system components**																	
a.	Dedicated cable network																	
b.	Supplementary wireless network (if necessary)																	
5.4	**Telework**																	
	Broadband Internet access (5.2a)																	
a.	Computer																	
b.	Other networked equipment, e.g. printer																	

* In situations of chronic illness
Basic level   Medium level   Optimal level

Table 36 – Cross-referencing of households and information and communication system

The information and communication network in the dwelling is the most important link, to which automation should be integrated. As previously stated, the various systems can only be integrated if they use the same language (communication protocol) and if they are linked together by sharing resources. In this way, the basic requirements for integrating ICT for all co-residing groups (Table 36) are the use of a standard protocol, cabling for the dwelling that envisages future extensions (supplemented by wireless networks) and broadband Internet access.

With regard to future extensions of the network, Baroni (Baroni *et al.*, s.d.) state that the network infrastructure for buildings should be designed to be expandable, flexible in terms of the location of devices and should facilitate:

- The installation of the system itself, to enable any electrician to solve the more common problems;
- The expandability of the system, by allowing for incorporation of new products that appear on the market. It should be possible to purchase a system with a limited number of functions and gradually increase them without excessive cost;
- The flexibility of the system, by enabling it to be adapted to each user over time. It should not be a rigid system, but a system that can accommodate a wide range of users and requirements.

An entertainment system (Table 37) can include the following options:

- Installation of a home cinema system with the following equipment and characteristics:
    - A fixed plasma screen or other type of screen;
    - A projection screen (e.g. roll-up screen that can be hidden in a false ceiling and rolled down over the fixed screen);
    - A high resolution projector (e.g. one which can be installed in a false ceiling in a "trapdoor" that can be lowered when the projector is being used and conceals it inside the false ceiling when not in use);
    - An audio and video amplifier;
    - A CD, DVD and Blu-Ray player;
    - Surround sound (Dolby digital / DTS / THX);
    - Speakers (also used by the multi-zone audio system);
    - Remote control;
    - Interaction with lighting, air conditioning and blinds/curtains raising/lowering systems to create scenarios.
- Installation of a centralised multi-zone audio system with the following equipment and characteristics:
    - Sound server with hard disc;
    - Amplifiers;
    - Central and rear speakers;
    - Interaction with lighting, air conditioning and blinds/curtains raising/lowering systems to create scenarios.
    - Remote control;
- Games consoles;
- Computer.

LEISURE & ENTERTAINEMENT

The domotic functions regarding leisure and entertainment are described in Table 37 which allows the decision-making process to assign domotic functions to specific profiles of family.

		Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
6.	**Leisure & entertainment**	Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
6.1	**Home cinema**																	
a.	Home cinema (dedicated room)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
b.	Home cinema (shared room)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
c.	Cinema viewing scenarios (Interacts with 3.1, 3.2, 3.3)	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
6.2	**TV , audio and consoles**																	
a.	Access to TV via cable, satellite, ADSL, IPTV	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
b.	Multi-zone audio system	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal
c.	Games consoles	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal

Basic level Medium level Optimal level

Table 37 – Cross-referencing of households and entertainment systems

The correct viewing distance for video content is an important piece of information in terms of sizing areas which involve leisure and entertainment functions.

In order to view a quality XGA screen (1024 x 768) the spectator should be seated at a distance (y) equal to three times or more the diagonal measurement (x) of the screen (e.g. x = 42″ = 1.05m; y = 3.15m). In order to view a poor quality VGA screen (640 x 480) the spectator should be seated at a distance (y) equal to five times or more the diagonal measurement (x) of the screen (e.g. x = 42″ = 1.05m; y = 5.25m).

Assistive technologies

The domotic functions regarding assistive technologies are described in Table 38 which allow the decision-making process to assign domotic functions to specific profiles of family.

		Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
		Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
7.	**Assistive technologies**																	
7.1	**Basic**																	
	Detection of gas, fire, flooding and power failures (defined in 1.1, 1.2, 1.3, 1.4)							-						-			-	-
	Control of air conditioning, lighting, blinds/screens, door and window opening systems (defined in 3.1, 3.2, 3.3, 3.4)							-						-			-	-
	Communication system (defined in 5.2)							-						-			-	-
a.	Personal alarm (portable trigger) / connection to a relative							Basic						Basic			Basic	Basic
b.	Telecare (community alarm - portable trigger / connection to a care centre)							Medium						Medium			Basic	Basic
c.	Panic button in rooms (e.g. bathrooms)							Basic						Basic			Basic	Basic
d.	Detection of falls							Optimal						Optimal			Optimal	Optimal
e.	Detection of occupation of bed / prevention of falls							Optimal						Optimal			Optimal	Optimal
f.	Night-time waking scenario – automated low-intensity lighting along the bedroom/bathroom route and in the rooms themselves (use of movement/presence sensors and pressure pad near de bed) (supplementing 3.2.b)							Medium						Medium			Medium	Medium
g.	Telephone call scenario (lights switched on in the circulation area leading to the telephone) (Interacts with 3.2a)							Medium						Medium			Medium	Medium
h.	Daily monitoring of consumption (to monitor activity or lack of activity)							Medium						Medium			Optimal	Optimal
l.	Telehealth							Optimal						Optimal			Optimal	Optimal
7.2	**Specific to certain disabilities**																	
a.	Reminder to take regular medicine							Medium						Medium			Medium	Medium
b.	Other memory aids (e.g. door open, oven switched on, fridge door open, tap on, appointments)							Medium						Medium			Medium	Medium
c.	Device to fill bath to controlled water level							Medium						Medium			Medium	Medium
d.	Temperature control for washbasins and baths to prevent burns.							Medium						Medium			Medium	Medium
e.	Sensors to turn on taps							Medium						Medium			Medium	Medium
f.	Height-adjustable kitchen work surfaces							Optimal						Optimal			Optimal	Medium
g.	Vertical push-button up or down adjustment of toilet and wash basin.							Optimal						Optimal			Optimal	Medium

Basic level Medium level Optimal level

Table 38 – Cross-referencing of households and comfort systems – assistive technologies

A home with assisted technologies can enable disabled and elderly people to lead safe and independent lives in their own homes.

These technologies aim at: i) providing an environment that is constantly monitored in order to ensure the safety of residents; ii) ensuring that the tasks the individual is unable to undertake are carried out; iii) ensuring a safe, protected environment and iv) providing autonomy and empowering residents for people with restricted mobility, physical or mental impairments.

It is not the intention here to define assistive technologies for various disabled or dependent profiles, but to provide an overview of certain technologies, systems and functions that may be useful to these groups. In these circumstances there should be a Process Facilitator (Dewsbury, 2000), as implemented in the CUSTODIAN project, to mediate ICAT integration in order to determine the real needs of the user.

Assistive technologies have been considered only for households which really need or may need them at the present time – elderly couples, single elderly people and people with restricted mobility or disabilities. Integration of assistive technologies is not considered relevant for the remaining households, since it represents a very specific proposal and, due to the high cost, it is not acceptable to install the technologies before they are actually necessary. Some technologies which serve both "aging in place" and the comfort of other co-residing groups, e.g. automated control of blinds, were considered in the previous sections.

As previously stated, there are various scenarios in which the methodology described in this study can be used. One of these is the integration of assistive technologies in a dwelling, e.g. for elderly people, without the need for any functional rehabilitation or constructional work. Within this context, assistive technologies have the role of promoting "aging in place", i.e. enabling the elderly to age in their own home supported by technology and essentially using wireless equipment.

ALARM SIGNALLING

The means of signalling used to activate local fire, gas leak, flood, intruder or other types of alarm may involve sound (a self-powered interior and/or exterior siren) or visuals (e.g. flashing lights, incorporating features of the safety and lighting systems).

In the basic ICAT pack the local alarms use sound and the siren is located in the entrance hall.

Interfaces

Table 39 allow the decision-making process to choose and assign interfaces to specific profiles of family.

		Couples with children			Couples without children					Single-parent households		Co-residence			Single people			
7.	**Interfaces**	Couples with dependent children/minors	**Couples with independent children/adults / default**	Couples with children and other individuals	Young couples who may eventually have children	Childfree couples	Couples whose children have left home	Elderly couple	Couples without children but with other individuals	Mother or father with children	Mother or father with children and other individuals	Young people co-residing with other young people	Adults co-residing with other adults	Couples/single elderly person with grandchild	Young people	Adults	The elderly	People with limited mobility or disabilities
a.	Fixed single command switches																	
b.	Fixed multifunctional switches																	
c.	Large, highly sensitive switches	-	-	-	-	-	-		-	-	-	-	-		-	-		
d.	Fixed push button																	
e.	Panel with keyboard and display																	
f.	Panel with LCD or touch screen																	
g.	Remote control																	
h.	Telephone /mobile phone																	
i.	Proximity sensor (e.g. to open doors or switch on lights)																	
j.	Computer / television screen																	
l-	Optical reader, fingerprint reader																	
m.	Magnetic card reader																	

\- Not applicable
Basic level / better option
Medium level
Optimum level
Basic level / minimum option
Interfaces not adapted

Table 39 – Cross-referencing of households and comfort systems – assistive technologies

Interfaces are the channels through which residents communicate with the system, and should be used as intuitively as possible. They should also be multifunctional in order to prevent the existence of several different interfaces (i.e. interfaces should be shared between different systems). In addition to assessing residents' ability to work with the different interfaces available on the market, it is important to analyse the choice criteria from the point of view of the "technology generation" of residents. In fact, as described in *Part 2: Chapter 3 "The human reaction to* technology*"*, different technology generations interact with different technologies (electro-mechanical, display or menu).

Special attention must therefore be paid to interfaces for dwellings whose households include elderly people and/or individuals with restricted mobility and disabilities in order to avoid installing complex interfaces (combining many options in the same interface) and small buttons or devices that may require dexterity and rapid movements.

3.1.3 Renewing the network for the building

In the case of building rehabilitation, particular attention must be paid to infrastructure networks whose repair, maintenance or replacement involves various measures that may present difficulties during intervention work.

The repair or upgrading of telecommunications, electricity, water, gas and even sewage networks is therefore a priority for buildings such as the ones in this study, which are over 50 years old.

THE COMMUNICATION NETWORK

As described in *Part 1: Chapter 6.1.4* (*Transmission media,* page 101), current trends indicate the dominance of optical fibre and, in terms of wireless transmission media, it is expected that radio frequency systems will come to play an increasingly important role in domotics applications. However, wireless transmission media is still expected play a role in supplementing physical cable networks.

With regard to introducing domotics into existing buildings which are to be renovated or rehabilitated, the role of wireless technology may extend to more than a simple supplement. In fact, in order to create a new cable infrastructure in an existing building, masonry work is necessary in order to open up cavities for laying cables. In the case of buildings renovated without masonry work, wireless radio frequency solutions may be adopted.

The use of wireless technology is advantageous in rehabilitation projects since it provides access to some or all applications, given that it offers greater flexibility, great ubiquity and may easily be adapted to a variety of needs. The disadvantages are less reliable communications, the shorter distance required between devices, the greater bandwidth and the slightly higher cost.

According to Graça Almeida (2006), although IP networks are increasingly being integrated into domotics solutions, there is still no domotics technology which functions 100% using this type of infrastructure. However, it is expected that the infrastructure for Ethernet networks will be used for this purpose, thus eliminating the need for a second control network for dwellings. At present, as it is not yet possible to use the Ethernet network, it is necessary to install a specific infrastructure for the command network.

For this reason, in the case of substantial rehabilitation work, it is recommended that a network is installed to meet current ITED requirements for telecommunications, together with a cabled network, possibly supplemented by a wireless network for home automation.

THE ELECTRICITY NETWORK

Within the scope of the proposed rehabilitation methodology, the electricity network must respond to the growing energy requirements of multiple electrical and electronic household appliances. The use of many appliances simultaneously leads to the need for a powerful electrical installation. Increasing electrical power is a common measure when rehabilitating a dwelling (Paiva *et al.*, 2006: 731). In fact, must houses built more than 50 years ago assumed electricity would only be used for lightning and a few other domestic appliances such as a refrigerator, turntable and radio.

According to Giebeler (2009: 68), an electrical installation must be renewed after 30-40 years. The buildings in the case study were constructed between 1945 and 1960, which means that their electrical installations are too old and need renewing. In addition, the existing cable loads and electrical power are insufficient for modern requirements. However, it is important to clarify that integrating home automation does not imply the need for more electrical power. In fact, the use of automation technologies is a measure that allows for better management of energy consumption.

The decision to renew or rehabilitate electrical installations must be based on certain criteria (Paiva *et al.*, 2006: 734):

- The electric installation should be renewed:
    - If the existing electrical installation (the network and final equipment) is unsafe;
    - If there is to be a substantial amount of intervention work on the building;
- The electrical installation can be partially rehabilitated.
    - If only some of the equipment has deteriorated;
    - If some parts of the installation do not comply with current legislation;
    - If new components have to be installed for security purposes.

In order to install a new domotics infrastructure it would be advisable not to repair the electrical installation but to replace it. It should be remembered that the oldest component in the system is often the least visible and is the weakest part of the system, as well as the one that is less frequently replaced. Usually, in small-scale refurbishments the exterior components of an electrical installation are replaced but the inside cable infrastructure is not, meaning that it becomes a critical element with less remaining useful life than the visible components. However, very small domotics installations that use wireless components can be incorporated without replacing the entire electrical and telecommunications infrastructure. In this case the damage to the existing components must be remedied before upgrading the network. Renewing the electrical installation also helps reduce the risk of fire in the building and in the dwelling. In fact, old and poorly maintained electrical installations usually lead to fire.

The adaptation or replacement of the electrical installation requires an increase in electrical power and adaptation to new requirements and legislation for materials (used to construct electrical networks and appliances) and safety requirements.

A new installation must provide an adequate number of power sockets and connections as well as a minimum number of circuits, a distribution board, automatic fuses and cables with adequate cross-sections. In bathrooms, power sockets and electrical installations are restricted to certain areas (Portaria 949A/2006).

When renewing the electrical installation, the existing switches must be replaced by new multifunctional switches used in home automation.

The integration of automation technologies involves supplying electricity to places where it was not previously required (e.g. sensors on the ceiling). Without a new electrical installation, batteries would have to be added to several automation components and information would have to be transmitted by wireless – which is less reliable, as previously demonstrated.

Cables therefore have to be laid in walls, ceilings or floors as described in the next chapter. Although Portuguese legislation does not impose specific zones for the installation of cables in the walls of dwellings (except in bathrooms) it is good practice to install them using certain criteria. Cables to be concealed in walls should be laid in specific installation zones and should run vertically and horizontally[65]. These installation zones are the ones specified in the next chapter for laying of domotics cables - through the top of the wall (behind moulding panels), through the bottom of the wall (behind skirting panels) and with vertical connections near the end of the wall (in the angle formed by two adjacent walls) or behind door frames.

In floors and ceilings cables can be laid in diagonals using the shortest route.

The electrical equipment, including pipes, should be located in places where it is possible to carry out the necessary inspection and maintenance work and access connections (Portaria 949A/2006) (Figure 172).

Old electric panels should be substituted by new ones with space for the present features and expected future upgrade of the domotic system (Figure 171).

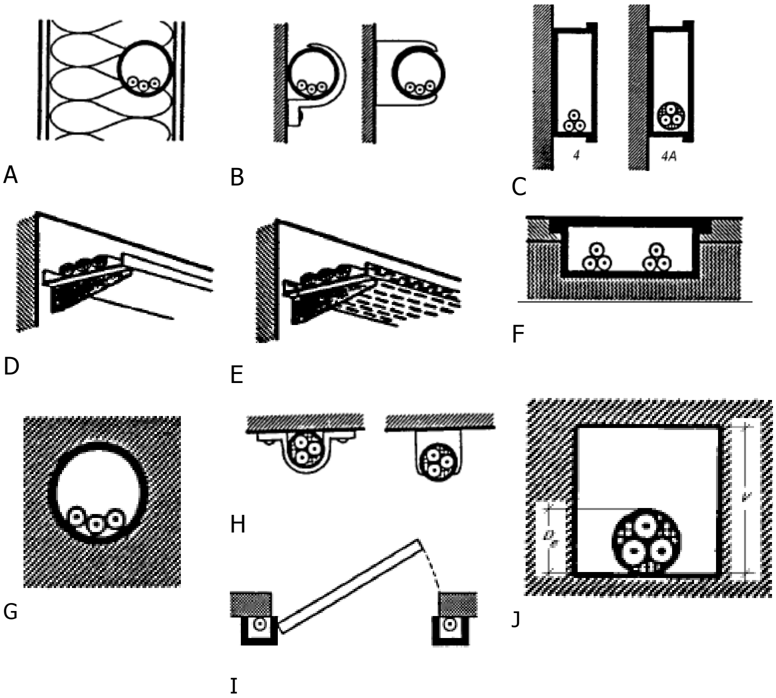

Figure 171 - New electric panel with domotics features

Figure 172 – Some types of electrical cable installations (Portaria 949A/2006). Top left to bottom right: A – cables inside pipe, embedded in drywall; B – cables inside pipe, surface-mounted on walls, C – cables inside duct, surface-mounted; D – cables in wireway or tray; E – cables in perforated wireway; F – cables inside under-floor duct; G – cables inside pipe and embedded in brick masonry walls; H – cables inside pipe and surface-mounted on ceilings; I – Cables inside door frame; J – Cables inside pipe in construction duct. Source: (Portaria 949A/2006).

THE WATER AND GAS NETWORK

Remodelling and intervention work on existing buildings which includes altering the water networks for the building should take the following into account: i) as far as possible, the intervention should comply with the regulations for the new construction, namely those referring to the installation of meters; ii) it should envisage fitting the meter to the exterior of the dwelling, next to the main entrance in a communal area, installed in box in acordance to the regulations; iii) in certain cases where it is impossible to install rows of meters, the design for the water network should involve installing meters on the stairways, with or without boxes; iv) if the existing network includes sections of lead piping, these should be completely replaced (EDP, 2009).

With regard to replacing the sewage network, the planned intervention would involve the whole building.

The buildings in the study already had mains gas. During rehabilitation of the dwellings, a new gas network should be built or renovated and this work should conform to the requirements stipulated for original constructions. The requirements for gas meters are the same as those for water meters.

3.2 THE ADAPTED ICAT PACK

In order to satisfy the requirements for the ideal ICAT pack defined in the previous chapter, varying degrees of intervention work must be carried out in the dwellings.

The capacity of a dwelling to meet current ICAT requirements depends essentially on the building construction system and the amount of rehabilitation work the residents want to undertake. In the proposed rehabilitation work, unlike buildings constructed from scratch, the ICAT pack for the dwelling is restricted by the existence of a specific building with a constructional system that may restrict certain types of rehabilitation work. Therefore the adapted ICAT pack for the dwelling described in this chapter cross-references information from the ideal ICAT pack for the dwelling with the actual construction and morphology, with the aim of implementing the ICAT pack as far as possible within the constructional and functional limitations of the existing dwelling.

The integration of ICAT in dwellings implies two possible strategies:

1. Using a wired infrastructure (more reliable communication):
    a. Surface-mounted casing;
    b. Concealed behind surface finishes;
    c. As intentional architectural featuring.
2. Using a wireless infrastructure (less reliable communication):

The use of a new wired infrastructure to support domotics implies full rehabilitation work involving walls, floors and ceilings unless the infrastructure is to remain visible, which is not the usual procedure in dwellings. This is the best option if functional adaptations are also to be carried out in the dwelling. However in some cases the goal may be the integration of certain ICAT functions, to support assistive technologies for example (see *Part 2: Chapter 3.1.2*), without undertaking any further rehabilitation work beyond the essential.

As described in Figure 170 (page 263), the adapted ICAT pack will use information from the ideal ICAT pack and from the existing dwelling and the adapted functional programme for the dwelling. This data will indicate the accommodation requirements in terms of number, area and connections. With this data the adapted ICAT packs that respond to these functional requirements will be defined by accommodation instead of by function, as the ideal pack was formulated. This strategy allows for a more practical and applicable view of ICAT needs in terms of system, functions and equipment.

In the last part of this chapter the construction strategies used to incorporate domotics appliances as well as wire and wireless infrastructures in rehabilitation work are defined. These strategies take into account the fact that, in intervening in an existing building, rehabilitation requires different construction techniques and cabling demands to be managed. Simultaneously, flexibility of space needs to be ensured, taking both present and future needs into account.

3.2.1 ICAT in rooms

This section begins by cross-referencing the systems and functions defined in the previous chapter (*Part 2: Chapter 3.1*), the existing dwelling and the adapted functional programme. Table 40 defines which domotics systems should be integrated into particular rooms. This is achieved by attributing two levels: *priority* inclusion - meaning that, if needed, the domotics function/system must be included in the accommodation; and *optional* inclusion - meaning that, if needed, the domotics function/system could also be included in the accommodation.

Finally the domotics functions and equipment required for each type of accommodation are defined, which will, at the end of the rehabilitation methodology, be combined with the adapted function programme in order to define the adapted description of the dwelling (Figure 170, page 263).

	Double bedroom	Twin bedroom	Single bedroom	Main bathroom	Second bathroom	Guest bathroom	Combined living/dining room	Living room	Dining room	Home office	Media room	Kitchen	Laundry	Corridors	Hall / **central control unit**	Storage	Balconies
Safety																	
Detection of fire	–	–	–	–	–	–	–	–	–	–	–	●	–	–	●	–	–
Detection of gas leaks	–	–	–	–	–	–	–	–	–	–	–	●	●	–	–	–	–
Detection of flooding	–	–	–	●	●	●	–	–	–	–	–	●	●	–	–	–	–
Detection of power failures	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–
Personal support (when appliances are fixed)	○	○	○	○	○	–	–	–	–	–	–	–	–	–	○	–	–
Security																	
Control of access	–	–	–	–	–	–	–	–	–	–	–	○	○	○	●	–	–
Detection of intruders	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●	–	–
Presence simulation	○	○	○	–	–	–	○	○	○	○	○	○	○	–	○	–	○
Comfort																	
Control of HVAC	○	○	○	○	○	–	○	○	○	○	○	○	–	○	○	–	–
Control of lightning	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●		○
Control of motors (blinds and curtains)	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	–	○
Control of motors (doors and windows)	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Control of watering	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○
Energy management																	
Control and distribution of energy	–	–	–	–	–	–	–	–	–	–	–	–	–	–	●	–	–
Management of electrical domestic appliances	○	○	○	–	–	–	○	○	○	○	○	●	●	–	–	–	–
Management of water resources	–	–	–	●	●	●	–	–	–	–	–	○	○	–	–	–	–
Information and communication																	
Communications between system components	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Local networks and Internet	●	●	●	○	○	○	●	●	●	●	●	●	○	○	●	–	–
Leisure & entertainment																	
Home cinema	–	–	–	–	–	–	○	○	–	–	●	–	–	–	–	–	–
TV, audio and games consoles	●	●	●	○	○	–	●	●	○	●	●	○	–	–	–	–	–
Assistive technologies																	
	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Alarms																	
	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●	–	○
Interfaces																	
Fixed appliances	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	○	○
Mobile appliances	○	○	○	○	○	○	●	●	○	○	○	○	○	○	○	○	○

● Priority ○ Optional – Not needed

Table 40 – ICAT systems according to their location in the dwelling

LIVING ROOMS

ASPECTS COMMON TO LIVING AND DINING ROOMS, HOME OFFICE AND MEDIA ROOM: PRIORITY

- Local networks and Internet: Ethernet and broadband Internet sockets;
- Wall-mounted interfaces;
- Wired infrastructure;

ASPECTS COMMON TO LIVING AND DINING ROOMS, HOME OFFICE AND MEDIA ROOM: OPTIONAL

- Detection of intruders: motion detector, CTV camera, central alarm, magnetic sensor to detect when door/window is open;
- Presence simulation: control of lights.
- Control of HVAC: controlled by room thermostats, controlled by timer, "long absence" setting, presence detector; HVAC may be operated by wall-mounted switch or remote control;
- Control of lightning: controlled lighting appliances, controlled power sockets; presence detector, light detector; light appliances may be operated by wall-mounted switch or remote control;
- Control of motors (curtains/blinds): motor over the curtain/blind implying the replacement of the existing curtains/blinds; light detector, wind detector; motor operated by wall-mounted switch or remote control;
- Control of motors (doors and windows): motor over the door/window implying the replacement of the existing door/windows; motor operated by wall-mounted switch or remote control;
- Energy management: controlled power sockets;
- Assistive technologies (see *Part 2: Chapter 3.1.2*);
- Alarm signalling: operated from domotics controller (notified by sensors), or pendant (personal alarm/assistive technologies); sound or visual (flashing lights or signal displayed on TV) alarm signal;
- Mobile control interfaces.

ASPECTS SPECIFIC TO LIVING ROOM, MEDIA ROOM AND HOME OFFICE: PRIORITY

- Leisure and entertainment: TV screen, audio appliances.

ASPECTS SPECIFIC TO LIVING ROOM: OPTIONAL

- Leisure and entertainment: home cinema with projection screen, projector, amplifier, CD/DVD/Blu-ray player, surround sound and speakers; game console;

ASPECTS SPECIFIC TO MEDIA ROOM: PRIORITY

- Leisure and entertainment: home cinema with projection screen, projector, amplifier, CD/DVD/Blu-ray player, surround sound and speakers; game console;

BEDROOMS (DOUBLE, TWIN AND SINGLE)

PRIORITY

- Local networks and Internet: Ethernet and broadband Internet sockets;

- Leisure and entertainment: TV screen, audio appliances.
- Wall-mounted interfaces;
- Wired infrastructure;

Optional

- Safety: wall-mounted personal alarms;
- Detection of intruders: motion detector, CTV camera, central alarm, magnetic sensor to detect when door/window is open;
- Presence simulation: control of lights.
- Control of HVAC: controlled by room thermostats, controlled by timer, "long absence" setting, presence detector; HVAC may be operated by wall-mounted switch or remote control;
- Control of lightning: controlled lighting appliances, controlled power sockets; presence detector, light detector; light appliances may be operated by wall-mounted switch or remote control;
- Control of motors (curtains/blinds): motor over the curtain/blind implying the replacement of the existing curtains/blinds; light detector, wind detector; motor operated by wall-mounted switch or remote control;
- Control of motors (doors and windows): motor over the door/window implying the replacement of the existing door/windows; motor operated by wall-mounted switch or remote control;
- Energy management: controlled power sockets;
- Leisure and entertainment: TV screen, audio appliances.
- Assistive technologies (see *Part 2: Chapter 3.1.2*);
- Alarm signalling: operated from domotics controller (notified by sensors), or pendant (personal alarm/assistive technologies); sound or visual (flashing lights or signal displayed on TV) alarm signal;
- Mobile control interfaces.

Bathrooms

Priority

- Detection of flooding: water detector, central alarm;
- Safety: wall-mounted personal alarms (in the guest bathroom this item is optional);
- Energy and water management: mixer tap operated by IR sensors; water temperature regulated by temperature sensor and mixer valve;
- Wall-mounted interfaces;
- Wired infrastructure;

Optional

- Detection of intruders: motion detector, central alarm, magnetic sensor to detect when door/window is open;

- Control of HVAC: controlled by room thermostats, presence detector; extractor fan (works when lights are on and switches off X minutes after lights go off); HVAC may be operated by wall-mounted switch or remote control;
- Control of lightning: controlled lighting appliances, controlled power sockets; presence detector, light detector; lighting appliances may be operated by wall-mounted switch or remote control;
- Control of motors (curtains/blinds): motor over the curtain/blind implying the replacement of the existing curtains/blinds; motor operated by wall-mounted switch or remote control;
- Control of motors (doors and windows): motor over the door/window implying the replacement of the existing door/windows; motor operated by wall-mounted switch or remote control;
- Energy management: controlled power sockets;
- Local networks and Internet: Ethernet and Internet sockets;
- Leisure and entertainment: TV screen, audio appliances.
- Assistive technologies (see *Part 2: Chapter 3.1.2*);
- Alarm signalling: operated from domotics controller (notified by sensors), or pendant (personal alarm/assistive technologies); sound or visual (flashing lights or signal displayed on TV) alarm signal;
- Mobile control interfaces.

KITCHEN AND LAUNDRY

PRIORITY

- Detection of flooding: water detector, central alarm;
- Detection of fire: temperature detector; central alarm (except in laundry area);
- Detection of gas leaks: gas detector; central alarm;
- Energy management: controlled power sockets, electrical domestic appliances;
- Local networks and Internet: Ethernet and broadband Internet sockets (in the laundry area this requirement is optional);
- Wired infrastructure;
- Wall-mounted interfaces;

OPTIONAL

- Control of access: entry phone;
- Detection of intruders: motion detector, central alarm, magnetic sensor to detect when door/window is open;
- Presence simulation: control of lights.
- Control of HVAC: controlled by room thermostats, presence detector; extractor fan; HVAC may be operated by wall-mounted switch or remote control (except in the laundry area);
- Control of lightning: controlled lighting appliances, controlled power sockets; presence detector, light detector; lighting appliances may be operated by wall-mounted switch or remote control;

- Control of motors (curtains/blinds): motor over the curtain/blind implying the replacement of the existing curtains/blinds; light detector, wind detector; motor operated by wall-mounted switch or remote control;
- Control of motors (doors and windows): motor over the door/window implying the replacement of the existing door/windows; motor operated by wall-mounted switch or remote control;
- Energy and water management: sink mixer tap operated by IR sensors;
- Leisure and entertainment: TV screen, audio appliances (except in laundry area);
- Assistive technologies (see *Part 2: Chapter 3.1.2*);
- Alarm signalling: operated from domotics controller (notified by sensors), or pendant (personal alarm/assistive technologies); sound or visual (flashing lights or signal displayed on TV) alarm signal;
- Mobile control interfaces.

CIRCULATION AREAS

ASPECTS COMMON TO HALL AND CORRIDORS: PRIORITY

- Wall-mounted interfaces;
- Wired infrastructure;

ASPECTS COMMON TO HALL AND CORRIDORS: OPTIONAL

- Control of HVAC: controlled by room thermostats, controlled by timer, "long absence" position, presence detector; HVAC may be operated by wall-mounted switch or remote control;
- Control of lightning: controlled lighting appliances, controlled power sockets; presence detector, light detector; lighting appliances may be operated by wall-mounted switch or remote control;
- Control of motors (curtains/blinds): motor over the curtain/blind implying the replacement of the existing curtains/blinds; light detector, wind detector; motor operated by wall-mounted switch or remote control;
- Control of motors (doors and windows): motor over the door/window implying the replacement of the existing door/windows; motor operated by wall-mounted switch or remote control;
- Assistive technologies (see *Part 2: Chapter 3.1.2*);
- Mobile control interfaces.

ASPECTS SPECIFIC TO HALL: PRIORITY

- Detection of fire: smoke detector, temperature detector; central alarm;
- Control of access: entry phone;
- Detection of intruders: motion detector, CTV camera, central alarm, magnetic sensor to detect when door/window is open;
- Local networks and Internet: Ethernet and broadband Internet sockets;

- Alarm signalling: operated from domotics controller (notified by sensors), or pendant (personal alarm/assistive technologies); sound or visual (flashing lights or signal displayed on TV) alarm signal;
- Control of lightning: automated lighting controlled by movement sensors in hall – safe entry to home.

Aspects specific to hall: Optional

- Safety: wall-mounted personal alarms;
- Presence simulation: control of lights.

Aspects specific to corridors: Optional

- Local networks and Internet: Ethernet and Internet sockets;
- Alarm signalling: operated from domotics controller (notified by sensors), or pendant (personal alarm/assistive technologies); sound or visual (flashing lights or signal displayed on TV) alarm signal;

Alarm

As previously stated, in the basic ICAT pack local alarms use sound and the siren is located in the entrance hall. The type of alarm required may differ according to the different resident profiles, as shown in Figure 173, which establishes the sequence of decisions required in order to determine the type of local alarm to be used, in accordance with the resident profile.

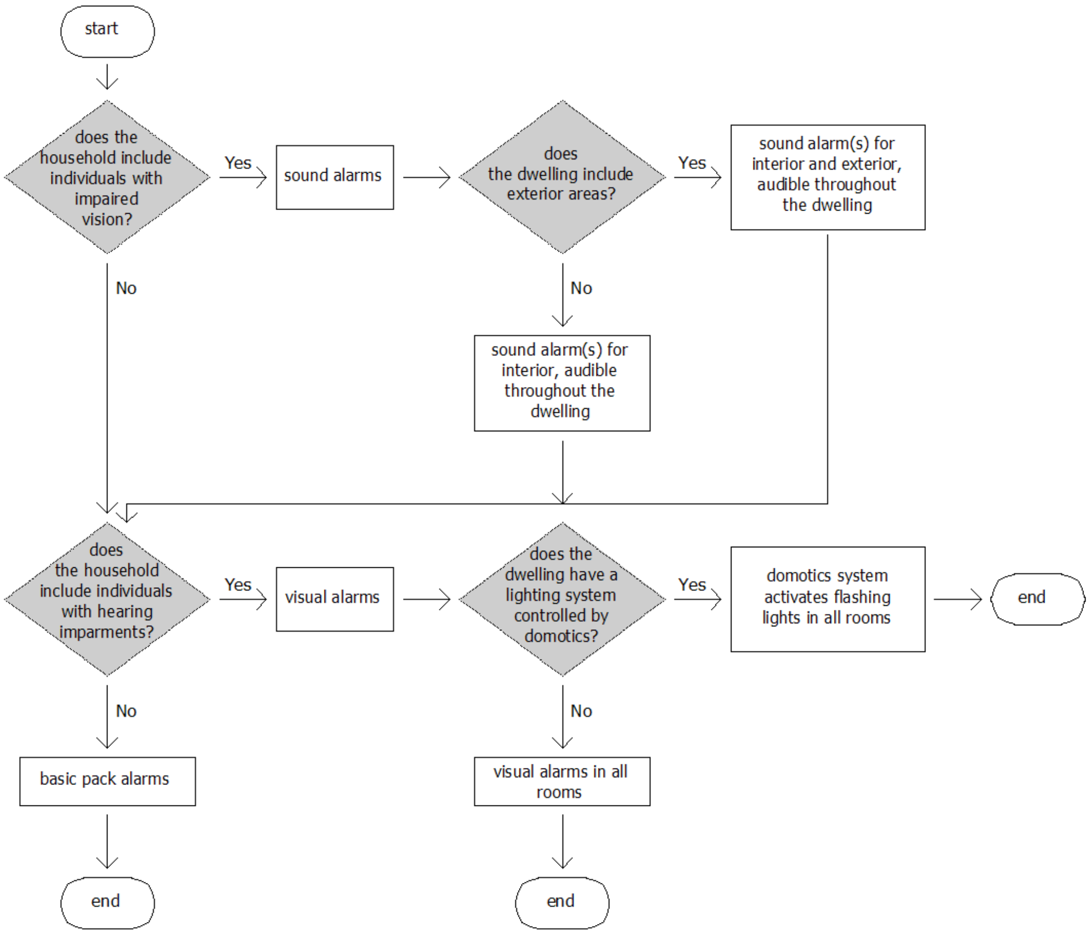

Figure 173 – Decision-making process for local alarms by household characteristics.

Detection of intruders

In addition to entrance hall(s), it may be necessary to install intrusion detectors in other locations in the dwelling in specific cases. Ground floor dwellings or those with balconies and/or windows bordering on neighbouring buildings a pose a risk of intrusion, and detection devices should be considered for other rooms in addition to the hall. Figure 174 establishes the decision-making process required to determine the need for movement detectors in other areas in addition to those which provide access to the dwelling entrance(s).

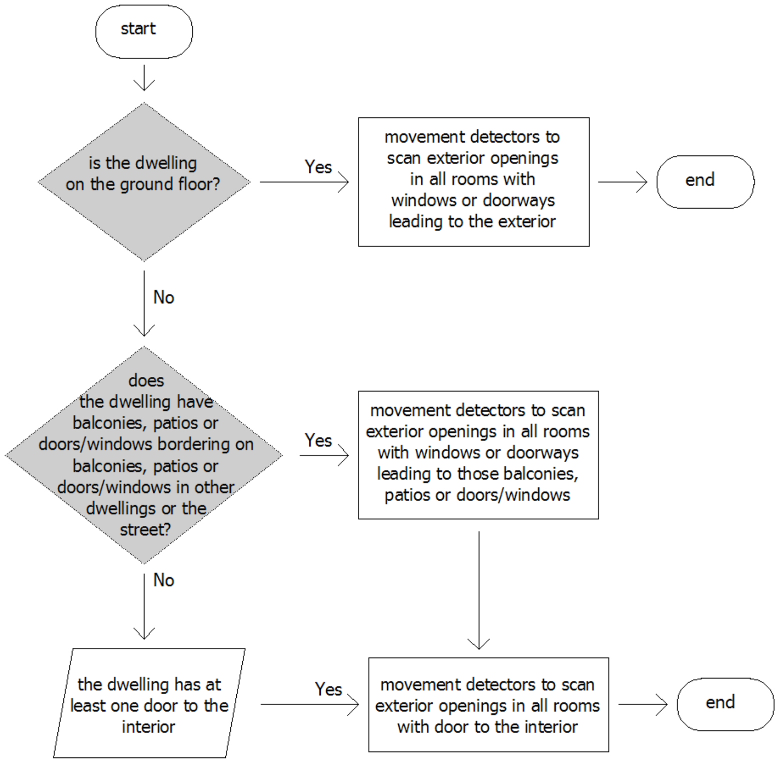

Figure 174 – Decision- making process for installing movement detectors in dwelling to detect intruders.

3.2.2 Construction strategies for ICAT installations in rehabilitated dwellings

Nowadays building services become outdated more quickly than the actual buildings due to the rapid development of new technology.

Buildings need to be upgraded with new ICAT infrastructures to increase functionality, reliability and efficiency and to improve use by adapting houses to meet new demands.

These goals can be achieved within different economic frameworks according to client demands. The decision to repair, add or replace components may depend on budget.

The presence of automation in the home creates a need for physical space to lay connecting cables between the components of the automation system. In addition to automation systems, the growing practice of working at home using ICT introduces various kinds of computer equipment, usually seen in office buildings, into the home. A high dependence on technology requires the presence of a series of domestic infrastructure for which architectural projects have not yet established a common criterion.

These requirements, combined with the trend towards flexibility and adaptability in living space, have led to the development of innovative construction solutions. From the large range of construction solutions, only those which enable ICAT to be used in rehabilitation work will be addressed here. They differ according to several factors, such as the desired level of ICAT integration, acceptable visual impact and the new layout proposed for the dwelling.

In order to provide flexibility and adaptability in dwellings, solutions are required for the installation of infrastructures that do not restrict adaptability. The location of technological components must be designed to allow for easy access and maintenance. For this purpose, components commonly used in office buildings, such as cable casings inside walls and floors, suspended ceilings and raised floors, allow for the upgrading and reconfiguration of the system as well as inspection and maintenance with minimal impact.

It is sometimes difficult to retrofit technical infrastructure components, including those required for communications and home automation, in existing dwellings and buildings since these buildings were often not designed to accommodate such extensive technology. Infrastructure distribution frequently causes problems which lead to architectural and constructional difficulties (Giebeler *et al.*, 2009: 29). For this reason it is strongly recommended that technical infrastructures are planned in advance, with the aid of specialists.

Figures 175 – telecommunications infrastructures mounted on facade. (photos: SE 2010)

Figures 176 – Left - Electric and telecommunications infrastructure in lobby. Right - Water pipe (surface mounted) and gas pipes (inside metal casing) in staircase after renovation. (photos: AC 2008)

Figures 177 – Left - Water and gas pipes embedded in staircase walls after renovation; Right - original. (photos: SE 2010)

The distribution networks for individual subsystems, e.g. the ICAT subsystem, must be ascertained. Distribution throughout the building may be horizontal, vertical, surface-mounted, concealed, via ducts or a combination of these arrangements. Inside the home, infrastructures can be concealed behind surface finishes, integrated into new construction elements or new prefabricated elements or even serve as "*intentional architecture featuring in order to define a new element* [that is] *clearly different from the existing* [one]" (Giebeler *et al.*, 2009: 29).

Renewing or adding building services such as ICAT installations by laying cables entails considerable intervention work on construction elements such as walls, floors, ceilings and surface finishes. Walls and ceilings are the recommended places for laying pipes and cables. Several options can be considered for this purpose and will be discussed in the following sections.

In small-scale rehabilitation work, the normal restrictions on laying cables may be overcome by using wireless networks to supplement the cable network. In fact, equipment that needs to be installed in the centre of rooms or in other inaccessible places can make use of wireless information transmission systems. However, it will always be necessary for the power supply to reach this equipment. Wireless equipment may be powered by batteries, which will need replacing roughly every six months to one year. Other types of equipment can be powered by photoelectric cells (creating their own energy from light) which allow for greater flexibility of location since they dispense the need to lay IT and power cables. Despite these possibilities, the use of dedicated cabling in dwellings is undoubtedly the best means of ensuring greater speed, reliability and resistance to electromagnetic fields.

In the residential buildings studied most of the facilities are located in chases cut into masonry walls or are embedded in floors. Vertical distribution is via cables embedded in walls and only in rare cases are vertical ducts installed exclusively for technical infrastructures.

COMMUNAL AREAS OF THE BUILDING

Any intervention work on communal areas of the building should be used as an opportunity to build new technical areas and ducts for cable and pipes as well as to renew (electric, water and gas) meters and electric service panels.

Since communal areas are narrow, the creation of a vertical duct implies using an area within the dwellings and therefore a reduction in their net floor area. It is proposed that ducts are installed with the minimal reduction of communal areas, using spaces in the dwellings if necessary to install upgraded meters.

We will now describe the three existing methods for cable and pipe distribution within "rabo-de--bacalhau" buildings, as well as their rehabilitation solutions and a fourth proposed distribution:

- **Cables mounted on the exterior facade**. These cables are mostly for telecommunications infrastructures (TV, telephone, Internet) (Figures 175).

  This is due to two reasons: most of the buildings did not have ICT infrastructures at the time when they were built, and these infra-structures were not added using integrated methods. This distribution method does not constitute a lasting solution but is a quick method of resolving infrastructure requirements. The exposed cables have a shorter life cycle and, in addition, the existence of unembedded sets of cables running along the facades spoils their appearance

  → The infrastructures must be distributed inside the building through: i) a new concealed vertical duct, ii) a new surface-mounted vertical duct near the communal stairs/elevator. Both hypotheses must provide access for maintenance purposes.

- **Cables running through the wall and floor on the stairs or elevator walls.** These infrastructures are for water, gas, electricity and, if it exists, telecommunications (Figures

177 right). At present, they are concealed inside walls but must be accessible for maintenance purposes. Care must be taken when renovating these networks to ensure that that the chases do not disrupt the original coating (Figures 177 left).

→ For maintenance purposes, wall penetrations can be covered with removable (e.g. screwed in) metal or plastic covers.

- **Cables surface-mounted on stair or elevator walls.** These infra-structures are for water, gas, electricity and telecommunications and are generally a result of infrastructure repair work. This solution has the disadvantage of using space in communal areas as well as obstructing people's movement. However, it does facilitate infrastructure maintenance (Figures 176).
- → **Cables and pipes running through a new vertical duct.** In the original buildings studied**,** this solution only exists in one case (a duct for ventilation and sewage pipes).

  This solution can only be implemented in major rehabilitation work that covers the entire building and it implies reinforcing building stability. The possible positions for the new duct are shown in *Part 2: Chapter 2.3.4*.

As previously stated, the most advisable solution for laying supply and evacuation infrastructure networks is through a duct system which allows for easy maintenance and upgrading. If possible, vertical ducts running throughout the building and accessible from the communal lobby on each floor via doors, is the most convenient way of distributing networks.

DWELLING WALLS

The existing buildings in the study have clay brick masonry internal walls. In the proposed transformation, sections of these walls are demolished and new walls constructed. Therefore, the new cabling must run through old and new walls and accommodate their differences.

Infrastructures can be installed in walls by laying pipes and cabling, as follows:

3. Using surface-mounted casing;
4. Concealed behind surface finishes
   a. Behind existing surface finishes in wall chases;
   b. Inside a metal frame or timber partition behind finished boards.
5. As intentional architectural featuring in order to define a new element that is clearly different from the existing one (Giebeler *et al.*, 2009: 54)

Figure 178 – Pipes and electrical, ICT and domotic cables inside a light construction wall system (frames and gypsum board). (photo: SE 2002)

Figure 179 – Multi-compartment casing system for electricity and IC cables. Glastonbury House, London (photo: SE 2004)

Figure 180 – New lightweight wall parallel to existing wall in order to provide space for cabling and piping. Glastonbury House, London (photo:SE 2004)

As previously stated (see *Part 2: Chapter 2.2)* the recommended construction system for new walls is lightweight partitions, partly prefabricated, with an inner metal or timber frame and finished boards on the outside. This solution is ideal for ensuring access to the installation and therefore maintenance and upgrading. The system allows cable casing to be fixed to the frame (for electrical, ICT and domotic elements) and laid inside walls to provide easy access. The remaining interior wall space is filled with acoustic insulation material. Once all the cables have been fitted, the frames are clad with gypsum-based boards or boards made from other materials (Figure 178, Figure 180 and Figure 181).

In residential buildings, the most commonly-used panels are plasterboard. Although they are light and easy to take down they are as not instantly removable as pre-fabricated removable panels, for example, which are screwed or clipped into place. However it is very simple and quick to open a hole in the plasterboard for repairs, which makes this a good choice in terms of the maintenance and upgrading of the cabling inside.

Using detachable skirting boards makes it easier to maintain and upgrade the network with extra cabling, add extra power or internet sockets or even move a cable nearer to the ceiling. Detachable moulding panels enable more sensors or other automation equipment to be installed (Figure 181).

There are several ways of laying cables and pipes in existing masonry walls: using wall penetration or surface-mounting with prefabricated standardised components.

Wall penetration can be used to lay cables or pipes but detachable panels are recommended to cover the chases. Painted plaster finishes are not detachable, which implies brickwork every time the cables are changed. Chases can be opened at skirting level or near the ceiling, and a finished panel therefore works well (Figure 182, right-hand hypothesis).

Service enclosure profiles provide a versatile and practical solution to the problems of concealing unsightly pipe work, electrical, ICT and domotic cabling.

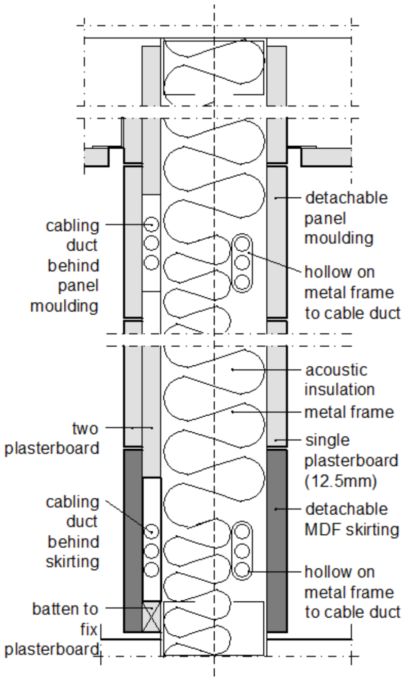

Figure 181 – Hypothesis for laying cables in a new wall to ensure easy maintenance and upgrading

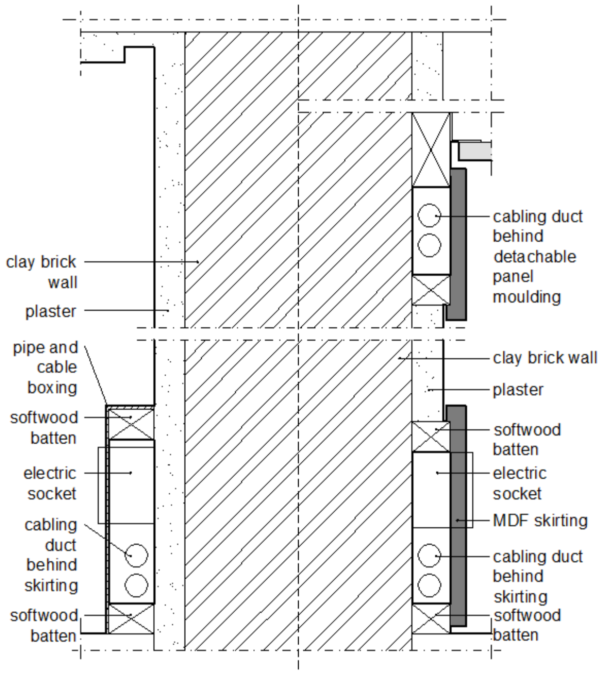

Figure 182 – Hypothesis for laying cables in an existing clay brick wall to ensure easy maintenance and upgrading

These casing systems can be mounted at skirting level or at ceiling level. Components such as multi-compartment casing systems for cable distribution are quicker to install on-site. If the aim is to avoid brickwork in existing walls, the perimeter services would not be totally disguised or hidden but this can be partly accomplished by using detachable skirting boards or detachable moulding at ceiling level (Figure 179 and Figure 182, left side hypothesis).

Vertical connections between cables at skirting and ceiling level (behind moulding panels or above suspended ceilings) may either be concealed behind a door frame or covering panel or in chases cut into the plaster.

Dwelling Ceilings

As previously mentioned, suspended ceilings are used primarily to provide a service void between the surface of the ceiling and the underside of the structural slab above it. This void, also called the plenum space, may be used for laying cables and pipes (Figure 184 and Figure 185) or even for HVAC air return.

A typical suspended ceiling consists of a grid-work of metal channels in the shape of an upside-down "T", suspended on wires from the overhead structure. These channels snap together in a regularly spaced pattern according to the material to be suspended.

There are two major types of suspended ceiling panels: panels or tiles that fit into the grid and are simply dropped into place, and panels that are screwed into place from underneath the grid frame. Tiles can be selected from a variety of materials, including wood, metal, plastic, or mineral fibres, and come in almost any colour. Plasterboard panels are the most commonly-used type in residential spaces.

The advantages of suspended ceilings are that they create a concealed space for cables and pipes, they can be easily removed to access the plenum, greatly simplifying repairs or alterations, and they provide acoustic insulation.

However, as with walls, access to the plenum will require opening holes in the plasterboard. The alternative is to build access hatches but these are difficult to conceal and often not very well integrated (Figure 183).

Space is required between the grid and any pipes or ductwork above it for ceiling panels and light fixtures. Cables and pipes are often fixed to the upper slab or walls.

Figure 183 – Access hatch in plasterboard suspended ceiling in rehabilitated dwelling (photo: AC 2008)

Figure 184 – Suspended ceiling in rehabilitated dwelling hiding extraction tube and beam. (photo: AC 2008)

Figure 185 – Suspended ceiling in rehabilitated dwelling hiding cables (photo: AC 2008)

Dwelling Floors

The use of under-floor infrastructures creates more flexibility in the use of space, as it allows for cable and pipe network distribution regardless of whether partition walls exist.

Infrastructures can be installed in floors by laying pipes and cabling, facilitating access for future maintenance, as follows:

1. By concealing them beneath surface finishes in floor penetrations.
    a. Concealed in ducts
    b. Concealed inside screed
2. By laying them below raised floors.

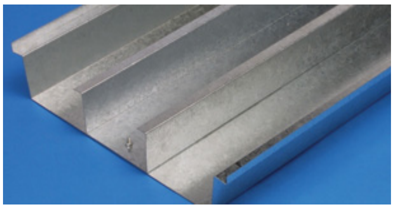


Figure 186 – Screed under-floor ducting. The pre-formed tray is produced from galvanised mild steel and a 12mm plywood cover. (source: http://www.pendock.co.uk/)

Figure 187 – Under-floor duct. (source: http://www.monosystems.com/)

Figure 188 – Trench duct system. Designed for a single run or an entire grid of duct. (source: http://www.monosystems.com/)

Figure 189 – Cables that will be concealed inside screed (photo:AC 2008)

Laying cables using floor penetration is advantageous but difficult for two major reasons: the space between the top of the slab and the finish is very narrow and the concrete slabs are thin and have no inner space for cables. Nevertheless, under-floor cabling and plumbing is a good solution when space is limited or interior walls do not exist or cannot be used for laying cables and pipes.

Concealing tubes and pipes inside screed is a common measure (Figure 189) but prevents direct access to the infrastructure and therefore makes maintenance and upgrading difficult. If pipes leak or cables are damaged, the floor finishes have to be removed and the screed destroyed in order to repair the infrastructure.

Under-floor ducts are usually installed to allow for maintenance. However some of these systems have the disadvantages of consuming a lot of space and being more expensive then the equivalent wall solutions. In addition, the ducts would have to have visible and accessible covers to allow for maintenance. This would mean that the duct covers were different from the floor finishes or would have to be custom-made to match certain finishes.

Several under-floor components can be embedded beneath finishes. Screed under-floor ducting is a two-part system comprising a pre-formed tray that can be fixed to the surface of the sub-floor before screeding, and a cover. Return flanges provide recessed support for the covers and are laid flush to the rest of the floor. The covers can be visible and lie flush to the finished floor or can be hidden and lie flush to the screed. In the latter case a floor finish can be laid over the tray cover to hide it.

Other under-floor ducts comprise trays and covers with different shapes and covering systems, such as the ones illustrated in Figure 186, Figure 187 and Figure 188.

Raised floors[66] are usually used in office buildings with a high service requirement for cables, wiring, electricity, air conditioning or chilled water pipes. This type of floor consists of a gridded metal framework or understructure with adjustable legs (called "pedestals") that provide support for individual floor panels (usually 60×60cm in size). The height of the pedestals is dictated by the volume of services provided beneath, but typically provides a clearance of at least 15cm. The raised floor area is used as either a supplement or an alternative to suspended ceilings.

In housing rehabilitation this system is often impracticable because it is extremely difficult to provide this clearance. Although ceilings are usually high (about 2.8m) the space between the top of the slab and the finish is very small. The use of a raised floor would therefore imply the need for a step inside the dwelling.

3.3 CURRENT RESEARCH AND FUTURE HOME AUTOMATION IMPLEMENTATIONS

The existence of domotics currently affects real estate values. Nevertheless, real smart homes that are well connected, integrated and offer all the appropriate applications are limited to demonstration houses so far. Home automation has been implemented in thousands of houses worldwide, but is still in its infancy due to several economic, social-cultural and technical factors. One of the key factors influencing further introduction of intelligent devices is broadband and wireless Internet access (Bierhoff and Berlo, 2007: 66). According to these authors, by using this form of access to the electronic highway houses will become smart by themselves, networking all devices and equipment in order to achieve maximum benefit and enjoyment.

The areas currently being researched internationally and which indicate the future paths for domotics are essentially:

- Full integration of systems;
- Technologies compatible with consumer electronics;
- Human-centric computer interaction: ubiquitous computing and ambient intelligence;

The compatibility of the technologies used in consumer electronics – in items such as fridges, washing machines, driers, and audio and video systems – with computer or air conditioning systems is one of the factors which will consolidate the application of home automation.

Compatible technologies will mean that the way in which the domotics system controls equipment will not be limited to a simple on/off or stand-by command but will be extended to access to all electronic equipment functions.

According to Buley (2003: 30), if home devices with embedded microchips (such as alarm clocks, microwave ovens, TV remote controls, the stereo and TV system and even children's toys) were manufactured with wireless connectivity they could be networked together and linked to the Internet.

In addition, ubiquitous computing and ambient intelligence is regarded as being the next generation of computing. The goal is to develop machines that fit the human environment instead of forcing humans to accommodate to their environment. This means that future digital environments will be sensitive and responsive to people (Van Houten, 2006). In this scenario, electronic devices will be integrated into almost everything, including soft and pliable items such as furniture, curtains or clothes. These devices will be *embedded* (mainly in an invisible or unobtrusive way) and will be *context aware* (understand their situational state), *personalised* (to respond to specific user needs), *adaptative* (able to learn) and *anticipatory* (anticipating the need for input by commands) (Van Houten, 2006:12).

As an example, a domestic ubiquitous computing environment might interconnect lighting and environmental controls to personal biometric monitors woven into clothing so that the lighting and heating conditions in a room can be modulated continuously and imperceptibly[67]. An example of adaptative advertising can be seen in the film Minority Report when the character, identified via retinal scans, sees advertisements on public walls chosen to reflect his preferences.

Within the home, the mouse, keyboard, switches and remote controls are beginning to be replaced by commands via voice recognition and motion, as well as eye tracking, and face recognition. This suggests that the "natural" interaction paradigm appropriate to a fully robust ubiquitous computing has yet to emerge.

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[64] **SACKMANN, R.; WEYMANN, A.** (1994): *Die Technisierung des Alltags: Generationen und technische Innovationen*. Bremen: BMFT. Cit. by **RAMA, M. Docampo** (2001): *Technology generations handling complex user interfaces*. Eindhoven: Technische Universiteit Eindhoven.

[65] As an example, in British standards cables concealed in a wall or partition at a depth of 50 mm or less from the surface should be installed in a "protected zone" as follows: within 150mm from the top of the wall or partition; within 150mm of an angle formed by two adjacent walls or partitions; run either horizontally or vertically to an accessory or switchgear on the wall or partition. In BS 7671: 2001 (AMD No 2: 2004) "Requirements for electrical installations". This standard concerns the safety of electrical wiring in buildings (dwellings, commercial, industrial or otherwise).

[66] Available at WWW <URL: http://en.wikipedia.org/wiki/Raised_floor> (accessed in Feb 2010)

[67] Example from the entry "Ubiquous computing" (Wikipedia)

4 TRANSFORMATION GRAMMAR

In this section Shape Grammar theories, addressed in *Part 2: Chapter 1.3.2*, will be used to develop a process for transforming dwellings based on specific rules. The proposed grammar will be called a transformation grammar, as it aims to transform dwellings to adapt them to contemporary user needs. Within this context, the concept of transformations in design explored by Terry Knight in her study on stylistic changes in different periods in the work of artists such as the De Stijl work of Georges Vantongerloo and Fritz Glarner or the work of Frank Lloyd Wright is used as a starting point (Knight, 1989) (Knight, 1994b). In this study Knight presents a process for describing stylistic alterations based on the concept of shape grammars. Knight states that in each phase of a painting produced by an artist it is possible to define a shape grammar and that for *n* different phases in the work of the same artist it is possible to define *n* different grammars (see Grammar 1 and Grammar 2 in Figure 190). The relationship between these different phases may be described by transformation operations which change one phase into another. These operations include eliminating, adding and altering rules. According to Knight, the grammars in each phase are the basis for the creation of particular shapes within a phase, and the rules are transformed between different phases. It is proposed here to call the work by Knight the *Meta* transformation grammar (Figure 190).

This work, however, proposes a different approach, in that it aims not to understand how rules evolve from a original "rabo-de-bacalhau" grammar through an adapted "rabo-de-bacalhau" grammar but the principles and rules that enable original dwellings to be adapted to new design that meet new lifestyles.

Also work done by Colakoglu (2005) explores a grammar that induces a type of transformation since it includes both the rules for generating traditional Hayat houses and the rules that enable the generation of these type of houses but conforming to a contemporary context. Again, this work does not aim to infere rules from the original dwelling layouts neither rules to design new contemporary adapted "rabo-de-bacalhau" dwellings but to transform the original dwellings into new ones.

Two different aspects are highlighted in this chapter: the transformation grammar and the process of inferring the transformation rules.

The transformation grammar enables one specific dwelling to be transformed into another by applying transformation rules and rather than generation rules as in a traditional shape grammar. In this grammar there is no predefined initial shape but there are countless possibilities since the initial shape is the floor plan of the existing dwelling, which can have many specific and complex shapes. This makes the proposed grammar a transformation grammar and not an original or analytical grammar.

With regard to the process of inferring the transformation rules, as schematised in Figure 190, these rules were not inferred from the generation of the original or the adapted dwellings. The rules of the transformation grammar were inferred from the process of transforming the dwellings as carried out by several architects (experts) who acted as experimental subjects in a procedure similar to the one used in expert systems (see the experiments undertaken in *Part2: Chapter 1.4*). These experiments are referred to as Style 1, Style 2 and Style 3 (and more) in Figure 190.

Figure 190 shows the main differences between what is called the *Meta* transformation grammar by Knight and the transformation grammar proposed in this thesis.

One of the goals of this research is to define a housing rehabilitation methodology. To achieve this goal it is first necessary to determine the functional programmes and ICAT packs for specific family profiles and, secondly, carry out the rehabilitation work by adapting the programmes to the existing building and vice-versa. As previously stated, these tasks can be performed as a standalone process or be systematised within a general rehabilitation methodology (Figure 191).

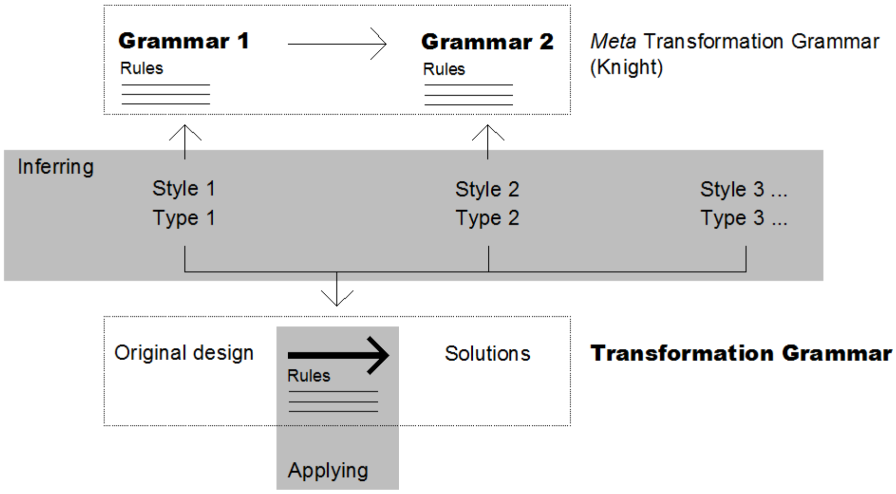


Figure 190 – Diagram illustrating the difference between standard Shape Grammars and Transformation Shape Grammars.

However, the use of a specific case study allows the methodology to be extended further. By using a specific building type, a transformation grammar can be developed for this particular building type, therefore producing a specific methodology for "rabo-de-bacalhau" rehabilitation (Figure 191).

The use of a shape grammar enables existing houses to be transformed in a very precise and systematic way. This process was used to manage shape transformation within dwellings to create a systematic and methodical process that could encompass all the valid transformation rules for a given dwelling. The transformations respond to functional and technical requirements as well as constructional requirements.

Although shape grammar was used to produce the transformation, there are, in fact, several ways of managing the architectural rehabilitation process. The traditional architectural process of planning and designing rehabilitation work relies on the architect's knowledge and proceeds by exploration, using the project programme, the existing building and their combined constraints. To these elements, architects add the human capacity of continuous adaptation and the ability to return repeatedly to the beginning of the process. Although rehabilitation processes can be executed on an individual case basis for each family/dwelling combination, defining a methodology to support the process clarifies decision-making and speeds up the design process.

This research explores a method which seeks to encode both the architect's knowledge and the knowledge acquired from other experiences of rehabilitation work in the form of rules. These rules are used to transform dwellings and incorporate substance and knowledge and are assumed to represent the architect's knowledge from a wider perspective. However, although vast, the grammar knowledge itself is limited to the data entered into the knowledge database.

The amount of variables required to incorporate all the possibilities in any given case of rehabilitation work is considerably greater than that which is required for a new building project. On the one hand, countless questions have already been defined *a priori* and there is no intention or possibility of changing them. In addition, it should be recognised that a well-defined morphology exists, based on a construction system which, following the principle of economic sustainability, allows little scope for change and would appear to permit only limited intervention work, subject to many restrictions.

Matters which are defined in advance include solar orientation, load bearing structure, the principal morphology of the building and aesthetic issues. Although not covered in detail in this thesis, questions such as fire safety and energy efficiency, amongst others, can also be integrated into a transformation grammar. In this case, the (shape and condition) rules would increase considerably.

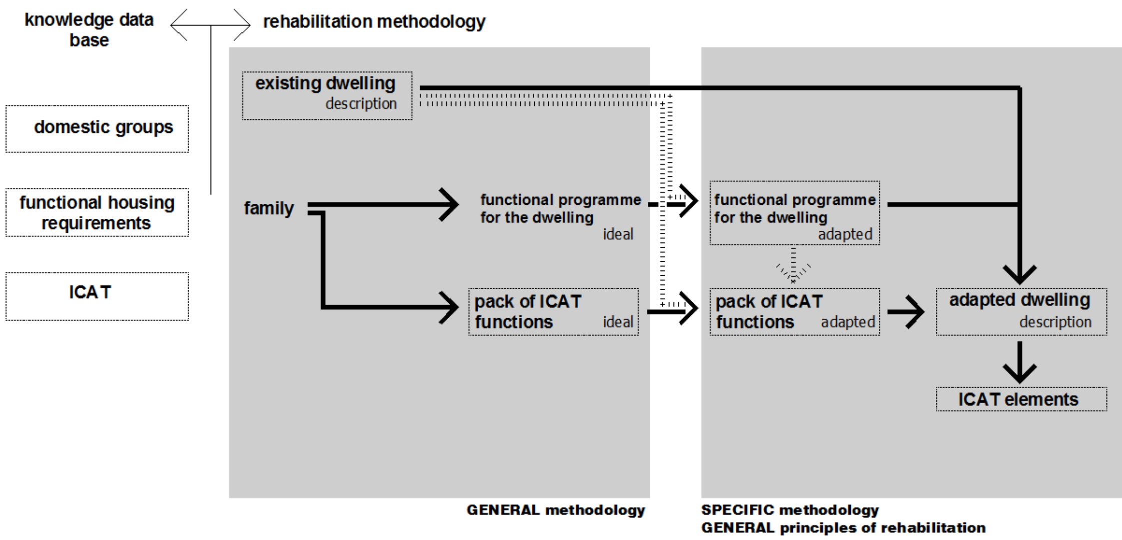


Figure 191 – General and specific rehabilitation methodology

Instead of just generating new shapes, as in a traditional shape grammar, a transformation grammar enables an existing design to be transformed into a new one that matches given requirements, using knowledge that relates family profiles to functional programmes and ICAT packs.

The proposed methodology seeks to produce rehabilitated designs that are "legal projects" because they are in the transformation language and "adequate projects" because they satisfy the *a priori* set of user requirements. (Duarte, 2007: 330) According to Duarte, a grammar applied to an architectural problem must satisfy two functions: it must create or transform an object within a specific language and it must create objects that satisfy requirements stated at the outset. As such, the grammar is structured as a discursive grammar, which includes a shape aspect and a descriptive aspect that evolve in parallel to guarantee that an appropriate dwelling design can be obtained from the description contained in the functional programme for the dwelling. However, unlike Duarte, our goal in developing and applying the transformation grammar is not to generate new dwellings using the same language as the existing ones. Instead, the aim is to understand the existing dwellings and new user requirements prompted by the use of technologies in order to devise transformation principles for adapting existing dwellings to meet these new requirements.

Although a Shape Grammar was not developed for the original "rabo-de-bacalhau" buildings as part of this study, a functional, constructional and social characterisation of the dwellings was produced. The functional and social characterisation provided an understanding of the logic of the spatial-functional organisation of the dwellings and the social reason for their existence, whilst the constructional characterisation allowed the constructional constraints affecting rehabilitation work on the buildings to be understood. Within the constructional context of the buildings and in the light of current concepts of rehabilitation work, the aim was for the proposed rehabilitation to follow the original language and not be too intrusive, essentially from a constructional point of view.

In order to verify the functional suitability of the original dwellings and the rehabilitation proposals, it was first necessary to determine the fundamental performance criteria by which housing spaces fulfil functional requirements, and then to find a formalism that could be used to analyse spatial configurations from this perspective. The first task was based on Pedro's work (2000), whilst space syntax was used for the functional analysis of spatial configurations (see *Part 2: Chapter 1.3.3*). The transformation grammar clarifies the principles behind the adaptation of the dwellings, such as making circulation more fluid by removing doors in hallways or enlarging social areas by connecting adjacent rooms. The grammar also encodes principles related to constructional constraints, such as avoiding the removal of concrete columns or other structural elements.

This chapter defines the rules and spatial relationships that enable an existing building to be transformed. It also presents the way in which the rules were altered during the process of developing the grammar until the final result was clear, unequivocal and fulfilled the objectives of the project. The aim of the transformation experiments described in *Part 2: Chapter 1.4* was to discover whether it was possible, during the rehabilitation process, to extract a set of rules or common principles that would allow a sequence of actions to be created which could later be systematised and applied to all rehabilitation work on "rabo-de-bacalhau" buildings.

4.1 IMPLEMENTATION OF THE TRANSFORMATION GRAMMAR

The mechanism used to generate solutions based on the proposed transformation grammar is to a certain extent, similar to an expert system because it uses the knowledge of an expert to the problem field and, by using a particular methodology, provides a solution.

Expert systems are used to simulate intelligent human processes for gathering, planning, rationalising and representing knowledge and to reproduce this in the form of computer-based representations. The aim of creating an expert system is to produce, by rationalisation and logical proposals, a representation of knowledge, demand, reasoning and problem solving. From this perspective an expert system lies at the core of the transformation grammar. The proposed transformation grammar is similar to a spatial and formal expert system because instead of just codifying the expert knowledge in rules using symbols, the transformation grammar also uses shapes.

The aim of using the transformation grammar model is to generate transformations based on a language composed of rules derived from the intervention criteria for the existing housing spaces defined by experts, as in an expert system.

The transformation grammar has a conditional part in addition to a shape part, which covers knowledge in terms of the dimensions and the functionality of the dwelling areas. This conditional part was firstly developed by using natural language (IF… Then conditions or tables and charts) and secondly by using a mathematical language that forms a descriptive grammar. These descriptions reveal certain characteristics that cannot be described in shapes.

As in an expert system, in its initial stage the knowledge contained in the conditional part of the rules could be informed by trees, flow diagrams and/or decision-making tables and operated manually. In this study the first phase of systematising the transformation principles and rules was carried out using tables, flow diagrams and text (see *Part 2: Chapter 2* and *Chapter 3*) and certain descriptive rules were produced to assess feasibility (see *Part 2: Chapter 4.3*).

On a more efficient level, the transformation grammar may be computerised and in this case will consist of a program that processes the data to generate a more rapid solution to a given problem.

Research into computerised grammar interpreters has developed substantially in recent years, but a great deal of ground still needs to be covered in order "to make an impact on industry methods using grammar based approaches" (Chase, 2010). The goal of creating a shape grammar interpreter is to make conceptual design tools that support designers' ways of thinking and working and enhance creativity, e.g. by offering design alternatives that would be difficult or impossible to produce without the use of such tools (Chase, 2010). According to Tapia (1999) it should be easier to use a program to try out shape grammars than it is to test them by hand.

Amongst the existing interpreters, the following should be highlighted since they are closest to the focus of this study: MALAG for the Malagueira grammar (Duarte and Correia, 2006), (Correia *et al.*, 2010); the interpreter for the Yingzao fashi grammar by Li (2001); the interpreter for the Queen Anne houses grammar by Flemming (1987); and other general interpreters such as those produced by Trescak *et al.* (2009) (2010) and Mark Tapia's (1999) GEdit.

Within the context of this thesis, a manually operated grammar is proposed, with the intention that it could subsequently be computerised in order to speed up rehabilitation procedures for the study universe analysed.

During the course of the experiments undertaken and described in *Part 2: Chapter 1.4* and specifically in Steps 2 and 3, it was evident that as the definition and details of the rules increased, it also became more complex to use them manually. In Step 2, although the grammar rules were essentially written in everyday language, the process of assimilating them proved lengthy and fallible for the individuals involved in the experiment.

The rules presented in Step 3 were already in the form of grammar rules (including a shape part and a conditional part) albeit simplified, and understanding the content of the conditions proved very time-consuming. This led to the conclusion that using the rules manually as described in this thesis would involve a lengthy learning process.

The creation of an interpreter for this transformation grammar would simplify the process and allow for a more flexible and faster manipulation of shapes, providing the user with complete control over the process of generating the grammar.

4.2 ELEMENTS OF THE GRAMMAR

The proposed grammar is a compound grammar defined in three algebras: i) the algebra *U02* and *U12* in which points and lines are combined on a plane supports the graph definition, ii) the algebra *U12,* in which lines are combined on a plane supports the plan definition, iii) the algebra *U22* in which planar surfaces are combined on a plane supports the spatial void definition (Figure 192) (see *Part 2: Chapter 4.2.1*). An algebra U_{ij} contains shapes which are a set of basic elements. These elements are points, lines, planes or solids that are defined in dimension i = 0, 1, 2 or 3, and combined in dimension $j \geq i$. (Stiny, 1992: 413)

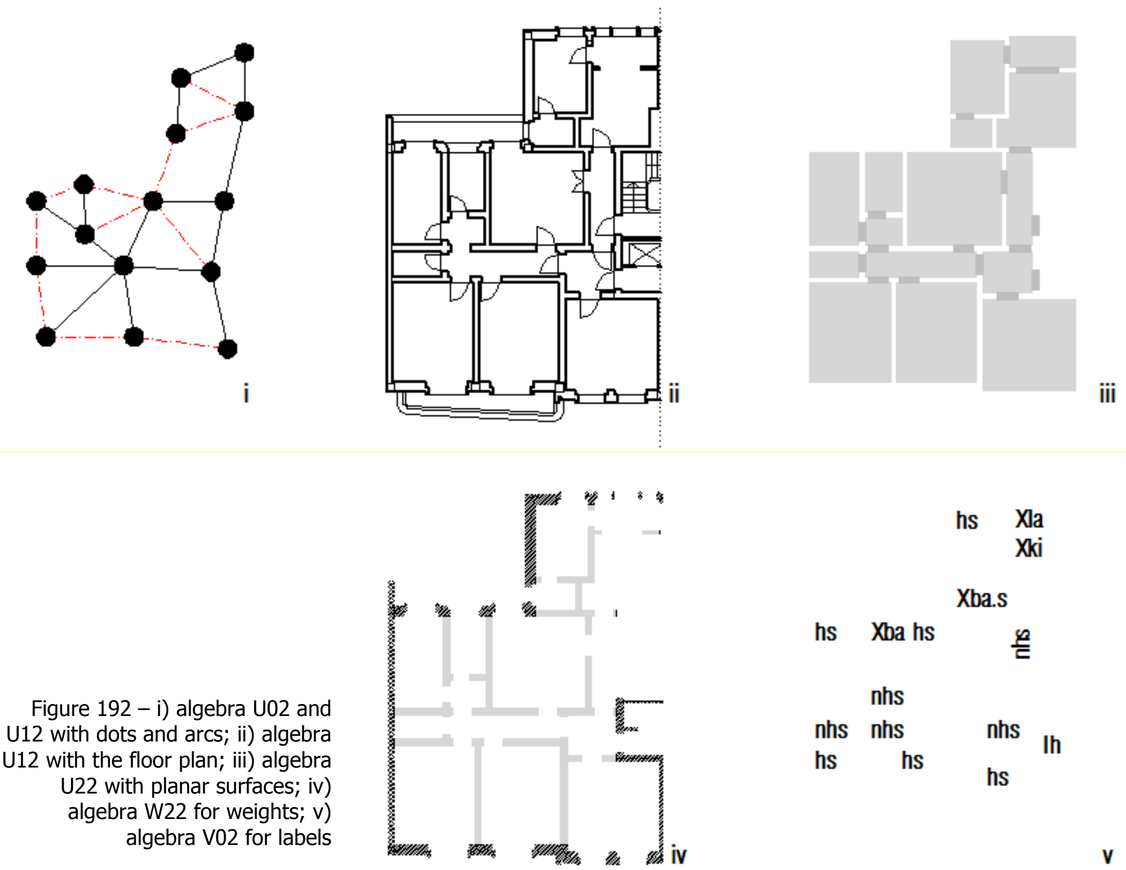


Figure 192 – i) algebra U02 and U12 with dots and arcs; ii) algebra U12 with the floor plan; iii) algebra U22 with planar surfaces; iv) algebra W22 for weights; v) algebra V02 for labels

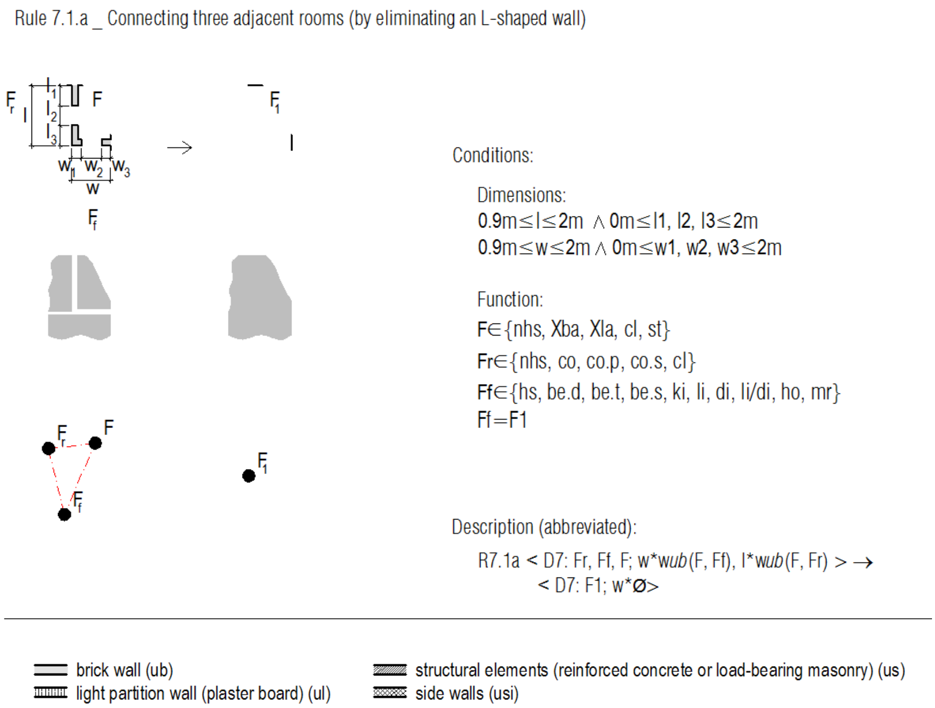


Figure 193 – Example of a rule for connecting two adjacent spaces by demolition of walls. The shape part is shown on the left (compound representation using partial floor plan with weights *U12* and *W22*, convex spaces *U22*, graph *U02* and *U12* and labels *V02*) and the conditional and descriptive parts are shown on the right.

These algebras are combined with labels in the algebra *V02* and weights in the algebra *W22* which will be explained in the following chapters *4.2.2* and *4.2.3* (Figure 192, iv) and v)).

Figure 193 shows a shape rule that includes a shape part defining the dwelling plans (with shape, labels, and weights – *S, L, W*), a conditional part controlling the functional and dimensional aspects, and a descriptive part (in an abbreviated form as explained in *Part 2: Chapter 0*) describing the characteristics of rules that cannot be defined by shapes.

In the initial version of the grammar certain rules, such as the one shown in Figure 194, were defined by a generic shape that was shared with other rules whose conditions or descriptions could change. After revising the grammar several times, the decision was made to combine the various rules into one single rule with various functional and dimensional conditions that would enable it to be applied to different situations and during different stages of the derivation.

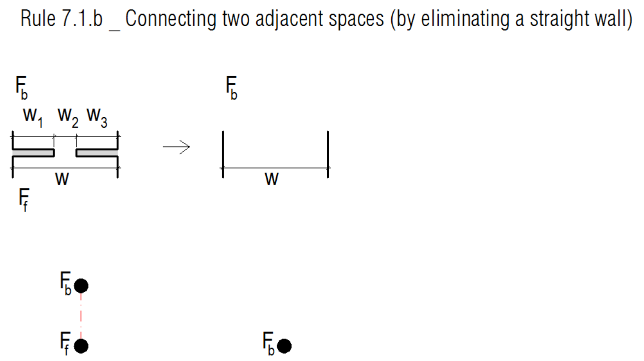


Figure 194 – Example of a rule for connecting two adjacent spaces by total demolition of walls. Only the shape part (partial floor plan and graph) is shown in this image.

4.2.1 Shapes: points, lines, surfaces and volumes

A building, a dwelling, or any other kind of construction is defined by its solid mass (e.g. walls, floors, ceilings) and spatial voids (e.g. spaces and rooms). Conventional representations of architecture use lines to represent the boundary between solid masses and spatial voids, in 2D drawings (Figure 195 *a* and *b*) or 3D models (Figure 196 *a*). These representations are abstractions of the real objects.

Another more abstract way of representing architectural space is by means of a graph when the exact shape is not of ultimate importance. In a graph, (Figure 195 *d* and *e*, Figure 196 *c*) the spatial void is represented by a node that connects to other nodes by vectors that are called arcs and represent spatial connections (doors, passages and windows.) In a graph, a spatial void can be represented as a convex spatial void, which means that if a room has *n* different convex spaces, it will be represented with *n* different nodes.

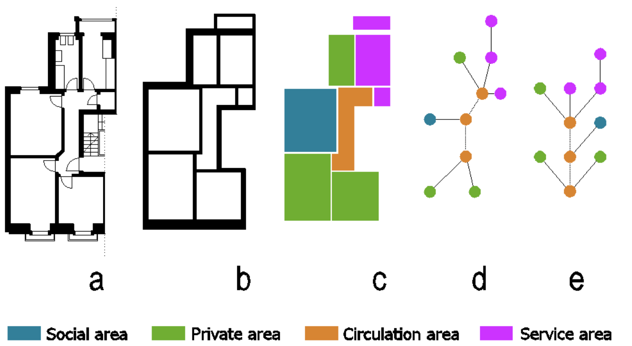


Figure 195 – Different ways of representing a dwelling in 2D: a) traditional floor plan; b) set of solid masses; c) set of spatial voids; d) graph or convex map; and e) justified graph. These representations use points, lines, and surfaces.

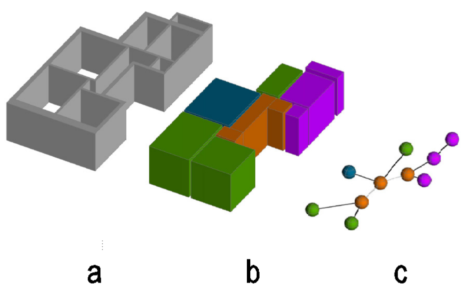


Figure 196 – Different ways of representing a dwelling in 3D: set of solid mass, set of spatial voids, and graph.

Different ways of representing dwellings and the transformation rules of the proposed rehabilitation methodology were considered for the current research. The decision regarding which ones to use depended on the architectural elements manipulated in the transformations.

The essential elements are walls, doors, and ceilings. Space use (function) was a fundamental attribute of void shapes. In other words, regardless of the architectural representation chosen for the material elements, spaces had an underlying functional meaning, shown in Figure 195 c, d and e, which also had to be included in the representation.

Different forms were established for representing the transformation rules, as shown in Figure 197.

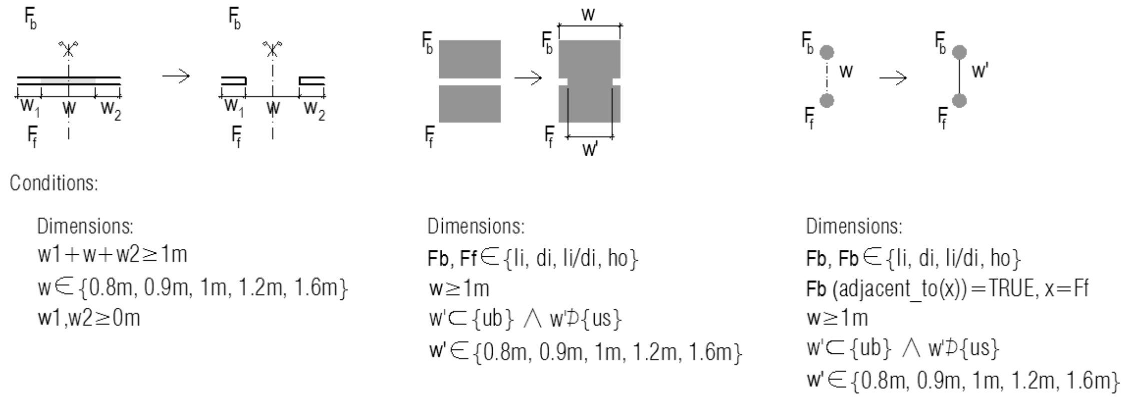


Figure 197 – Different ways of representing rules: left - using lines (walls); middle - planar surfaces (rooms); right - nodes (abstraction of rooms) and arcs (connections) forming graphs. The functional conditions are not shown as they are the same in each of the three hypotheses.

In this context, three forms of representation were explored:

a) Defining rules with lines representing the boundaries between solid masses and spatial voids (walls and openings - doors and windows) in 2D drawings. This representation allowed us: i) to assign functional meanings to elements; ii) to focus on particular elements (walls and openings) abstracted from the shape of the spaces; and iii) to focus on adjacency relationships between different spaces (Figure 195 *a* and Figure 197, left);

b) Defining rules with surfaces that represent spatial voids and their functional meaning. This option enables us to see the functional meaning of space and shows the adjacency relationships between different rooms. This representation forces us to use the entire spatial void as an element (Figure 195 *c* and Figure 197, middle);

c) Defining rules with justified graphs in which nodes have a functional meaning. This is the most abstract way of representing reality and it limits the possibility of understanding adjacencies, which is extremely relevant in rehabilitation processes. However, at this level of abstraction it is possible to clearly identify the position of a space in the house and characterise its presence, for instance in terms of integration and accessibility (Figure 195 *e* and Figure 197, right);

As they were more advantageous to the intended transformation grammar, it was decided to incorporate all the three representations in the transformation rules.

In addition to the floor plans justified graphs were used to supplement the description and evaluate spatial properties (see *Part 2: Chapter 4.2.4*) and surfaces to represent spatial voids when the space itself was relevant and not its boundary (e.g. surfaces for bedrooms, bathrooms, etc.). These three types of representation are used as a compound grammar to manipulate complex problems in the transformation rules (e.g. area, existence of windows, shape, among others).

With regard to spatial voids, two representations were used: i) a parametric shape to create correspondence between the geometries of the different rooms within the dwellings studied; ii) a subshape of the parametric shape when the significant aspect was a room with a certain function assigned rather than its shape (Figure 198).

Graphs (arcs and nodes) were used as a third representation which, in comparison with the other two, focuses on spaces and their relationships (connections via doors, via passages or adjacency) (Figure 197, right).

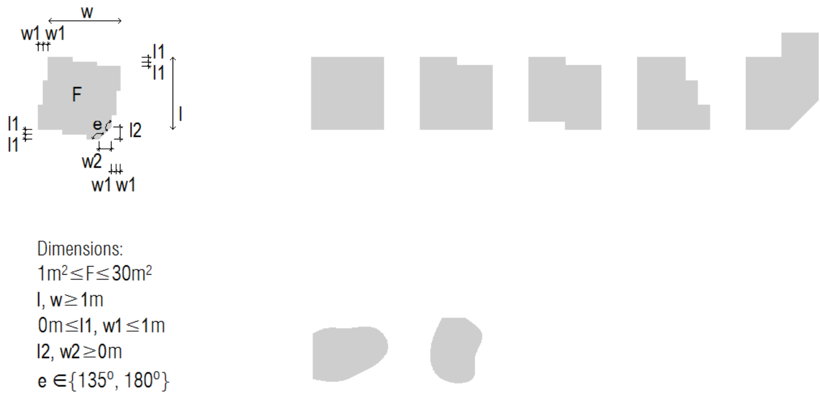


Figure 198 – Parametric shape on the top left; different possibilities for the room shape on the top right; sub-shapes used in the transformation grammar to indicate a single room on the bottom right; dimensional conditions on the bottom left.

The compound grammar was used to represent the 25 dwellings in the case study (*Appendix 1*) as well as the proposed rehabilitation drawing possibilities (see examples in *Appendix 2* and *4*).

Interpreting a building by reducing it to 2 dimensions is obviously an abstraction and only emphasises two spatial dimensions at a time. However, these methods of representing a building are frequently used, since they explain the spatial dimensions that are most representative. In fact, according to Mitchell (2008: 77) in architecture, representation essentially aims to represent "*building components and materials*".

Representation using lines, points and surfaces includes a series of ambiguities and predefined rules for graphic simplification which are coded and understood only by those who have mastered this language. Architectural designs are interpreted by "*recognising examples of types of abstract forms (…) and applying our knowledge of conventions and representation*" (Mitchell, 2008: 113). Although not used in this thesis, three-dimensional representation involves a greater and more complex amount of data and may even simulate reality, facilitating our understanding of the object and also the process of transferring the representation to the physical world. The transfer of three-dimensional computerised models for rapid prototype modelling is one example of this.

4.2.2 Labels

Labels add information not provided by shapes. In the proposed transformation grammar, the algebra *U12* is combined with labels in the algebra *V02,* in which label points are used to define dwelling functions. These labels are "where" labels because they specify which subshape or subshapes a rule may be applied to and because their location in relation to the associated shapes is essential to their function. These labels only identify the shapes but do not alter their symmetries and therefore do not restrict the sub-shapes to which the rule can be applied or the Euclidean transformation under which it can be applied (Knight, 1983).

The labels used, shown in Table 41, define the existing and proposed dwelling functions.

When the grammar is first applied, a label is attributed to each existing space in the dwelling, according to the following criteria:

- Habitable space (hs) – habitable spaces are spaces with an area equivalent to, or greater than, the minimum area allowed for a bedroom – $7m^2$ (with a tolerance of 10%) and receive natural light and ventilation via windows. Kitchens are excluded from this group;
- Non-habitable space (nhs) – non-habitable spaces are spaces which do not correspond to the above description. Bathrooms are excluded from this group;
- Existing bathrooms (Xba) – the fact that water and sewage infrastructures already existed led to the consideration that existing bathrooms (mainly those in the private area) should preferably maintain their function in any proposal presented;
- Existing kitchens (Xki) – the fact that water, drains and fume extraction infrastructures already existed led to the consideration that existing kitchens should maintain their function in any proposal presented;
- Existing laundries (Xla) – the small size of the laundry/glassed veranda areas and the connections to kitchens led to the consideration that these spaces should preferably maintain their function in any proposal presented;
- Existing closed balcony (Xbc) – A balcony space that had been originally designed as an enclosed area (as a kind of conservatory) was found in only one of the dwellings The classification of this space as *nhs* would create misunderstandings in the application of the rules and it was therefore decided to consider it as a 6th category.

An example of the assignment of the previous defined labels is provided in Figure 199 *c*.

In the shape part of the rule				**In original dwellings**	
label	**Space/meaning**	**label**	**Technology**	**label**	**Space**
F	Function	wd	Water detector	nhs	Non-habitable spaces
F*n*	Function 1, 2, 3…	sd	Smoke detector	hs	Habitable spaces
Fb	Function of back room	gd	Gas detector	Xba	Existing private bathroom
Fl	Function of room on the right	td	Temperature detector	Xba.s	Existing service bathroom
Fr	Function of room on the left	cp	Control panel	Xki	Existing kitchen
Ff	Function of front room	c	Oven and stove	Xla	Existing laundry
		g	Gas operating device	Xbc	Existing closed balcony
		i	Control panel		
		ms	Multifunctional switch		

In transformed dwellings					
label	**Space**	**label**	**Space**	**label**	**Space**
be	Bedroom	ki	Kitchen	co	Corridor
be.d	Double bedroom	la	Laundry	co.p	Private corridor
be.s	Single bedroom	se	Service room*	co.s	Service corridor
be.t	Twin bedroom	li/di	Combined living/dining room	hl	Hall
ba	Bathroom	li	Living room	lh	Lift hall
ba.p	Private bathroom	di	Dining room	sh	Stair hall
ba.p1	Main private bathroom	ho	Home office	bc	Balcony
ba.p2	Second private bathroom	mr	Media room	st	Storeroom
ba.p3	Third private bathroom			cl	Walk-in closet
ba.g	Guest bathroom				
ba.s	Service bathroom*				
lv	Lavatory				

Table 41 – Labels used in shape rules. * When the dwellings were originally built (in the 1950s), these areas were for the exclusive use of the live-in maid.

After assigning the first labels to the initial shape (original dwellings) derivation begins and the labels are replaced by others indicating the main function for which the various spaces are destined. At the end of the derivation, one of the labels from the bottom line in Table 41 should have been attributed to each of the spaces.

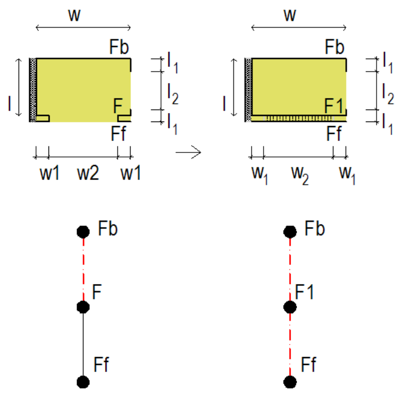
Certain rules allow labels to be assigned when two functions are associated with the same room. Examples of this kind of association include spaces such as the following: living room with home office (li/ho); dining room with home office (di/ho); living room with media room (li/mr); kitchen with laundry (ki/la). In the case of spaces that are demarcated or delimited within the same room (if a room has 2 different convex spaces) the labels, if different, are each assigned to the respective convex space.

The initial shape ***I*** (Figure 199a) is defined by a set of shapes ***S*** with labels ***p*** as shown in the next equation. In initial shape ***I*** there is a set of shapes S1, S2, S3 and each has one ***p*** label. Labelled shapes ***Sp*** are parameterised polygons and represent rooms with an associated function or characteristic.

$$I = \{(Sp)_1 + (Sp)_2 + (Sp)_3 + ... + (Sp)_k\} \text{ , } K \geq 1$$

Figure 199 – Floor plan representation a) without labels (initial shape), b) with labels showing the original dwelling functions (not used in the grammar), c) with labels indicating whether rooms are habitable, non-habitable, kitchen, laundry or bathrooms d) with labels showing one final dwelling layout. Colour is used to help distinguish between the different types of functions (b and d) and room types (c).

Rule 2.9 _ Create a second private bathroom (next to side wall or on a parallel wall)



Conditions:

$Z' \supset \{ba.p1\} \wedge Z \supset \{ba.p2\} \wedge Z' \not\supset \{ba.p2\}$

Dimensions:

$1m \leq l \leq 2.6m$

$1m \leq w \leq 4m$

$0.1m \leq w1, l1 \leq 3m$

$0.8m < w2 < 3.8m$

$0m \leq l2 \leq 3.8m$

Function:

$F \in \{nhs\}$

Fb, Ff $\in$ {nhs, hs, be.d, be.t, be.s, li, di, li/di, ho, mr, ki}

F (inside(x))=TRUE, $x \in$ {uba}

F (adjacent_to(x))=TRUE, $x \in$ {usi}

F1=ba.p2

Description:

R2.9 < D2: I; F; Z; Z' > →

< D2: I; ba.p2; Z - {ba.p2}; Z' + {ba.p2} >

Figure 200 – Labels applied to rules – shape part, condition part and descriptive part.

Within a shape rule, such as the one in Figure 200, labels appear in various ways:

- in the shape part, labels are Fb, Ff, Fl, Fr, F or F*n* (Table 41);
- in the conditions part, *If* labels are also Fb, Ff, Fl, Fr, F or F*n* and *then* labels (after the rule application) are the ones presented in the bottom line of Table 41;
- in the description part, they are the same as in the conditions part.

4.2.3 Weights

In order to define constructional constraints, weights (Stiny, 1992) were used to incorporate shape properties.

The algebras used - U12 (for shapes) and V02 (for labels) - are combined with algebra W22 to obtain a new algebra used to execute the proposed dwelling transformation. This combination of algebras is useful in practice, as Stiny has pointed out (Stiny, 1992). Weights are defined as planes with an interior filled with a pattern (Figure 201).

The attribution of weight to the shapes used in the proposed grammar is intended to characterise two different aspects: the existing and proposed construction systems for walls, and the acceptable position of new spaces within the dwelling.

For the wall construction systems four weights were used to represent four different types of wall. It was necessary to define these types of wall in order to establish rules that take construction and location requirements into account:

- Existing brick walls (ub), - these are the only walls that can be demolished and even then there are size restrictions on demolition;
- Existing structural elements (us) - these walls (front and back facade and inside columns) are made of reinforced concrete or load-bearing masonry and cannot be demolished under any circumstances;
- Existing side walls (usi) - these walls mark the lateral limits of the building and border on neighbouring buildings. Existing side walls cannot be demolished. Although they are structural, they were considered separately from the structural elements because, together with the other building metrics, they define an appropriate area for the installation of the new technical infrastructures needed for new bathrooms;
- Proposed light system (ul) - any partly or totally new wall must be constructed as a light partition wall, e.g. in plaster board.

Two types of weights were used to identify the acceptable area for the allocation of new infrastructured spaces within the dwelling: appropriate areas for accommodating new bathrooms (uba), and appropriate areas for accommodating new kitchens (uki).

As with the initial labels, the initial weights – ub, us, usi – must be placed in the initial shape before derivation begins. The "uba" weight and the "uki" are placed in a specific step in the grammar. These two weights are only needed if the functional programme asks for Strategy 1 (repositioning the kitchen) – requiring the use of "uki" – or for a second private bathroom – requiring the use of "uba".

Figure 201 – Weights associated with the transformation grammar.

4.2.4 Representing topological features

In addition to the floor plans, justified graphs were used to complement the description and evaluate spatial properties. Graphic representation, whether convex or justified, is an abstraction, since it emphasises particular characteristics to the detriment of others. In fact, neither walls nor spatial dimensions are represented but instead nodes, representing space, and arcs, representing connections. In a graph, the existence of a space is emphasised to the detriment of its shape. Direct connections between spaces (doors, passages, windows) are emphasised and adjacency relationships are not considered. In addition, other characteristics, such as capacity and spaciousness, are not taken into consideration.

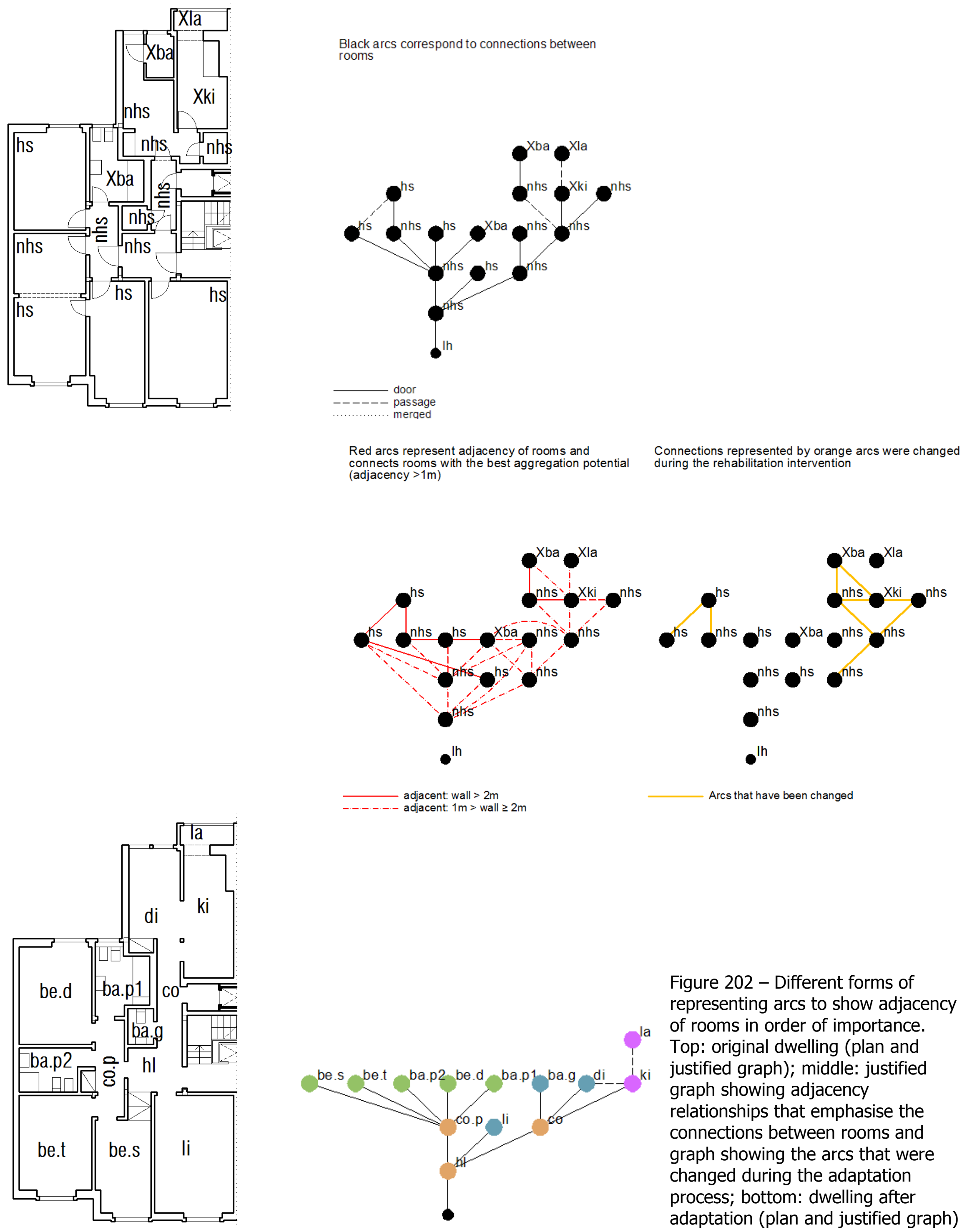


Figure 202 – Different forms of representing arcs to show adjacency of rooms in order of importance. Top: original dwelling (plan and justified graph); middle: justified graph showing adjacency relationships that emphasise the connections between rooms and graph showing the arcs that were changed during the adaptation process; bottom: dwelling after adaptation (plan and justified graph)

Three aspects of the use of topological relationships were considered in terms of integration within the grammar:

- The choice of adjacency as one of the most important features involved in decisions on rehabilitation work (construction and partial or total demolition of walls);
- The use of graphs as supplementary descriptors for rules;
- The use of justified graphs during derivation.

With regard to the first aspect, given that adjacency proved to be an essential feature of decision-making throughout the rehabilitation process, consideration was given to including it in the dwelling graph using a different form of representation, as illustrated in Figure 202, where red arcs are used for this purpose. However, the resulting large number of arcs in the graph was not very easy to manipulate during derivation.

Graphs were also used in rules to complement descriptions when connections were indicated between 2 or 3 spaces in the system referred to in the rule.

In order to characterise the different forms of connections, descriptors were attributed in natural language (English), mathematical language, as graphs or as shapes (Figure 203). In this way, any of these forms of description can be used to indicate the topological properties of the rooms.

Finally, graphs were also used to track the development of spatial relationships between rooms during the various transformation stages.

The complementarity of these forms of analysis – space syntax and shape grammar – enabled the interaction between the formal principles of the project and the spatial and shape properties of the objects designed to be understood, thus guiding the generation of solutions.

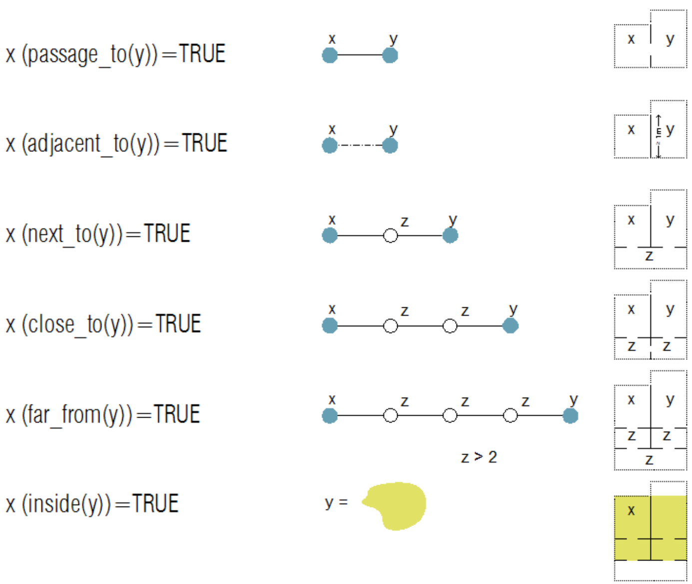


Figure 203 – Methods of representing topological relations between rooms mathematically, as a graph and by showing the topological relationships between rooms.

4.2.5 Conditions

The conditions part, which is included in the shape rule, is essential in order to ensure that its use is limited to particular cases.

The conditions are divided into dimensional and functional conditions. The former includes minimum areas and linear dimensions and the latter an indication of the functions of the room referred to in the rule (see the example in Figure 200, page 315).

In addition to the labels defined in *Part 2: Chapter 4.2.2*, the weights defined in *Chapter 4.2.3,* the topological relationships defined in *Chapter 4.2.4*, and universal mathematical symbols, the conditions also use the notations and categories of description defined in Table 42 and described in detail in *Chapter 4.4.3*.

	Description		Description
E	Set of existing rooms (still available for assignment)	w	Width
Z	Set of rooms required by the functional programme	l	Length
Z′	Set of rooms assigned to the proposed dwelling	a	Area
X	Set of ICAT devices required by the ICAT pack		
X′	Set of ICAT devices assigned to the proposed dwelling		
D*n*	Stage in derivation		
w*n*	Wall of a specific construction system *n* (*n*: ub, ul, us, usi) ub – brick wall ul – ligt partition wall us – structural wall usi – side walls		
b	Back wall of building		
f	Front wall of building		
p	Interior party wall (stairs and lift)		
s	Side wall of building		
i	Interior wall		

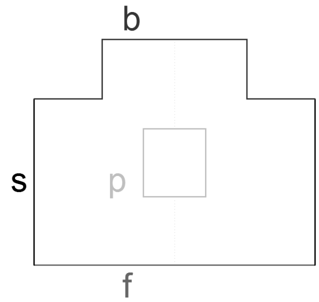


Table 42 – Symbols used in rule conditions and/or descriptions

4.3 DESCRIPTIVE GRAMMAR

As previously stated, a descriptive grammar consists of a description of shapes using symbols instead of shapes, as in a shape grammar.

Even though designs are technically shapes it is possible to use a recursive schema to describe them in terms of functionality, construction and meaning, among other factors which do not refer directly to their component spatial elements (Stiny, 1981: 257).

Stiny (1981: 258) states that design descriptions specify the relevant features and properties of designs in a finite way, determined according to certain relevant fixed criteria. Choosing these criteria is an important step in defining the description of the design, from the initial shape and throughout the derivation until the final design is completed.

In the present case the description must include building properties such as dwelling capacity, spaciousness and type, room function, area and dimensions, connections between different rooms and wall construction system and dimensions.

On the basis of these assumptions it can be said that the development of descriptive grammars involves two crucial questions:

- The content of the description:
- The development of descriptive rules.

A transformation grammar allows for two types of description:

- The description of the design derivation, from the initial shape to the finished design, which includes all the criteria defined for the descriptions;
- The rule descriptions, which may include some or all of the criteria selected for the descriptions (e.g. a rule that eliminates a wall may only include criteria for the construction system of the said wall, in addition to its dimensions and a definition of the spaces in which demolition takes place).

At the beginning of the definition of the descriptive grammar synthetic descriptions were developed in an abbreviated form that will be shown in the next section (*Part 2: Chapter 0.*). This abbreviated description proved to be insufficient in terms of implementing the grammar in computer software since it does not have all the information required. Thus, in a more advanced stage of the research, a detailed description was defined which is also explained in the next section. Although fully described in *Chapter 0.*, this detailed description was only implemented in a sample rule from each of the different types of rules.

It was considered necessary to establish two parallel descriptions for the transformation grammar that could be combined to define the final design description:

- A description of the functional programme and ICAT pack, identified by the symbol β (Table 43);
- A description of the dwelling, identified by the symbol α (Table 44).

The proposed transformation grammar is a discursive grammar since it is able to generate syntactically and semantically correct designs that satisfy *a priori* requirements. This grammar is both a shape grammar (to generate legal projects) and a descriptive grammar (to generate adequate projects). These two grammars are combined in two stages of the rehabilitation methodology: firstly in the generation of the (functional and ICAT) programmes and secondly in the generation of the design solution (Figure 204).

In the first stage a programming grammar is used which involves processing the data for the family and the existing dwelling in order to generate the adapted functional housing programme and the adapted set of ICAT functions (see *Part 2: Chapter 2* and *Chapter 3*). Thus the programming grammar uses a descriptive part (regulations, recommendations and family data) as well as a shape part (the existing dwelling). The designing grammar generates a dwelling transformation using the previous data. The designing grammar uses a descriptive part (previously defined programmes) and a shape part (the transformation grammar).

This approach is similar to the one used by Duarte (2007: 332) in the Malagueira grammar except for the use of shape in the programming grammar since, in the present case, a specific dwelling is available from the beginning of the process and is used to define the adapted programmes.

	Programming grammar	**Designing grammar**
Descriptive grammar	√	√
Shape grammar	√	√

Figure 204 – Programming and designing grammars (adapted from (Duarte, 2007: 332))

Description of the functional programme and pack of ICAT				Variables
Typology				
	Personalisation		β1	< personalisation > *Values: customised, typified*
	Users		β2	< number [(age, kinship, share, period of occupation, special needs) ,…] > *Values for share: bed, bedroom, none* *Values for period of occupation: 100%, 50%, …* *Values for special needs: Yes, No*
	Quality for the functional programme		β3	< desired_quality > *Values: minimum, recommended*
	Quality for the ICAT functions		β4	< desired_quality > *Values: basic, medium, optimum*
Morphology				
	Type		β5	< possible_type_of_dwelling1, possible_type_of_dwelling2, …> *Values: A, B, C, D*
Spaciousness				
	Capacity (dwelling)			
		Obligatory spaces	β6	< [function, number ((articulation, number) …)]… > *Values for number: 1, 2, 3, 4, 5* *Values for articulation: isolated, demarcated, included*
		Extra spaces	β7	< [function, articulation, priority]… > *Values for priority 1, 2, 3, 4, 5*[a] *Values for articulation: isolated, demarcated, included*
	Spaciousness (dwelling)			
		Required net floor area	β8	< minimum_area, recommended_area > *Values: between* $70m^2$ *and* $215m^2$
	Spaciousness (rooms)			
		Area	β9	< [function, area)]… > *Values: between* $1m^2$ *and* $30m^2$
		Dimensions (length, width)	β10	< [function, (l, w)]… > *Values: between 1m and 3.5m*
Topology			β11	< [(room1, room2, connection, priority)] … > *Values for connection: passage to, next to, close to, far from.*
ICAT Functions			β12	< [function (equipment, room), …] … >

a _ In terms of priority, 1 represents the space with the highest priority

Table 43 – Description of the functional programme and pack of ICAT (adapted from (Duarte, 2007: 336, 340))

The description of the functional programme includes the most relevant criteria that must be incorporated into the housing rehabilitation. These criteria were adapted from Duarte's (2007: 336-340) criteria for the housing programme for the Malagueira grammar. A different kind of context was used for the criteria defined by Duarte (not urban, land lot and solar orientation but family and dwelling), and aesthetics and final cost were not considered since these features were not addressed in the present research but could be included later.

Table 43 defines the required criteria and assigns a symbol and variables to them. Five groups of properties were established to describe the functional programme and ICAT pack, namely morphology, typology, spaciousness, topology and ICAT functions, all of which are requirements contained in the functional programme and the ICAT pack for a given family. The values for the first group - typology - are introduced by the user. They correspond to personalisation (customised – if the required functional programme is for a given family, or typified – for a typical family - β1), users (user characteristics such as age, kinship, the possibility of sharing a bedroom, the period of occupation and special needs if applicable - β2), quality level for the functional programme (minimum or recommended - β3), and quality level for the pack of ICAT functions (basic, minimum or optimum - β4). The second group describes the viable possibilities of the building's morphology within building types A, B, C and D (β5) in terms of meeting family requirements. These possibilities result from the required dwelling area and family profile. The third group describes the spaciousness characteristics of the functional programme, namely the dwelling capacity (a list of the obligatory rooms - β6, and the extra rooms requested by the family - β7), spaciousness (required net floor area - β8), and the spaciousness of rooms (area - β9, and length and width - β10).

The fourth group describes the most relevant and necessary connections between spaces, assigning a priority to each in order to rank them in terms of satisfying the requirements presented for the transformation of the dwelling (β11). Categories β6 to β11 are grouped in a Z group for the set of spaciousness requirements according to the functional programme and in a Z' group for the set of spaciousness requirements assigned to the proposed dwelling during a derivation.

The final group describes the ICAT functions and equipment required for the given family according to the domotic systems classification (β12).

The description of the dwelling (Table 44) is composed of six groups: morphology, spaciousness, topology, construction, stage in the derivation and ICAT functions. Morphology includes a definition of the dwelling type – A, B, C or D (α1). Spaciousness describes the dwelling capacity (a list of the existing rooms – α2), spaciousness (the net floor area of the existing rooms – α3), and room spaciousness (area – α4, greater length and width of the existing rooms – α5).

The third group describes topological relationships within the dwelling. For this purpose topology is defined (under three variables composed of two spaces and the type of connection between them – passage to, next to, close to or far from - α6) and adjacency (this property makes it possible to predict whether one space can be connected to another or not – α7). The fourth group describes the constructional characteristics of the dwelling walls which are important in determining whether existing walls can be demolished or new ones constructed. Exterior walls cannot be demolished but can be altered. Existing interior walls can be partly or totally demolished and new walls can be constructed. A definition of the wall type is needed in order to describe the exterior walls (wall type and construction system - α8) and interior walls (wall construction system, rooms for which the wall is a boundary and the wall's dimensions - α9). The fifth group – α10 – states the stage in the derivation, assuming the value of ∅ before the derivation starts and changing each time a step is completed (steps are defined in *Part 2: Chapter 4.4*). The final group – α11 – states the ICAT elements and functions integrated into the dwelling.

Categories α2 to α7 are grouped into an E group for the spaciousness and topology set that characterises the dwelling during the various stages of the derivation. In this group, in any specific stage of the derivation, some rooms are still available for assignment whilst others have already been assigned.

Description of the dwelling				Variables
Morphology				
	Type		$\alpha 1$	< type_of_dwelling > *Values: A, B, C, D*
Spaciousness				
	Capacity (dwelling)	spaces	$\alpha 2$	< [(use$_{number}$,articulation)) …]… > *Values for use: hs, nhs, Xba, Xki, Xla, Cbc* *Values for number: 1, 2, 3, 4, 5 (e.g: nhs_1)* *Values for articulation: isolated, demarcated, included*
	Spaciousness (dwelling)	net floor area	$\alpha 3$	< area >
	Spaciousness (rooms)	Area	$\alpha 4$	< [(use$_{number}$, area)…] … >
		Dimensions (length, width)	$\alpha 5$	< [(use$_{number}$, l, w), …] … >
Topology				
	Connections (rooms)		$\alpha 6$	< [(room1, room2, connection)] … > *Values for connection: passage to, next to, close to, far from, window_to.*
	Adjacency (rooms)		$\alpha 7$	< [(room1, room2, adjacency) …] > *Values: adjacent to*
Construction				
	Exterior walls[c]	type, construction	$\alpha 8$	< (wall_type, wall_construction)… > *Values for wall type: b, f, p, s* *Values for wall construction: us, usi*
	Interior walls[d]	type, construction	$\alpha 9$	< [(w$_{wall_construction}$(room1, room2, l)) … > *Values for wall construction: ub, us, ul* *Values for l: between 0m and 10m*
Stage of the derivation			$\alpha 10$	< step_derivation > *Values:∅, -1, 0, 1, 2, 3, 4, 5, 6, 7, 8*
ICAT Functions			$\alpha 11$	< [function (equipment, room), …] … >

c _ f = front wall; b = back wall; e = end wall; p = party walls
d _ ub = brick wall ; us = structural wall

Table 44 – Description of the dwelling

During a derivation the description of the dwelling starts as a description of the initial shape – the original dwelling – with all the categories defined in Table 44 filled and evolves as the transformation proceeds step by step.

The use of these descriptions will be illustrated in *Appendix 4* when exemplifying the use of the transformation grammar.

4.4 TRANSFORMATION GRAMMAR: RULES

The different experiments undertaken during the process of inferring the rules of the transformation grammar revealed certain rehabilitation patterns. The decision-making processes used by the experimental subjects tended to be similar and to follow the same sequence for major decisions, for instance, the location of private and social areas.

As described in *Part 2: Chapter 2.3.2*, there are three different rehabilitation strategies for the buildings in the case study, but the goals proposed in this study only included strategies that do not change the overall size of the dwelling, namely the first and second strategy. However, the current grammar could be enlarged to include the remaining strategy.

In developing the grammar it was decided to consider only those which maintained the dimensions of the dwelling, namely the first and the second strategies. The rules corresponding to these first and second strategies are described in this chapter and were inferred from experiments in which the solutions generated followed this strategy. The third rehabilitation strategy is described in *Part 2: Chapter 2.3.2* but is not detailed as a grammar.

The rehabilitation of a dwelling using this transformation grammar includes two major steps:

_ Choosing an appropriate dwelling (addressed in *Part 2: Chapter 2.3.1*);

_ Adapting the dwelling (addressed in this chapter).

After choosing an appropriate dwelling, the next decision involves adapting the family dwelling to the new functional programme and required ICAT pack.

The adaptation of the dwelling includes 10 steps, numbered -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, listed in Table 45 and explained in detailed in *Part 2: Chapter 0*. These steps may be divided into three different stages, firstly the preparation of the design (step -1), secondly the functional adaptation of the dwelling (step 0 to step 7) and thirdly the integration of ICAT components (step 8).

The first step (step -1) enables a compound representation of the dwelling to be generated and the transformation to begin.

The second step (step 0) enables the first important transformation decision to be made by locating the kitchen in accordance with the chosen strategy.

The third step (step 1) locates the hall. The hall function will be needed to define relationships with the functions of other rooms.

The following – step 2 – may be i) the definition of the private area if the functional programme asks for 2 or more bedrooms, ii) the definition of the social area if the functional programme asks for less than 2 bedrooms.

Step 3 will be the definition of the private area or the definition of the social area according to what was generated in the previous step.

Step 4 is the definition of the circulation area. Step 5 is the definition of the service area and step 6 is the definition of the storage area.

Step 7 is the adaptation of the room's shape which may also be generated in each of the previous steps if there is no room to include the required rooms in Z.

The last step – step 8 - is the integration of ICAT in rooms.

At the end of each step there is a rule which changes to the next step if the previous conditions have been met.

As mentioned above, we will show how adaptation proceeds according to the first and second rehabilitation strategies.

-1	Preparing the floor plan	**-1.1**	Generation of a parallel representation – using surfaces
		-1.2	Generation of a parallel representation – using graphs
		-1.3	Attribution of labels for the spaces in the dwelling
		-1.4	Attribution of weights for the walls in the dwelling
		-1.5	Change from step -1 to step 0
0	Define kitchen / according to the chosen strategy	**0.1**	Assignment of kitchen (ki) (if strategy 2)
		0.2	Introduction of new kitchen position weight (if strategy 1)
		0.3	Assignment of kitchen (ki) (if strategy 1)
		0.4	Elimination of new kitchen position weight (if strategy 1)
		0.5	Change Xki label
		0.6	Change from step 0 to step 1
1	Assignment of hall	**1.1**	Assignment of hall (hl)
		1.2	Change from step 1 to step 2
2	Define private area (if functional programme has 2 or more bedrooms, if not go to Rule 3)	**2.1**	Assignment of bedrooms (be.d)
		2.2	Assignment of bedrooms (be.t)
		2.3	Assignment of bedrooms (be.s)
		2.4	*Change from step 2 to step 7 if there are no spaces to satisfy rules 2.1, 2.2, 2.3*
		2.5	*Change bedroom assignment*
		2.6	Assignment of first private bathroom (ba.p1)
		2.7	Introduction of new bathroom position weight
		2.8→2.15	Assignment of second private bathroom (ba.p2)
		2.16	Elimination of new bathroom position weight
		2.17	*Permute functions*
		2.18	*Change from step 2 to step 7 if there are no spaces to satisfy rules 2.8 to 2.15*
		2.19	Change from step 2 to step 3
3	Define social area (if functional programme has 2 or more bedrooms, if not go to Rule 2)	**3.1**	Assignment of living room (li)
		3.2	Assignment of dining room (di)
		3.3	Assignment of combined living/dining room (li/di)
		3.4, 3.5	Assignment of home office (ho)
		3.6	Assignment of combined home office/living room (li/ho)
		3.7	Assignment of combined home office/bedroom (be/ho)
		3.8	Assignment of media room (mr)
		3.9	Assignment of combined living/media room (li/mr)
		3.10	*Change from step 3 to step 7 if there are no spaces to satisfy rules 3.1 to 3.9*
		2.7	Introduction of new bathroom position weight
		3.11→3.14	Assignment of guest bathroom (ba.g)
		3.15	Change Xba label
		3.16	*Change from step 3 to step 7 if there are no spaces to satisfy rules 3.11 to 3.14*
		2.15	Eliminate new bathroom position weight
		3.17	Change from step 3 to step 4
4	Define circulation	**4.1**	Assignment of private corridor (co.p)
		4.2	Assignment of social corridor (co)
		4.3	Assignment of service corridor (co.s)
		4.4	*Change from step 4 to step 7 if rooms with no connections are assigned*
		4.5	Change from step 4 to step 5
5	Define service area	**5.1, 5.2**	Assignment of laundry room (la)
		5.3	Change Xla label
		5.4	Change from step 5 to step 6
6	Define storage spaces	**6.1,6.3,6.4**	Assignment of clothes storage
		6.2,6.3,6.4	Assignment of general storage
		6.5	Change from step 6 to step 7
7	*Adapt shape*	***7.1***	*Connect*
		7.2	*Separate*
		7.3	*Create circulation*
		7.4	*Change room size (add and subtract wall)*
		7.5	*Change room layout and assignment*
		7.6	*Change a door position*
		7.7	Change from step 7 to step 8
8	Integrate ICAT	**8.1**	Allocation of detectors/sensors
		8.2	Allocation of alarms
		8.3	Allocation of CCVT cameras

	8.4	Allocation of controlled HVAC appliances
	8.5	Allocation of controlled lights
	8.6	Allocation of controlled blinds and screens
	8.7	Allocation of controlled doors and windows
	8.8	Allocation of controlled watering
	8.9	Allocation of controlled domestic appliances
	8.10	Allocation of interfaces
	8.11	Allocation of controlled sockets
	8.12	Allocation of ITED (Telecommunications Infrastructures in Buildings) sockets
	8.13	Allocation of Home cinema components

Table 45 – Steps to follow in adapting a dwelling. Optional steps are in italics and mandatory steps in ordinary script.

All the transformations proposed in the grammar involve the construction or demolition of walls, as well as the assignning or permuting room functions. Therefore, the proposed rules include the following types of actions: i) assigning functions to rooms; ii) permuting functions between rooms; iii) adding walls to enable rooms to be divided and wall openings to be removed or reduced; iv) eliminating walls to enable adjacent rooms to be joined into a single rooms or rooms to be connected together; v) changing the stage in the derivation; vi) preparing the floor plan; vii) integrating ICAT elements.

4.4.1 Types of rules

The strategy required to transform dwellings involves work on the walls. All the transformations proposed involve assigning functions to rooms and constructing or demolishing walls. The proposed rules therefore include the following types of rules: i) rules for the assignment of functions to rooms; ii) rules for permuting room functions; iii) rules which add walls to enable rooms to be divided and wall openings to be eliminated or reduced; iv) rules which eliminate walls to enable rooms to be connected or one room to be enlarged; v) rules for changing the stage in the derivation; vi) rules for preparing the floor plan; vii) rules for integrating ICAT elements.

Next, one example of each type of rule is shown with the shape part, the condition part (functional and dimensional) and the description.

The categories of description included in the rules were identified according to the information required to apply the rules as described in *Part 2: Chapter 4.3*. The following descriptions made for rules are detailed descriptions. A synthetic version of the description is also shown. This synthetic description is used for all the transformation grammar rules included in *Appendix 3*.

ASSIGNMENT RULES

Assignment rules allow the functions and rooms required by the functional programme to be assigned to the existing rooms. The format for these rules is shown in Figure 205.

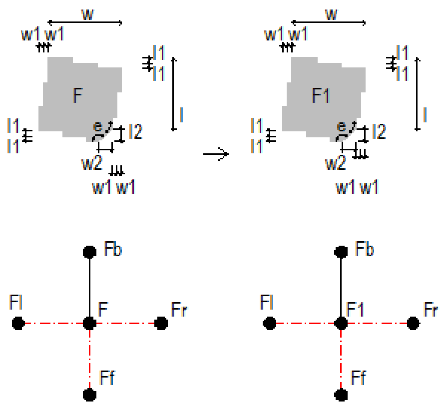
The detailed description of the assignment rule must include (as shown in Figure 205): the room to be assigned and its articulation ($\alpha 2$); the net floor area of the room ($\alpha 4$); the greater length and width of the room ($\alpha 5$); the connections required between the room and the surrounding rooms ($\alpha 6$); the adjacency of the room to the surrounding rooms ($\alpha 7$); the stage in the derivation ($\alpha 10$).

The abbreviated description of an assignment rule (e.g. Ri) must describe: the stage in the derivation (Dn); the functions of the surrounding rooms (Fb – function of the back room, Ff – function of the front room, Ff – function of the left room, Fr – function of the right room); the function involved (F); the set of rooms required in the functional programme (Z); the set of rooms assigned to the proposed dwelling layout (Z'). These rules have the following format:

$$Ri < Dn: Fb, Fr, Ff, Fl; F; Z'; E > \rightarrow < Dn: Fb, Fr, Ff, Fl; F1; Z' + \{F1\}; E - \{F\}, E + \{F1\} >$$

The abbreviated description of Rule 2.1a (shown in Figure 205) states that this rule belongs to the 2nd stage (D2). In the left part of the rule are the function of the surrounding rooms required (exterior; corridor, private corridor or closet; any function in Ff and Fl); the current function of the room (F); the set of rooms already allocated in the proposed dwelling layout (Z'); and the set of current rooms in the dwelling at the time the rule is applied (E). In the right part of the rule the functions of the surrounding rooms are described, a new function is assigned to the space (double bedroom – be.d), the be.d function is added to the Z' set of rooms as it has been assigned, the be.d function is added to the E set of current dwelling rooms and one hs room is deleted from the E set (since the be.d has replaced the hs room).

Rule 2.1.a _ Assignment of double bedroom (minimum level)



Conditions:

$Z \supset \{be.dn\} \wedge Z' \not\supset \{be.dn\}$

Dimensions:

$10{,}5m^2\ (\pm 10\%) \leq F \leq 30m^2$

$w, l \geq 2{,}7m$

$0m \leq l1, w1 \leq 1m$

$l2, w2 \geq 0m$

$e \in \{135^0, 180^0\}$

Functions:

$Fb \in \{ext\}$

$\exists\ Ff \vee Fr \vee Fl \in \{nhs, co, co.p, cl\}$

$Ff \vee Fr \vee Fl \notin \{hl\}$

$F \in \{hs\}$

$F1 \in \{be.d\}$

Description (detailed):

$\alpha 1 \rightarrow \alpha 1$: –

$\alpha 2 \rightarrow \alpha 2$: (be.d, isolated)

$\alpha 3 \rightarrow \alpha 3$: –

$\alpha 4 \rightarrow \alpha 4$: (be.d, area)

$\alpha 5 \rightarrow \alpha 5$: (be.d, l, w)

$\alpha 6 \rightarrow \alpha 6$: (be.d, Fb, window_to)

$\alpha 7 \rightarrow \alpha 7$: (be.d, Fl, adjacent_to), (be.d, Ff, adjacent_to), (be.d, Fr, adjacent_to)

$\alpha 8 \rightarrow \alpha 8$: –

$\alpha 9 \rightarrow \alpha 9$: –

$\alpha 10 \rightarrow \alpha 10$: S2

Description (abbreviated):

R2.1b < D2: ext, {nhs, co, co.p, cl}, Ff, Fl; F; Z'; E > →
< D2: ext, {nhs, co, co.p, cl}, Ff, Fl; be.d ; Z' + {be.d}; E - {hs}, E + {be.d} >

Figure 205 – Example of an assignment rule (Rule 2.1a), with shape part, condition part and descriptions (detailed and abbreviated),

Permuting rules

Permuting rules allow the functions between two rooms to be permuted due to criteria such as area and topology. These rules have the format shown in Figure 206.

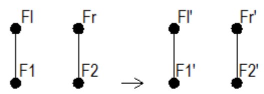
The detailed description of permuting rules must include (as shown in Figure 206): the rooms involved and their articulation (α2); the net floor area of the rooms (α4); the greater length and width of the rooms (α5); the connections between the rooms and surrounding rooms (α6); the stage in the derivation (α10).

The abbreviated description of a permuting function rule (e.g. Rii) must describe: the stage in the derivation (Dn); the functions of the connecting rooms (Fr, Fl) and the functions of the rooms involved (F1, F2). These rules have the following format:

$$\text{Rii} < \text{Dn: F1, Fl; F2, Fr} > \rightarrow < \text{Dn: F1', Fl; F2', Fr} >$$

The abbreviated description of Rule 2.5 (as shown in Figure 206) states that this rule belongs to the 2nd stage (D2). The left part of the rule describes the pairs of current connecting rooms (F1 with Fl and F2 with Fr). In the right part of the rule the rooms F1 and F2 are permuted and the connecting rooms updated and described as F1' with Fl and F2' with Fr.

Rule 2.5 _ Permuting bedroom assignment due to area criteria



Conditions:

Dimensions:

If F1>F2 $\wedge$ F1∈{be.s} $\wedge$ F2∈{be.t} ⇒ F1'∈{be.t} $\wedge$ F2'∈{be.s}
If F1>F2 $\wedge$ F1∈{be.s} $\wedge$ F2∈{be.d} ⇒ F1'∈{be.d} $\wedge$ F2'∈{be.s}
If F1>F2 $\wedge$ F1∈{be.s} $\wedge$ F2∈{be.d} ⇒ F1'∈{be.d} $\wedge$ F2'∈{be.s}

Function:

F1, F2, F1', F2'∈ {be.d, be.t, be.s}
Fl, Fr∈ {nhs, co.p, co, cl}
F1≠F2

Description (detailed):

α1 → α1: –
α2 → α2: ({be.d, be.t, be.s}, isolated) ({be.d, be.t, be.s}, isolated)
α3 → α3: –
α4 → α4: ({be.d, be.t, be.s}, area) ({be.d, be.t, be.s}, area)
α5 → α5: ({be.d, be.t, be.s}, l, w)({be.d, be.t, be.s}, l, w)
α6 → α6: ({be.d, be.t, be.s}, {nhs, co.p, co, cl}, passage_to)
({be.d, be.t, be.s}, {nhs, co.p, co, cl}, passage_to)
α7 → α7: –
α8 → α8: –
α9 → α9: –
α10 → α10: S2

Description (abbreviated):

R2.5 < D2: F1, Fl; F2, Fr > → < D2: F1', Fl; F2', Fr >

Figure 206 – Example of a permuting rule (Rule 2.5), with shape part, condition part and descriptions (detailed and abbreviated)

Rules to divide rooms or eliminate/reduce wall openings (adding walls)

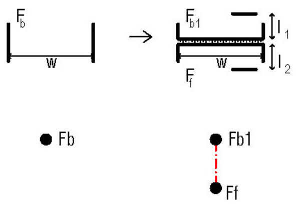
A rule for adding walls enables a room to be divided and a wall opening eliminated or reduced. These rules have the format shown in Figure 207.

The detailed description of these rules must include (as shown in Figure 207): the rooms involved and their articulation (α2); the net floor area of the rooms (α4); the greater length and width of the rooms (α5); the adjacency between the rooms (α7); the wall construction system, the rooms bounded by the wall and the wall dimensions (α9); the stage in the derivation (α10).

The abbreviated description of this type of rule (e.g. Riii) must describe: the stage in the derivation (Dn); the functions of the rooms involved (F1, F2); the width of the wall to be added (w); the new wall construction system (w_{cs}) and its position (between rooms F1 and F2). E stands for the set of available rooms in the dwelling to be assigned to the proposed dwelling layout. On the right, the F2 function is added to the E set of rooms. These rules have the following format:

$$\text{Riii} < \text{Dn: F1; E} > \;\rightarrow\; < \text{Dn: F1, F2; E} + \{\text{F2}\}\text{; w*w}_{cs}\text{ (F1, F2)} >$$

Rule 7.2.b _ Dividing a room in two by adding a wall



Conditions:

7.2.b1 Dividing a bedroom

Dimensions:
If *mimimum_level* $\wedge$ Fb$\in${be.d} $\Rightarrow$ Fb1 $\geq$ 10,5m² $\wedge$ w, l1 $\geq$ 2,7m
If *recommended_level* $\wedge$ Fb$\in${be.d} $\Rightarrow$ Fb1 $\geq$ 12m² $\wedge$ w, l1 $\geq$ 2,7m
If *mimimum_level* $\wedge$ Fb$\in${be.t} $\Rightarrow$ Fb1 $\geq$ 9m² $\wedge$ w, l1 $\geq$ 2,1m
If *recommended_level* $\wedge$ Fb$\in${be.t} $\Rightarrow$ Fb1 $\geq$ 14,5m² $\wedge$ w, l1 $\geq$ 2,1m
If *mimimum_level* $\wedge$ Fb$\in${be.s} $\Rightarrow$ Fb1 $\geq$ 7m² $\wedge$ w, l1 $\geq$ 2,1m
If *recommended_level* $\wedge$ Fb$\in${be.s} $\Rightarrow$ Fb1 $\geq$ 8,5m² $\wedge$ w, l1 $\geq$ 2,1m
Ff $\geq$ 1m² $\wedge$ l2 $\geq$ 1m

Function:
Fb, Fb1$\in${be.d, be.t, be.s}
Ff$\in${nhs}
Fb$\neq$Ff

7.2.b2 Dividing a private bathroom

Dimensions:
w, l1, l2 $\geq$ 1m
If *mimimum_level* $\Rightarrow$ Fb $\geq$ 5m² $\wedge$ Fb1 $\geq$ 3,5m²
If *recommended_level* $\Rightarrow$ Fb $\geq$ 7,5m² $\wedge$ Fb1 $\geq$ 5m²
Ff $\geq$ 1m²

Functions:
Fb, Fb1$\in${ba.p}
Ff$\in${ba.p, ba.g, cl, nhs}

7.2.b3 Dividing social rooms

Dimensions:
Fb$\in${li} $\Rightarrow$ Fb1, lb $\geq$ *dimensions_of* Rule3.1a
Fb$\in${di} $\Rightarrow$ Fb1, lb $\geq$ *dimensions_of* Rule3.2a
Fb$\in${li/di} $\Rightarrow$ Fb1, lb $\geq$ *dimensions_of* Rule3.3a
Fb$\in${ho} $\Rightarrow$ Fb1, lb $\geq$ *dimension_of* Rule3.4a
Fb$\in${mr} $\Rightarrow$ Fb1, lb $\geq$ *dimensions_of* Rule3.5a
Ff $\geq$ 1m² $\wedge$ l2 $\geq$ 1m

Function:
Fb, Fb1$\in${li, di, il/di, ho, mr}
Ff$\in${nhs}
Fb$\neq$Ff

7.2.b4 Dividing a kitchen

Dimensions:
w, l1, l2 $\geq$ 1m
If *mimimum_level* $\Rightarrow$ Fb1 $\geq$ 6m² ($\pm$10%)
If *recommended_level* $\wedge$ If *nhab=4* $\Rightarrow$ Fb $\geq$ 10,5m² ($\pm$10%)
If *recommended_level* $\wedge$ If *nhab* $\geq$ 5 $\Rightarrow$ Fb $\geq$ 11,5m² + 0,5m²(n-5) ($\pm$10%)
Ff $\geq$ 1m²

Functions:
Fb, Fb1$\in${ki}
Ff$\in${nhs}

Description (abbreviated):

Rule7.2b < D7: Fb; E > $\rightarrow$
< D7: Fb1, Ff; E+ {Ff}; w * *wul*(Fb1, Ff) >

Description (detailed):
α1 $\rightarrow$ α1: –
α2 $\rightarrow$ α2: (Fb1, articulation) (Ff, articulation)
α3 $\rightarrow$ α3: –
α4 $\rightarrow$ α4: (Fb1, area) (Ff, area)
α5 $\rightarrow$ α5: (Fb1, l, w) (Ff, l, w)
α6 $\rightarrow$ α6: –
α7 $\rightarrow$ α7: (Fb1, Ff, adjacent_to)
α8 $\rightarrow$ α8: –
α9 $\rightarrow$ α9: (*wul*(Fb1, Ff, l))
α10 $\rightarrow$ α10: S7

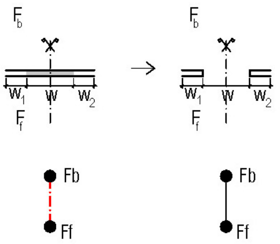
Figure 207 – Example of a rule to divide rooms (Rule 7.2b), with shape part, condition part and descriptions (detailed and abbreviated)

The abbreviated description of Rule 7.2b states that this rule belongs to the 7th stage (D7). In the left part of the rule there is a double bedroom and the set of available rooms in the dwelling not already assigned (E). In the right part of the rule, a second function (nhs: non-habitable space) has been added to the double bedroom, the nhs function is added to the E set of available rooms and a light partition wall with a specifi width (w) is added to divide them (w_{ul}(bed., nhs)).

RULES TO CONNECT OR ENLARGE ROOMS (ELIMINATING WALLS)

A rule for eliminating walls enables rooms to be connected or one room to be enlarged. These rules have the format shown in Figure 208.

Rule 7.1.f _ Connecting two adjacent rooms (by eliminating part of a straight wall, in the middle of the wall)



Description (detailed):

α1 → α1: –
α2 → α2: (Fb, articulation) (Ff, articulation)
α3 → α3: –
α4 → α4: (Fb, area) (Ff, area)
α5 → α5: (Fb, l, w) (Ff, l, w)
α6 → α6: (Fb, Ff, passage_to)
α7 → α7: –
α8 → α8: –
α9 → α9: (*wub*(Fb, Ff, l))
α10 → α10: S7

Conditions:

Dimensions:
w1+w+w2≥1m
w∈{0.8m, 0.9m, 1m, 1.2m, 1.6m}
w1,w2≥0m

Function:

Private areas
Fb∈{be.d, be.t, be.s} ∧ Ff∈{nhs, co.p, co} ∧ Fb (passage_to(x)=FALSE, ∀ x∈{nhs, co.p, co}) ⇒ w∈{0.8m, 0.9m, 1m}
Fb∈{be.d, be.t, be.s} ∧ Ff∈{cl, ba.p} ∧ Ff (passage_to(x)=FALSE, ∀ x∈{Z, hs, nhs}) ⇒ w∈{0.8m, 0.9m, 1m}
Fb∈{ba.p, cl} ∧ Ff∈{nhs, co.p, co} ∧ Fb (passage_to(x)=FALSE, ∀ x∈{Z, hs, nhs}) ⇒ w∈{0.8m, 0.9m, 1m}

Living areas
Fb∈{li, di, li/di, ho, mr} ∧ Ff∈{nhs, co, co.s, hl} ∧ Fb (passage_to(x)=FALSE, ∀ x∈{nhs, co, hl})
Fb∈{li} ∧ Ff∈{di, ho, mr}
Fb∈{di, li/di} ∧ Ff∈{li, ho, mr, ki}
Fb∈{ho} ∧ Ff∈{li, di, li/di, mr, co.p, ki, cl, st, be.d}
Fb∈{mr} ∧ Ff∈{li, di, li/di, ho}

Service areas
Fb∈{ki} ∧ Ff∈{co, co.s, hl} ∧ Fb (passage_to(x)=FALSE, ∀ x∈{co, co.s, hl}) ⇒ w∈{0.8m, 0.9m, 1m}
Fb∈{ki} ∧ Ff∈{di, li/di, la} ∧ Fb (passage_to(x)=FALSE, ∀ x∈{di, li/di, la})

Circulations areas
Ff, Fb∈{nhs, co, co.p, co.s, hl}

Storage areas
Fb∈{cl} ∧ Ff∈{co, co.p, be.d, be.t, be.s} ∧ Fb (passage_to(x)=FALSE, ∀ x∈{co, co.p, be.d, be.t, be.s}) ⇒ w∈{0.8m, 0.9m, 1m}
Fb∈{st} ∧ Ff∈{co, co.s, hl, ki, la, ho, mr} ∧ Fb (passage_to(x)=FALSE, ∀ x∈{co, co.s, hl, ki, la, ho, mr}) ⇒ w∈{0.8m, 0.9m, 1m}

Description (abbreviated):

R7.1f < D7: Fb, Ff; w**wub*(Fb, Ff) > →
< D7: Fb, Ff ; w*Ø >

Figure 208 – Example of a rule to connect rooms (Rule 7.1f), with shape part, condition part and descriptions (detailed and abbreviated)

The detailed description of these rules must include (as shown in Figure 208): the rooms involved and their articulation (α2); the net floor area of the rooms (α4); the greater length and width of the rooms (α5); the type of connection between the rooms (α6); the wall construction system, the rooms bounded by the wall and the wall dimensions (α9); the stage in the derivation (α10).

The abbreviated description of this type of rule (e.g. Riv) must describe: the stage in the derivation (Dn); the functions of the rooms involved (F1, F2); the width of the wall to be eliminated (w); the old wall construction system (w_{cs}) and its position (between rooms F1 and F2). These rules have the following format (for connected rooms):

$$Riv < Dn: F1, F2; w * w_{cs}(F1, F2) > \rightarrow < Dn: F1, F2; w' * w_{cs}(F1, F2) >$$

The abbreviated description of Rule 7.1f states that this rule belongs to the 7th stage (D7). In the left part of the rule there is a room Fb and a room Ff, with a brick wall dividing these rooms (the brick wall is divided into three sections to allow for a door opening) (w*w*ub*(Fb, Ff), w1*w*ub*(Fb, Ff), w2*w*ub*(Fb, Ff). The rooms Fb and Ff still appear in the right part of the rule and part of the brick wall has been demolished (w*Ø).

Rules for changing the stage in the derivation

This type of rule enables the derivation to proceed from one step to the next. These rules have the format shown in Figure 209.

The detailed description of these rules must include (as shown in Figure 209) the stage in the derivation (α10).

The abbreviated description of this type of rule (e.g. Rv) must describe the stage in the derivation (Dn).

$$Rv < Dn > \rightarrow < Dn' >$$

The abbreviated description of Rule 0.6 states that this rule is called up in stage 0 (D0) and activates the beginning of the 1st stage (D1).

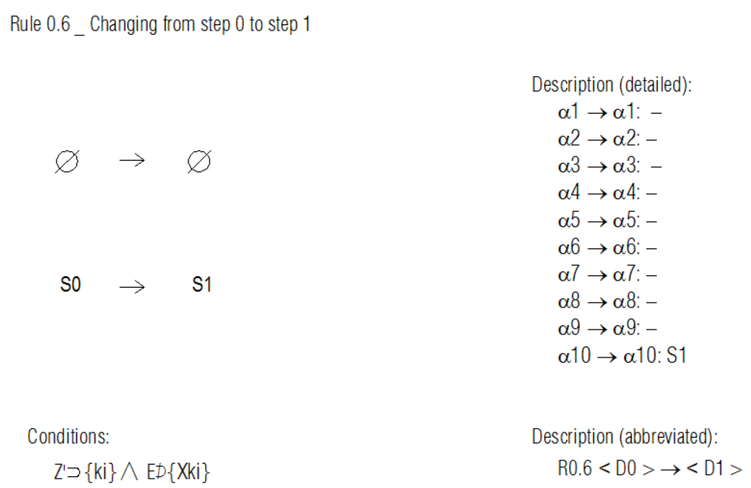


Figure 209 – Example of rule for changing the stage of the derivation (Rule 0.6), with shape part, conditional part and descriptions (detailed and abbreviated)

RULES FOR PREPARING THE FLOOR PLAN

This type of rule enables the floor plan to be prepared in order to begin the dwelling transformation. These rules include the following actions: generating a compound representation by adding dots, arcs and surfaces to the floor plan; adding labels to the existing rooms; adding weights to the existing walls.

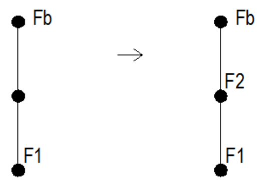
The rules for adding labels have the format shown in Figure 210. The detailed description of these rules must include: the room to which the label is added and its articulation ($\alpha2$); the type of connection between the rooms and the surrounding ones ($\alpha6$); the stage in the derivation ($\alpha10$).

The abbreviated description of this type of rule (e.g. Rvi) must describe the stage in the derivation (Dn) and the rooms involved (F1, F2).

$$Rvi < Dn: F1, \varnothing > \rightarrow < Dn: F1, F2 >$$

The abbreviated description of Rule -1.3c states that this rule belongs to stage -1 (D-1). In the left part of the rule there is a label Fb and a label F1. To the labels Fb and F1 a third label is added – F2 – in the right part of the rule.

Rule -1.3c _ Attribution of Xla label



Conditions:

Dimensions:
$1.5m^2 \leq F2 \leq 9m^2$

Function:
F1=Xki
Fb=ext
F2=Xla

Description (abbreviated):
R-1.3c < D-1: Fb, ∅, F1 > → < D-1: Fb, F2, F1 >

Description (detailed):
$\alpha1 \rightarrow \alpha1$: –
$\alpha2 \rightarrow \alpha2$: (Xla, isolated)
$\alpha3 \rightarrow \alpha3$: –
$\alpha4 \rightarrow \alpha4$: –
$\alpha5 \rightarrow \alpha5$: –
$\alpha6 \rightarrow \alpha6$: (Xki, Xla, passage_to)
$\alpha7 \rightarrow \alpha7$: –
$\alpha8 \rightarrow \alpha8$: –
$\alpha9 \rightarrow \alpha9$: –
$\alpha10 \rightarrow \alpha10$: S-1

Figure 210 – Example of rule for adding labels to the existing rooms (Rule -1.3c), with shape part, condition part and descriptions (detailed and abbreviated)

RULES FOR INTEGRATING ICAT ELEMENTS

This type of rule enables ICAT elements to be integrated and has the format shown in Figure 211.

The detailed description of these rules must include (as shown in Figure 211): the room involved and its articulation ($\alpha2$); the wall construction system and the side of the wall (room) in which the equipment will be placed ($\alpha9$); the stage in the derivation ($\alpha10$); the description of the ICAT function and equipment integrated ($\alpha11$).

The abbreviated description of this type of rule (e.g. Rvii) must describe: the stage in the derivation (Dn); the functions of the room involved (F1); the wall construction system and the side of the wall (room F1) in which the equipment will be placed (w_{cs}); the equipment integrated (T); the ICAT set integrated into the dwelling layout (X'). These rules have the following format:

$$Rvii < Dn: F1; w_{cs}(F1); \varnothing; X' > \rightarrow < Dn: F1; w_{cs}(F1); T; X' + \{T\} >$$

The abbreviated description of Rule 8.1a states that this rule belongs to the 8th stage (D8). In the left part of the rule there is a room Ff, a brick wall bordering the room (w*ub*(Ff)), and the ICAT set integrated into the dwelling (X'). The room Ff still appears in the right part of the rule as well as the wall bordering the room (w*ub*(Ff)). The water detector is integrated (wd) and is added to the X' ICAT set (X' + {wd}).

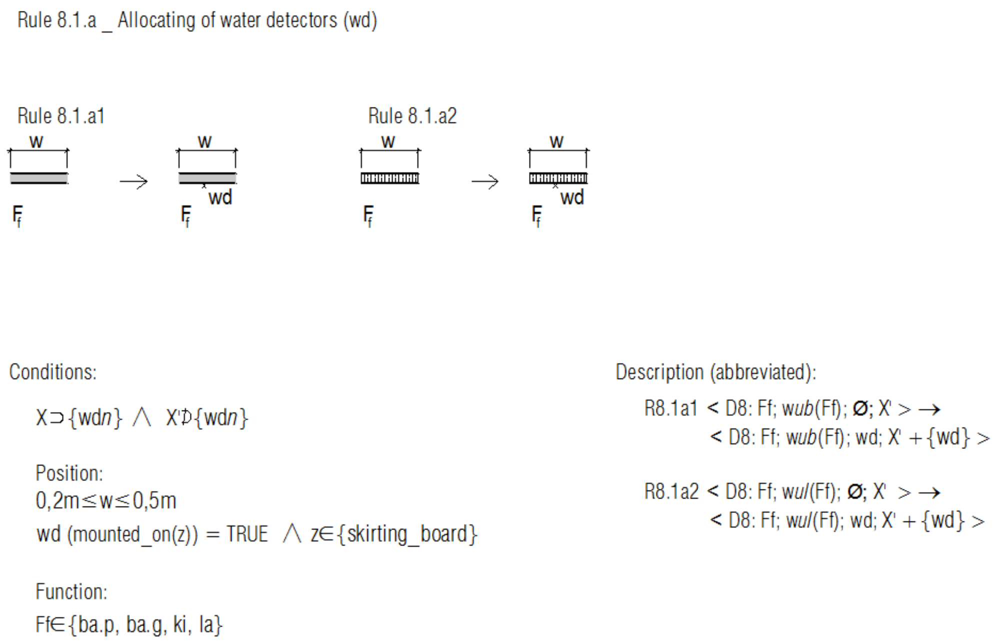


Figure 211 – Example of rule for integrate ICAT elements (Rule -1.3c), with shape part, conditional part and descriptions (detailed and abbreviated)

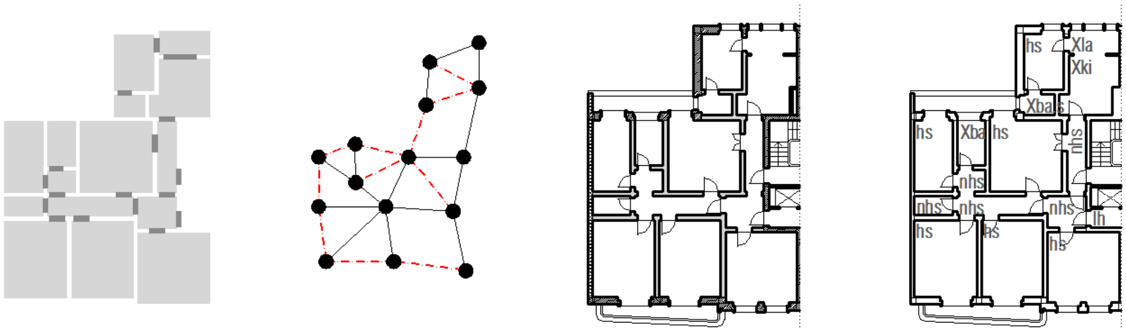
4.4.2 Sequence of rules

This section describes all the steps in the transformation grammar and their rules, which are listed in *Appendix 3* due to their size. Thus, in the following description only some rules are exemplified in order to show a sample of all types of rules.

Step -1: Preparing the floor plan

The transformation grammar starts with the following actions in the given order:

1. Generation of a compound representation
    - using surfaces to represent the spatial voids of rooms and connections. Rules -1.1 (Figure 212 a);
    - using graphs to represent rooms (dots), connections (continuous line) and adjacencies (red dashed lines). Rules -1.2 (Figure 212 b);
2. Assignment of labels for the dwelling spaces: nhs, hs, Xki, Xla, Xba, Cbc. Rules -1.3 (Figure 212 d) (see *Part 2: Chapter 4.2.2*);
3. Attribution of weights to the dwelling walls. Rules -1.4 (Figure 212 c) (see *Part 2: Chapter 4.2.3*).



a) Use of surfaces to represent spatial voids (rooms and connections) (algebra U22)

b) Use of graphs to represent rooms, connections and adjacencies (algebra U02 and U12)

c) Attribution of weights (algebra W22)

d) Attribution of labels (algebra V12)

Figure 212 – Transformation step number -1.

The need to use different representations of the dwelling in the rules led to the addition of a step in the grammar to enable the system to generate these representations based on the original dwelling layout.

The first step – Rules -1.1 – generates convex surfaces from the spatial void and the passages void. The rule which generates a convex surface for a given space includes, in the right side of the rule, both the representation of the partial floor plan (constructional elements) and the representation of the spatial void (an example is shown in Figure 213).

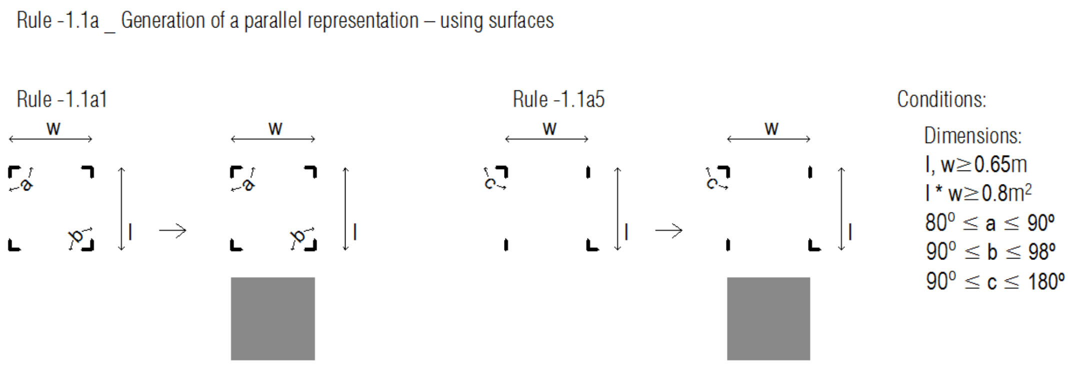


Figure 213 – Rule -1.1a – This rule creates a compound representation using a grey surface.

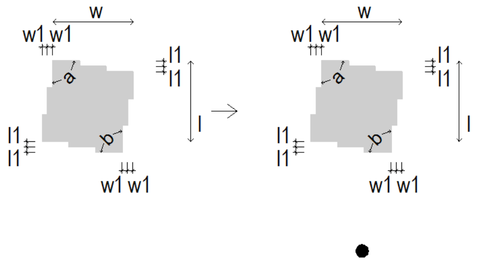
Rules -1.2 generate graphs from the convex surfaces generated in the previous step. These rules include, in the right side of the rule, both the representation of the convex surface (spatial void) and the representation of the dot (space) or line (connection or adjacency) (an example is shown in Figure 214).

The first set of Rules -1.2 introduces a dot in the graph, representing a room (Rule -1.2a to Rule -1.2g) (Figure 214) and the second set of rules introduces arcs to connect the dots assigned in the previous steps. The arcs represent the types of relationships between rooms and are created in the following order:

1. Firstly the arcs between connecting spaces (two convex surfaces with a passage between them) (Rule -1.2h) (Figure 215);
2. Secondly the arcs between adjacent spaces (two convex surfaces without a passage between them) (Rule -1.2i);

3. Thirdly the arcs between a space and the exterior (one convex surface with a passage/window to the exterior) (Rule -1.2j).

Rule -1.2a



Conditions:

Dimensions:
l, w≥0.65m
l * w≥0.8m²
0m≤l1, w1≤1m
80⁰ ≤ a ≤ 90°
90⁰ ≤ b ≤ 98°
90⁰ ≤ c ≤ 180°

Figure 214 – Rule -1.2a – This rule creates a parallel representation using a dot to represent a rooms.

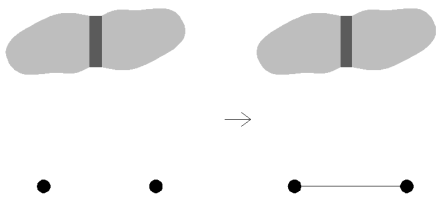
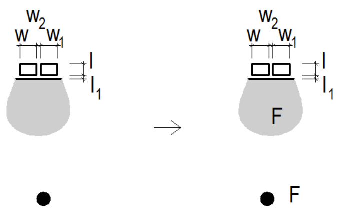


Figure 215 – Rule -1.2h – This rule completes the representation by adding an arc between two connecting rooms

Rules -1.3 assign labels to the dwelling spaces using both the convex surfaces and the graph generated in the previous steps. These rules identify spaces using one or more of the representations (partial floor plan, convex surface, graph) in the left side of the rule. The label is introduced in the right side of the rule the label (an example is shown in Figure 216).

The set of Rules -1.3 has to be applied in the following sequence: 1) the attribution of the Xba label(s); 2) the attribution of the Xki label; 3) the attribution of the Xla label; 4) the attribution of the Xbc label(s); 5) the attribution of the hs labels; 6) the attribution of the nhs labels.

Rule -1.3b _ Attribution of Xki label



Conditions:

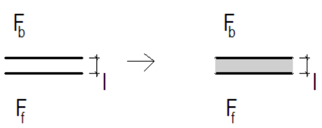
Dimensions:
0.1m≤l≤0.3m
0.2m≤w≤0.5m
0m≤w1≤0.5m
0.1m≤w2,l1≤0.2m
F≥6m²

Function:
F=Xki

Figure 216 – Rule -1.3b – This rule introduces the Xki label to the space represented by a dot and by a partial floor plan representation in the left part of the rule.

Rules -1.4 attribute weights to the dwelling walls according to their geometry, dimensions and adjacent spaces. These rules identify the wall properties using a partial floor plan representation in the left side of the rule. The weight is introduced in the right side of the rule (an example is shown in Figure 217).

Rule -1.4a _ Attribution of brick wall (ub) weight



Conditions:

Dimensions:
l≤0.25m

Functions:
Fb, Ff∈{hs, nhs, Xki, Xba, Xla}

Figure 217 – Rule -1.4a – This rule attributes the brick wall weight to the correspondening walls in the dwelling.

Rule -1.5 is used to change the stage of the derivation from -1 to 0 when the following conditions are fulfilled: every room has a label, a surface and a dot attributed, every connection has an arc attributed and every wall has a weight attributed.

Step 0: Assignment of kitchen

The grammar starts by locating the kitchen. In accordance with the chosen strategy, the kitchen can be assigned to one of the following locations:

- 1st strategy: move the kitchen from its original position in the back to the front of the building (Figure 218). Call rule 0.2, rule 0.3 and rule 0.4;
- 2nd strategy: maintain the kitchen position. Call rule 0.1 (Figure 219).

No rules have been defined for kitchens that are demarcated or included in other rooms, since these solutions are only considered in transformation strategy 3.

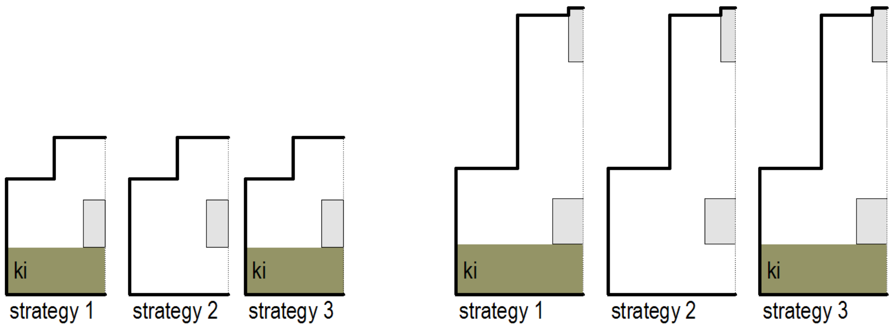


Figure 218 – Possible positions for new kitchens, depending on chosen strategy. Images on the left exemplify types *a* and *b* and images on the right types *c* and *d*.

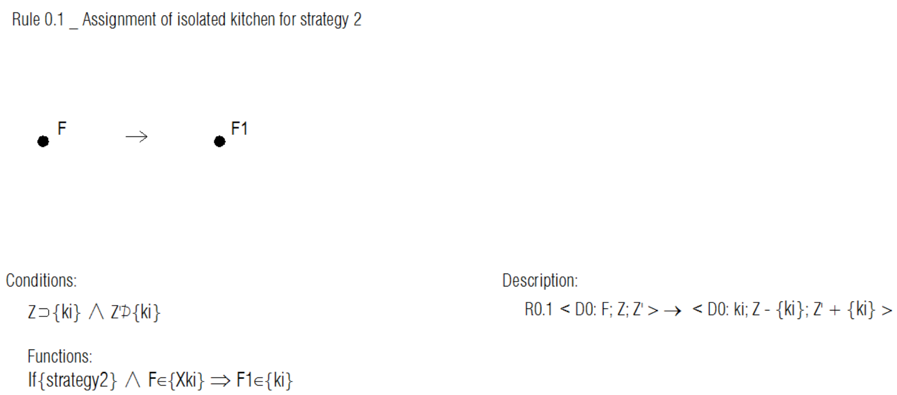


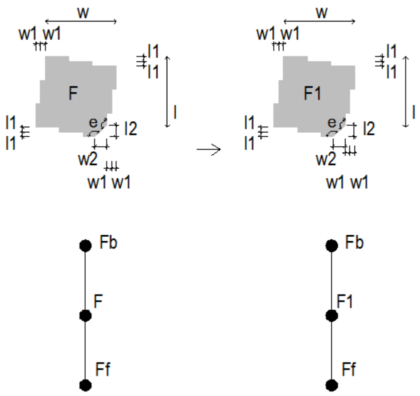
Figure 219 – Rule 0.1 from the Step 0

Step 1: Defining the position of the hall

The second step to be defined is the assignment of the function hall to a room since a set of other criteria relating to dwelling entry/exit distances, autonomy, depth, and other factors depend on this position. In strategies 1 and 2 the hall maintains its original position.

The rule for the assignment of the hall is Rule 1.1 (Figure 220).

Rule 1.1 _ Assignment of hall



Conditions:

Dimensions:
l, w≥0,9m
$1m^2 \leq F \leq 20m^2$
0m≤l1, w1≤1m
l2, w2≥0m
e ∈{135º, 180º}

Functions:
F∈{nhs}
Fb∈{lh} ∧ F (passage_to(lh))=TRUE
Ff∈{nhs} ∧ F (passage_to(nhs))=TRUE
⇒ F1∈{hl}

Description:

R1.1 < D1: lh, nhs; F; Z; Z' > →
< D1: lh, nhs; hl ; Z - {hl}; Z'+{hl} >

Figure 220 – Rule 1.1 from the Step 1

The grammar continues by locating the private and social areas, proceeding as follows:

a. If a private area requires two or more bedrooms, this area should be located first either at the front or rear of the building. Call rules from Step 1.

b. If a private area requires fewer than two bedrooms, the social area should be located first at the front or rear of the building. Call rules from Step 2.

The main private and social areas are defined as follows:

– In Strategy 1
  a. The new kitchen will be located in the smallest room facing the main facade (Rule 0.3a, Rule 0.3b), meaning that the social area will occupy the rooms adjacent to it (the number of rooms will be defined by the programme) (Rules 3.1 to Rule 3.9);
  b. The private area will occupy the rear of the dwelling (Rules 2.1 to Rule 2.3).
– In Strategy 2
  a. If the private area includes more than 2 bedrooms, it will be considered first and the grammar will proceed with Step 2;
  b. If the private area includes 2 bedrooms or fewer, the social area will be considered first and the grammar will proceed to Step 3 and return later to Step 2.

STEP 2: DEFINING THE PRIVATE AREA

The rules in Step 2 allow for three types of actions: assigning the bedroom function – e.g. double bedroom – to an existing space; assigning the private bathroom function to an existing space; permuting of bedroom functions.

Specifically, considering the required number of bedrooms *n,* as defined in the functional programme, the grammar finds *n* rooms that satisfy the following requirements:

– The bedroom net floor area must conform to the areas shown in Table 21, as expressed in the dimension conditions part of the grammar rules;
– Bedrooms must be habitable rooms, as defined in Rule 2.1, Rule 2.2 and Rule 2.3;
– The connections accepted between bedrooms and the surrounding rooms are expressed in the function conditions of the grammar rules:
    a. Bedrooms must connect directly to a corridor;

b. Circulation between different bedrooms may only take place via a private corridor or a service corridor;

c. Bedrooms must connect to other bedrooms via one intermediate corridor (next_to) or two intermediate corridors (close_to).

Some of the requirements of each rule can be overridden by specific family requirements if, for instance, a family wants a bedroom that can be accessed directly from the living-room.

The rules that enable bedrooms to be assigned are Rules 2.1 for double bedrooms, Rule 2.2 for twin bedrooms (Figure 221) and Rule 2.3 for single bedrooms. This sequence of assignment rules must be followed.

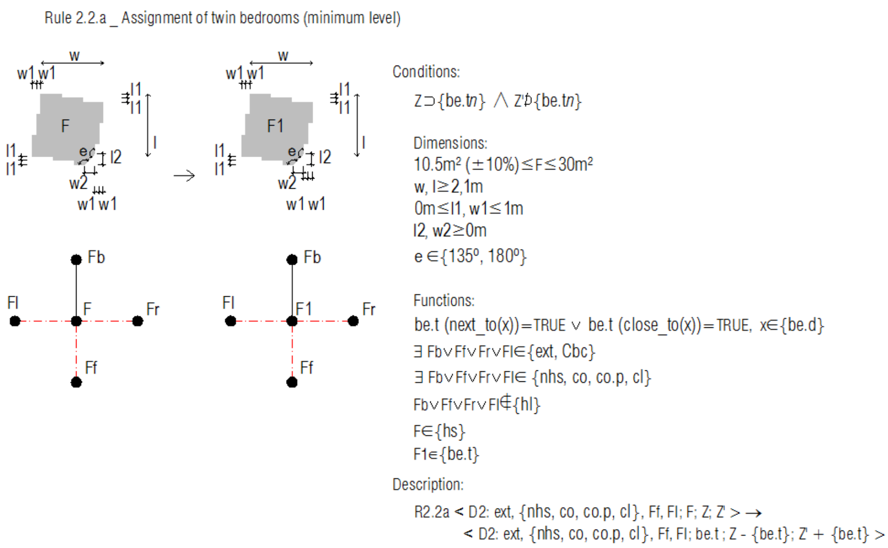


Figure 221 – Rule 2.2a from the Step 2

If there are not enough spaces to accommodate all the bedrooms in accordance with the conditions required in the rules, Rule 2.4 is activated and the transformation proceeds to Step 7 in order to adapt the existing rooms to create space for the remaining ones.

The rules in Step 7 used for this purpose are Rules 7.1 or 7.4, which allow rooms to be merged by (partly or totally) eliminating walls.

The application of Rule 7 may result in changes to the dimensions of the bedrooms that have already been attributed which contradict the hierarchy of size – e.g. a single bedroom which is larger than a double bedroom ($A_{be.s} > A_{be.d}$). In this case Rule 2.5 should be used to change the assignment of the bedrooms.

In accordance with Table 45, the next step will be the assignment of the private bathrooms.

On the basis of the number of private bathrooms calculated in the programme and defined here as *n*, *n* bathrooms must be found, which meets the following requirements:

– The private bathroom net floor area must conform to the areas shown in Table 21 (page 213), as expressed in the dimension conditions part of the grammar rules;

– The connections accepted between the private bathrooms and the surrounding rooms are expressed in the function conditions of the grammar rules:

  a. Private bathrooms must connect directly to a corridor;

  b. If there is more than one private bathroom, it can connect to a double or twin bedroom;

c. Circulation between private bathrooms and bedrooms may only take place via private or service corridors;

d. Private bathrooms must connect to bedrooms via one intermediate corridor (next_to) or two intermediate corridors (close_to).

– Private bathrooms must be assigned to non-habitable rooms or to an existing bathroom (Xba).

These requirements may only be altered if the requirements of particular households differ (for example, if one household wants all the private bathrooms to be accessed via bedrooms).

The attribution of private bathrooms includes the following sequence of actions:

– The first private bathroom is located where the original larger private bathroom stands (Xba) – Rule 2.6;
– If more than one private bathroom is required, the following procedure is necessary:
    - Introduction of *weight* to areas where new bathrooms may be located – Rule 2.7 (Figure 222 and Figure 223);
    - Assignment of private bathrooms – Rule 2.8 to Rule 2.15;
    - Removal of *weight* from areas where new bathrooms may be located – Rule 2.16.

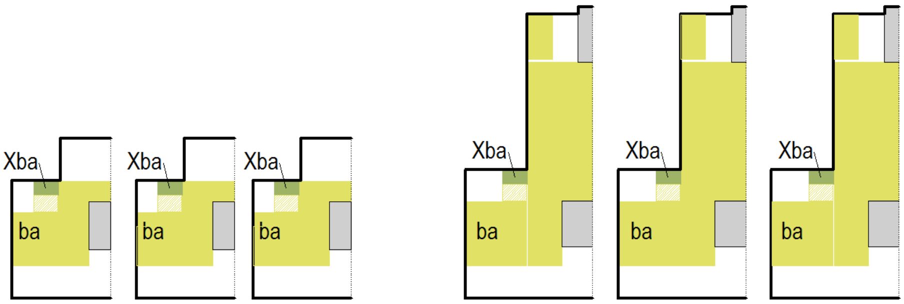
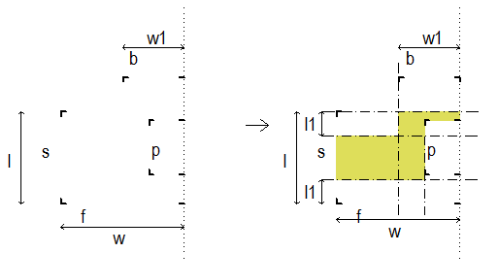


Figure 222 – Possible positions for new bathrooms, according to the strategy chosen. If the Xba position is as illustrated, a new bathroom can be created by continuing the geometry (Rule 2.7c)

Rule 2.7.a _ Attribution of new bathrooms placement weight: uba (type a and b)



Conditions:

$Z' \supset \{ba.p1\} \wedge Z \supset \{ba.p2\} \wedge Z' \not\supset \{ba.p2\} \vee$
$Z' \supset \{ba.p1\} \wedge Z \supset \{ba.p3\} \wedge Z' \not\supset \{ba.p3\} \vee$
$Z' \supset \{ba.p1\} \wedge Z \supset \{ba.g\} \wedge Z' \not\supset \{ba.g\}$

Dimensions:
$9.4m \leq l \leq 14m$
$5.7m \leq w \leq 18.5m$
$3m \leq w1 \leq 7.2m$
$l1 = 3m$

Description:

$R2.7a < D2: l, w, w1; \varnothing > \rightarrow < D2: l, w, w1, l1; uba >$

Note:

–·–·–·–·– auxiliary lines

Figure 223 – Rule 2.7a from the Step 2

The same situation that occurs with the attribution of bedrooms may be encountered: insufficient spaces with the requisite features for accommodating private bathrooms. Rule 2.18 is therefore activated and the transformation proceeds to Step 7 in order to adapt the shape of the existing rooms to find space for the remaining ones.

STEP 3. DEFINING THE SOCIAL AREA

The rules in Step 3 allow for two types of actions: assigning the habitable social room functions – i.e. combined living/dining room, living room, dining room, home office, media room – to an existing space, and assigning the guest bathroom function to an existing space.

Specifically, considering the required number of social rooms *n, as* defined in the functional programme, the grammar finds *n* rooms that satisfy the following requirements:

- The social room net floor area must conform to the areas shown in Table 21 (page 213), as expressed in the dimension conditions part of the grammar rules;
- The combined living/dining room and the isolated living room have to be habitable rooms as defined in Rule 3.1 and Rule 3.3;
- The dining room, home office and media room may be assigned to non-habitable rooms under certain conditions expressed in Rule 3.2, Rule 3.4 and Rule 3.8;
- A delimited or included home office is assigned by rules 3.5, 3.6, 3.7 (Figure 224);
- An isolated or included media room is assigned by rules 3.8 and 3.9 respectively;
- The connections accepted between each of the social area rooms are expressed in the function conditions of the grammar rules;

Some of the requirements in each rule can be overridden by specific family requirements such as when, for instance, a family might want a larger living room.

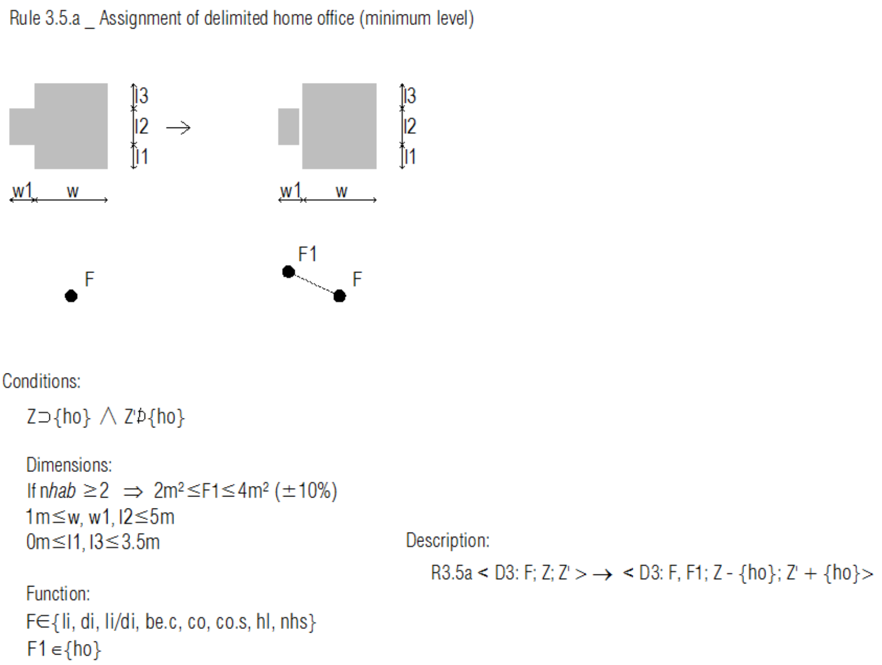


Figure 224 – Rule 3.5a from the Step 3

As was the case with private areas in Step 2, if there is not enough space to accommodate all the social areas required by the functional programme, Rule 3.10 is activated and the transformation proceeds to Step 7 in order to adapt the shape of the existing rooms to find space for the remaining ones.

The rules in Step 7 used for this purpose are Rules 7.1 or 7.4, which allow rooms to be merged by (partly or totally) eliminating walls.

This is followed by the assignment of the guest bathroom, which must meet the following requirements:

- The guest bathroom net floor area must conform to the areas shown in Table 21, as expressed in the dimension conditions part of the grammar rules;
- The connections accepted between the guest bathroom and the surrounding rooms are expressed in the functions conditions of the grammar rules:
    a. The guest bathroom can only be directly connected to a corridor from the social or service area;
- The guest bathroom must be assigned to a non-habitable room or to an existing bathroom (Xba).

These requirements may only be altered if the requirements of particular households differ (for example, if one household wants the guest bathroom to be located in the private area).

The attribution of the guest bathroom includes the following sequence of actions:

- Attribution of weight to areas where new bathrooms may be located – Rule 2.7;
- Assignment of guest bathroom – Rule 3.11 to Rule 3.14;
- Removal of weight from areas where new bathrooms may be located – Rule 2.16.

After the guest bathroom has been assigned and no more bathrooms are needed, Rule 3.15 allows the label of a remaining existing bathroom to be changed (e.g. an original bathroom used exclusively by the live-in maid).

The guest bathroom should be located within the area defined by weight and within the following hypotheses defined in the rules:

- In a non-habitable space or an existing bathroom (Rule 3.11);
- Adjacent to a side wall (Rule 3.12)
- As a part of the hall (Rule 3.13);
- As a part of an existing private bathroom (Rule 3.14).

After attributing the guest bathroom it may be necessary to change the shape of this space and the spaces adjacent to it and Step 7 is therefore activated.

STEP 4. DEFINING THE CIRCULATION AREA

The rules in Step 4 allow for one type of action, namely assignment of the circulation functions – corridor, private corridor and service corridor – to an existing space.

Given the need to connect the different functional areas within the dwelling, spaces must be found to meet this requirement. The grammar must therefore find rooms that satisfy the following criteria:

- Circulation spaces must be non-habitable rooms, as defined in Rule 4.1, Rule 4.2 and Rule 4.3;
- Circulation spaces are divided into 4 types:
    a. The hall (already assigned in Step 1 – Rule 1.1);

b. The private corridors (co.p) – spaces that only connect private rooms (be.d, be.t, be.s, ba.p, cl) to each other or to another circulation space. A private corridor may also connect to a social space (living, dining room or home office) if this space has one other door connecting to another corridor (co);
c. The service corridors (co.s) – spaces that only connect service rooms (ki, la, st) to each other or to another circulation space;
d. Other corridors (co) – spaces that connect social rooms (li, di, li/di, ho, mr, ba.g) to each other or to some of the other rooms;

The rules that assign the circulation areas are Rules 4.1, 4.2, 4.3.

Unlike the previous steps, there is no requirement for this step to conform to minimum areas but it should ensure that all the rooms attributed in the previous steps are connected to a circulation area.

If rooms are already assigned that do not have access via a corridor, one must be created. In this case Rule 4.4 is activated and the transformation proceeds to Step 7 in order to create a new circulation area. The rules in Step 7 used for this purpose are Rules 7.3, 7.5 or 7.6.

STEP 5. DEFINING THE SERVICE AREA

The service area consists of the kitchen and laundry. As the kitchen is already assigned in Step 0, the rules in Step 5 allow for only one action, the assignment of the laundry function to an existing room.

The functional programme always requires one laundry, so the grammar finds one room that satisfies the following requirements:

– The laundry net floor area must conform to the area shown in Table 21 (page 213), as expressed in the dimension conditions part of the grammar rules;
– The connections accepted between the laundry and other spaces are expressed in the functions conditions of the grammar rules.

The laundry should be located according to one of the following hypotheses defined in the rules:

– In the existing laundry area - Xla (Rule 5.1), in the case of Strategy 1 or 2;
– Included in the kitchen area (Rule 5.2), in the case of Strategy 1;

The rules that assign the laundry are Rules 5.1 and 5.2.

After attributing the laundry it may be necessary to alter the shape of this space and the adjacent spaces, and Step 7 is therefore activated.

STEP 6. DEFINING THE STORAGE AREA

The rules in Step 6 allow for one action, namely assigning storage areas – general storage and clothes storage – to an existing space.

The assignment of storage areas is not an obligatory step in the grammar, as furniture can be used to provide storage space in the dwelling.

Step 6 is used if there are non-habitable spaces still available in the dwelling (E) or if the functional programme (Z) asks specifically for these spaces.

When assigning storage areas to existing spaces, the spaces should meet the following requirements:

- Clothes storage areas (cl) can only be assigned to a non-habitable space inside the private area. Clothes storage areas must have a passage to, or be next to, a private area (co.p, be.d, be.t, be.s, ba.p) or the home office (ho). Rules 6.1, 6.3, 6.4;
- General storage areas (st) can be assigned to a non-habitable space that has a passage to, or is next to, a circulation area (hl, co, co.s, co.p), social area (ho or mr) or service area (ki, la). Rules 6.2, 6.3, 6.4;
- The connections accepted between the storage spaces and other spaces are expressed in the functions conditions of the grammar rules.

The rules that assign storage space are Rules 6.1, 6.2, 6.3 and 6.4.

A storage area is always:

- a spare space near the bedrooms (Rule 6.1 for clothes storage and Rule 6.2 for general storage);
- a space occupying the end zone of a corridor (Rule 6.3);
- a fitted cupboard built into a wall between a habitable room and a circulation area (Rule 6.4).

After attributing storage spaces it may be necessary to change the shape of these area and the areas adjacent to them and Step 7 is therefore activated.

STEP 7. ADAPTING ROOM SHAPE

Step 7 allows changes to be made to the shape of the spaces and all the rules for this step are optional. Step 7 is activated after each of the previous steps if it is necessary to make adjustments to spaces, or after Step 6.

This step includes rules that allow for 5 types of actions with various possible effects:

- Connecting spaces (Rules 7.1) (Figure 225)
    a. By eliminating entire walls (Rules 7.1a, 7.1b, 7.1c, 7.1d)
    b. By eliminating sections of walls (Rules 7.1e, 7.1f, 7.1g, 7.1h, 7.1k, 7.1l)
    c. By widening existing connections (Rules 7.1i, 7.1j)
- Separating spaces (Rules 7.2) (Figure 225)
    a. By adding a section of wall (Rule 7.2a)
    b. By adding an entire wall (Rule 7.2b)
    c. Reducing an existing connection by adding section of wall (Rule 7.2c)
- Creating or changing circulation (Rules 7.3 and 7.5)
    a. By first eliminating and then adding a wall (Rule 7.3a, 7.3b, 7.3c)
    b. By first eliminating and then adding a wall with the aim of changing the position of the guest bathroom (Rule 7.5a, Rule 7.5b, Rule 7.5c)
- Expanding spaces (Rules 7.4)
    a. By first eliminating and then adding a wall (Rule 7.4a, 7.4b, 7.4c) (Figure 226)
    b. By first eliminating one wall and then adding two walls (Rule 7.4d)
- Changing the position of a door by eliminating and then adding a wall (Rules 7.6)
    a. Changing to a position aligned with another door (Rule 7.6a)
    b. Changing to a position next to a partition wall (Rule 7.6b)
    c. Changing to a perpendicular wall (Rule 7.6c)

d. Changing the position of a door to create a connection to another space (Rules 7.6d, 7.6e)

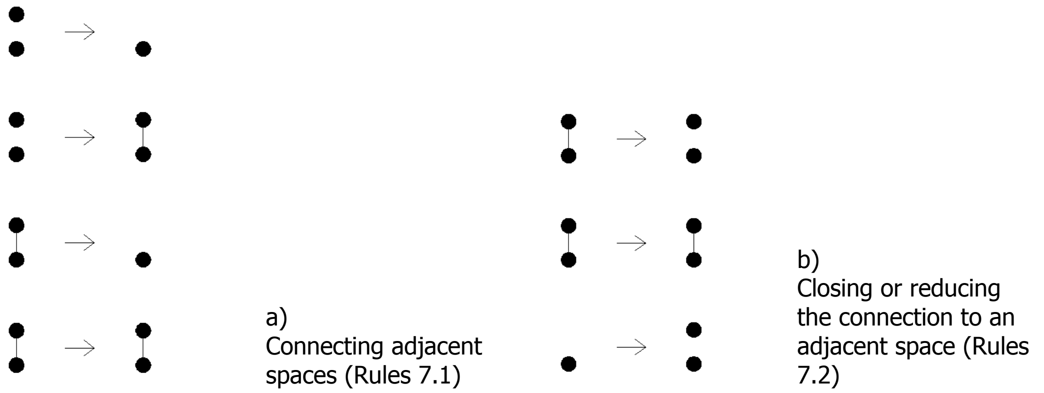


Figure 225 – Possible topological transformations involved in the adaptation of space shapes by connecting or separating spaces. Other types of shape adaptation involve non-changing graphs or a greater variety of hypotheses.

The use of graphs helped group the rules according to the topological transformations involved, without considering specific shapes. For instance, several rules may be used to add an adjacent space, but in all cases two nodes are merged (Figure 225 a)). As previously mentioned, graphs are used in a parallel grammar in which nodes and arcs are descriptions of space configurations.

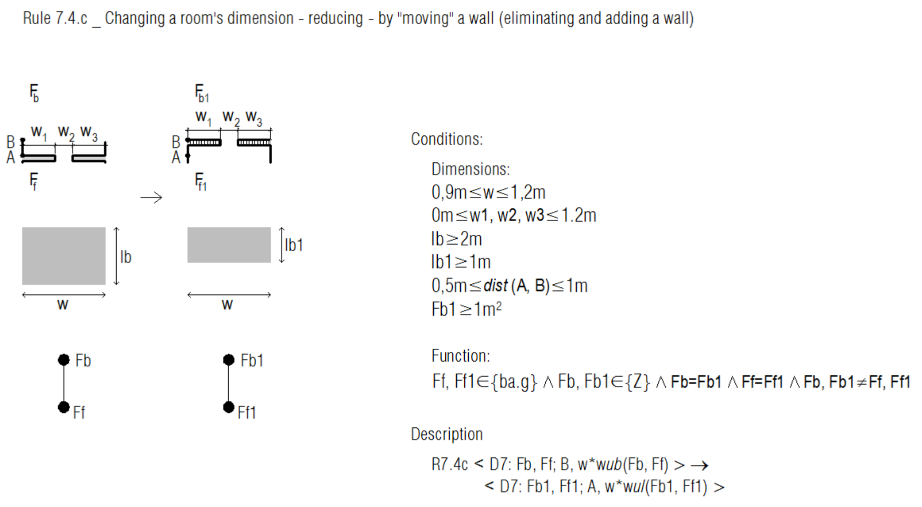


Figure 226 – Rule 7.4c from the Step 7

Step 7 is the last step in the functional adaptation of the dwelling and the final result that emerges is the final layout for the dwelling.

After this set of steps, ending with step 7, ICAT starts to be integrated into the new dwelling spaces. Step 8 of the grammar enables the technologies required by the adapted ICAT pack to be integrated into the dwelling.

STEP 8. INTEGRATION OF ICAT

The rules in Step 8 allow for the integration of all the major technology devices needed for the domotics system. Although the aim of the previous steps was to transform a dwelling using rules that work with the existing elements, Step 8 intends to integrate new elements into an already defined dwelling and therefore uses rules for adding devices.

The symbol *X* is used to describe the set of devices belonging to the ICAT pack needed for each family. During the transformation, the symbol *X′* is used to describe the ICAT set already incorporated into the proposed dwelling.

Given the large number of rules that had to be created to enable all the ICAT components to be integrated, it was decided to develop some as an illustration and leave the others for a future project.

The choice was therefore made to define rules for the integration of the sensors most commonly used in domotics, namely gas, smoke, temperature, water and movement sensors.

The positioning of sensors, namely gas, temperature and water sensors, is related to the arrangement of the bathroom and kitchen equipment, such as the wash basin, bath, dishwasher, washing machine, boiler, cooker and oven. Other sensors, such as movement sensors, may also be affected by the way in which furniture is arranged. In order to ensure that the shape grammar for the integration of this equipment is correct, the design for the dwelling should incorporate all the component elements, such as fixed and moveable equipment.

In accordance to the definitions established up to this stage, the representation of the dwellings in the study includes a definition of the spaces and construction components based on the traditional architect's floor plan, graphs and convex shapes. Given that the original plan for the dwellings comes from the architectural records held by the CML, the bathroom equipment and related definition of the kitchen equipment are defined on the basis of the original plans.

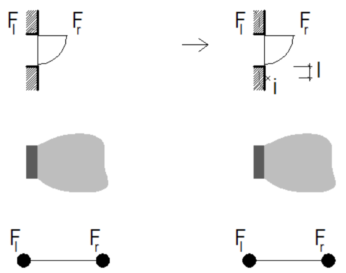
However, no grammar rules were developed for the design of new bathrooms or new kitchens, since the work did not aim to cover this level of planning. Therefore the development of grammar rules for positioning sensors or other domotics devices affected by fixed and moveable equipment in the dwellings was not considered.

This step includes the following rules for allocating the different ICAT components:

- **Allocation of detectors and sensors (Rules 8.1)**
    a. Water detectors (Rule 8.1a)
    b. Smoke detectors (Rule 8.1b)
    c. Temperature detectors (Rule 8.1c)
    d. Gas detectors (Rule 8.1d)
    e. Movement detectors (Rule 8.1e)
- Allocation of alarms (Rule 8.2, not designed)
- Allocation of CCVT cameras (Rule 8.3, not designed)
- Allocation of controlled HVAC appliances (Rule 8.4, not designed)
- Allocation of controlled lights (Rules 8.5, not designed)
- Allocation of controlled blinds and screens (Rules 8.6, not designed)
- Allocation of controlled doors and windows (Rules 8.7, not designed)
- Allocation of controlled watering (Rule 8.8, not developed)
- Allocation of controlled domestic appliances (Rule 8.9, not designed)
- **Allocation of interfaces (Rules 8.10)**
    a. Control panel (Rules 8.10a) (Figure 227)
    b. Multifunctional switches (Rules 8.10b)

- Allocation of controlled sockets (Rule 8.11, not designed)
- Allocation of ITED (Telecommunications Infrastructures in Buildings) sockets (Rule 8.12, not designed)
- Allocation of home cinema components (Rules 8.13, not designed)

Rule 8.10.a1 _ Allocating of interfaces: control panel (i)



Conditions:

$X \supset \{in\} \wedge X \not\supset \{in\}$

Position:

$0.2m \leq l \leq 0.8m$

i (mounted-on(z)) = TRUE $\wedge$ $z \in \{wall\}$

Function:

$Fl \in \{lh, sh\}$

$Fr \in \{hl, co, co.s\}$

Figure 227 – Rule 8.10a1 from the Step 8

4.4.3 Strategy three _ an approach to the transformation rules

Although transformation strategy 3 – which envisages dividing one dwelling into two autonomous dwellings (see *Part 2: Chapter 2.3.2*) – was not pursued from a methodological point of view, this chapter presents some conclusions that were reached during the transformation process and which summarise the main options involved in using this strategy in the sample studied.

The process of dividing one dwelling into two smaller autonomous ones involves the following sequence of steps: i) choosing the desired typologies; ii) defining the method for dividing the dwellings; iii) defining the access to the dwellings; iv) defining the new kitchen (Figure 228 and Figure 229); v) defining the new bathroom(s) (Figure 228 and Figure 229); vi) defining the social area; vii) defining the private area; viii) defining the circulation area; ix) defining the storage area.

The first step involves deciding on the intended typologies. This decision is restricted to T0, T1 e T2 dwellings and, depending on the type of "rabo-de-bacalhau" building in question and its area, a dwelling may be divided as follows: (Table 23, page 228):

- 2 T1s
- 1 T0 and 1 T2
- 1 T1 and 1 T2
- 2 T2s

In the next step the location for the room of the dwellings is chosen, according to the different types of dwelling morphologies. As previously stated, there are three possibilities for this rehabilitation option, which are illustrated in the tree in Figure 141 (page 230) and in Figure 145 (page 237):

- Dividing the dwelling into two autonomous units, with the larger one retaining all the rooms in the main facade and one room facing the rear facade of the main wing, whilst the other, smaller unit only receives natural lighting and ventilation via the rear wing facades;

- Dividing the dwelling into two autonomous units by means of a straight line parallel to the main facade, with one of the new dwellings receiving natural lighting and ventilation via the main facade and the other via the rear façade of the main wing and the side and rear façades of the rear wing;
- Dividing the dwelling into two autonomous units with the smaller one (T0 or T1) facing the main facade only and the larger one receiving natural lighting and ventilation from all façades.

In most of the cases studied, access to the new dwellings requires an extension to the existing lift/stair lobby. In the hypotheses tested , this was not required only in cases where the main vertical access nucleus to the dwelling contained two direct entrances (see the image on the left in Figure 231).

Dividing one dwelling into two autonomous dwellings involves doubling the bathrooms and kitchen. Therefore, whilst always bearing in mind the possibility of combining this option with the other rehabilitation strategies (the 1st and 2nd strategies), the aim was to position the new kitchen and bathrooms to allow for some superimposition over the various floors, thereby promoting the construction and use of a new vertical duct for infrastructures (Figure 228 and Figure 230).

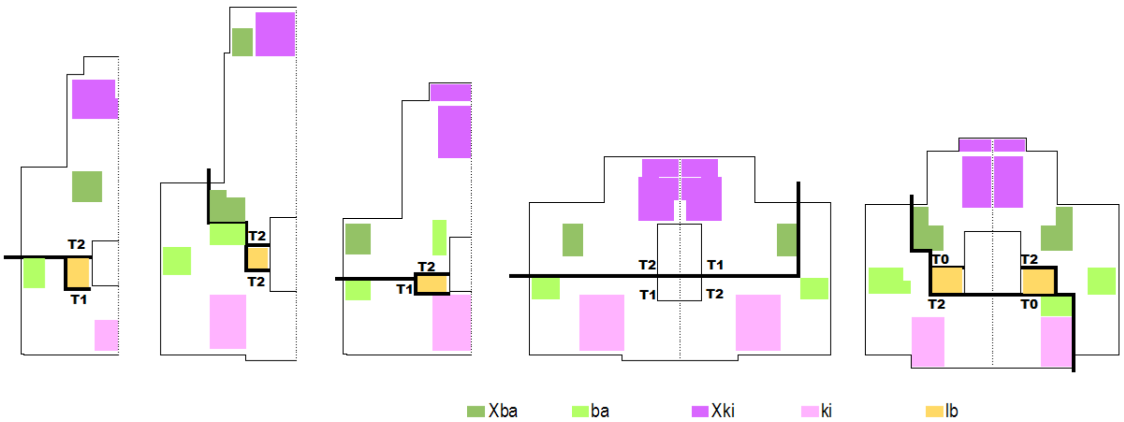


Figure 228 – Examples of locations for new bathrooms and kitchens according to different dwelling types.

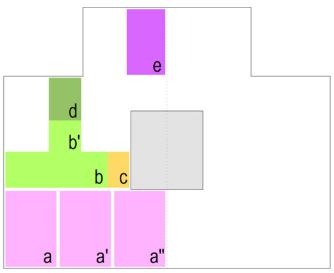


Figure 229 – Scheme for the allocation of new spaces using the 3rd rehabilitation strategy

a, a' and *a"* – Allocation of the new kitchen. The kitchen should be located in the smaller space – *a, a'* or *a"*

b e *b'* – Allocation of the new bathrooms

c – Extended floor lobby to provide access to both dwellings on each side of the floor

d – Existing bathroom

e – Existing kitchen

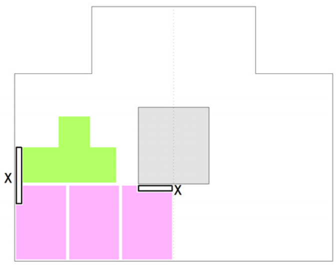


Figure 230 – Possible location (x) of infrastructure ducts to be built if the entire building is to be rehabilitated.

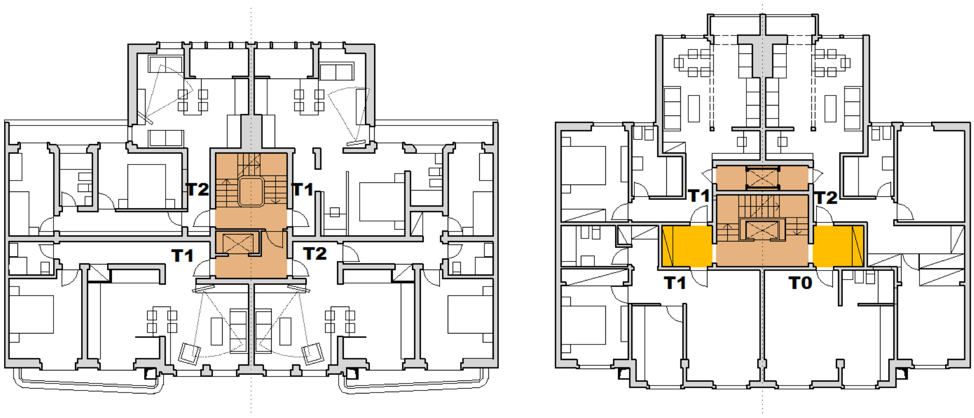


Figure 231 – Left: building whose vertical access nucleus provides access to 4 dwellings on each floor without the need for any intervention work. Right: building in which an extension to the lobby has been created, since the main vertical access nucleus only provides access to two dwellings.

CONCLUSION

As stated at the beginning of this thesis, this research aims to propose a methodology for rehabilitating the existing housing stock to enable it to respond to new housing requirements resulting from the use and integration of technology, essentially ICT and domotics.

This objective emerges from various arguments which were presented at the beginning of the text, relating to the following areas:

- ICAT
  - The use of technologies, namely ICT and domotics, is essential nowadays and affects the spatial/functional organisation of housing;
  - ICATs should be integrated into housing in accordance with the real needs of users and should have the potential to be upgraded;
- Housing rehabilitation
  - The future of housing, in the Portuguese context and in particular in the urban centres, involves rehabilitation of the existing stock;
  - It is possible and desirable to integrate ICAT into the existing housing stock;
- The rehabilitation methodology
  - It is possible to produce a proposal for a rehabilitation methodology that provides for an improved and efficient process based on predefined criteria;
  - The formalism of shape grammars enables to infer rules from the transformation of an original dwelling into an adapted dwelling, following clear criteria;
  - The use of space syntax in combination with shape grammar guarantees that designs with adequate functional organisation are generated.

These themes were explored in the theoretical framework developed in *Part 1* of this thesis and the concepts defined were applied in elaborating the rehabilitation methodology, which is developed in *Part 2* of the thesis.

This section aims to summarise the arguments that have been used throughout the thesis to justify the main arguments. It also aims to illustrate the impact and the contributions that the thesis brings to architectural practice and research and, finally, to identify future lines of research within the context of the themes covered by the thesis.

THE ROLE OF ICATS IN HOUSING AND IN REDEFINING LIFESTYLES

Information is playing an increasingly important role in our lives and, as a consequence, ICAT is changing the ways in which we inhabit spaces.

The situation in Portugal with regard to the Information Society (*Part 1: Chapter 1*) shows that a growing percentage of the population uses ICT in several aspects of their daily life. Recent intelligent technologies aim to maximise the use of information with the dual goal of providing houses with increased access to information and using automated control systems. The incorporation of intelligent features adds value to homes and enhances the inhabitants' quality of life, whilst also contributing towards better housing management. Home automation technologies increase comfort in houses and help inhabitants with routine domestic tasks, thus promoting independence. This fact is of major importance to the elderly and people with reduced mobility or other disabilities.

This thesis proposes an interpretation of the changes affecting housing resulting from the use of technologies, namely ICT and automation technologies. These changes were included in the housing requirements using various strategies: increasing the area of rooms; introducing new essential functions (e.g. telework) or secondary functions (e.g. home cinema); relationships between rooms.

At present, domotics is incorporated into multi-residential buildings without prior knowledge of the end users and generally using proprietary protocols which restrict the upgradability of the domotics system. However, different households may be at different stages in the family lifecycle, which may call for certain activities and not others. Other apparently similar families may have different priorities due to certain circumstances. This means that ICAT must be integrated with a focus on end user needs or at least through a basic ICAT pack which allows the system to be easily upgraded by future residents.

This thesis proposes three scalable levels of ICAT integration according to different family profiles. This scalable process allows for a more flexible form of integration, in accordance with the family budget but without compromising the upgradability of the system, by proposing the use of open domotics standards.

HOUSING REHABILITATION AND ICAT INTEGRATION

The rehabilitation of existing housing stock is a priority in the political agenda. In addition to the need to upgrade constructional features, the existing housing stock must meet the new space-use requirements demanded by new information age life-styles as well as ecological, social, and economic sustainability requirements.

The integration of ICAT into housing has repercussions, both in terms of the functional organisation of dwellings due to new forms of occupying space, and in terms of construction, due to the need to install cabling that will allow for the maintenance and upgrading of all components in the system.

The repercussions of the use of these technologies in housing rehabilitation imply different kinds of restrictions, affecting both the existing rooms in dwellings and the laying of cables (including a low floor-to-ceiling height, lack of depth in flooring for embedding cables, and the need for numerous chases due to the exclusive use of brick masonry walls, amongst other factors).

The thesis identifies strategies that enable an adequate balance to be achieved between the stated goals.

> "In a world inundated by new things it is not a bad strategy for the architect to seek maximum continuity with the past, without rejection of what is of our own times. Let the circumstances and practical needs to be added to the spatial tradition and enrich it, rather than replace what is still valued" (Habraken, 1988: 18)

Within this line of thought, it was decided to use a form of rehabilitation work that would respect the existing situation, keeping demolition and new construction work to a minimum whilst also enabling the proposed objectives to be met.

In *Part 2: Chapters 2, 3 and 4,* methodologies were therefore proposed for housing rehabilitation from the point of view of the functional aspects and ICAT to be integrated and how this can be achieved in constructional terms.

FUTURE NEEDS

From the outset, the aim of this research was to ensure that the proposals presented in the thesis would respond to contemporary needs, including both current and future needs. "Contemporary" refers here to the time when the adaptation is performed, implying that the methodology still remains accurate even if different future parameters are used.

These goals raise several questions concerning the proposals.

One of the questions is whether the proposed rehabilitation principals are adequate for future as well as contemporary contexts. A second question concerns whether the ICAT in question will remain the technology used in the future.

This thesis offers answers to both questions that are based on current trends in the evolution of families and technologies.

Regarding families and households, the thesis considers contemporary household types and the perspectives for their evolution in the near future. These considerations are based on statistical forecasts for the Portuguese population and on sociological literature. Although new forms of families are emerging they are not threatening the traditional family types, meaning that there will always be several different kinds of households.

Single people, heterosexual or same-sex cohabitation, families separated by time and space, people of different genders, races, classes or ages are all contemporary and future families (Zinn and Eitzen, 2005). All of them have the same basic needs and some specific needs. This thesis presents three rehabilitation strategies that respond to the needs of different households. The final solutions range from smaller to bigger houses, smaller to bigger specific rooms, different forms of connections and the possibility of customising housing requirements at an early stage in the process. These strategies are considered to be as flexible as possible in order to ensure that any dwelling can be adapted to meet contemporary and future needs. The transformations carried out in the initial rehabilitation do not obstruct or prevent future interventions, since they are not very intrusive in terms of demolition and building work.

Two aspects that were not explored in this thesis are: i) the different forms and future trends for legally occupying a house, such as ownership, and long or short-term (individual or collective) rental; ii) the possibility of rehabilitating a dwelling for a group of unknown people who will rent part of the dwelling, rather than for a group of people already acquainted with each other. These possibilities will respond to new requirements for short-term house occupation as well as increasing the mobility of households. Studies of these situations are therefore extremely important in terms of increasing the future success of housing rehabilitation.

The future application of the proposed technologies is the most unpredictable aspect to emerge. Although the specific technologies addressed here may change or evolve in the future to become more sophisticated, some general aspects of ICAT have been highlighted and are applicable regardless of the technology in question. These aspects are: i) considering the real needs of users instead of a "standard" set of domotic appliances; ii) the need to use a reliable and integrated automation system; iii) the advantages, in terms of future upgrades, of using an open domotic communication protocol; iv) the definition of a recommended basic level of ICAT integration for all family profiles, together with all the necessary cable infrastructures that will enable the system to be upgraded in the future.

Rehabilitation methodology and the formalism of the transformation grammar

The main goal of this thesis was to define a methodology to support architects involved in the process of adapting existing dwellings and incorporating ICAT.

The use of the proposed methodology allows for different rehabilitation solutions according to variable factors, namely the different families and their needs and lifestyles.

The proposed methodology therefore presents a precise sequence of steps which include the family as a key reference point in defining the housing programme and the ICAT pack to be installed. In the absence of a real-life family the methodology can also be followed by using a family type as a reference. This proposed process allows both for rehabilitation on a large scale in one or more buildings, or rehabilitation of only one dwelling, with customisation being the objective in both cases.

This customisation allows for a wider range of typologies within the building, in terms of the number of rooms per dwelling, the number of dwellings per floor and the areas available.

In order to test the methodology in a specific case and explore it in greater detail, a case study was chosen involving "rabo-de-bacalhau" buildings, due to the fact that these buildings are already more than half a century old and consequently need functional, constructional and technological rehabilitation and also because they have a very clearly defined morphology.

Shape grammar formalism was used as a tool in the rehabilitation of existing "rabo-de-bacalhau" buildings. In this context, formalism is used to encode the rules for transforming existing dwellings into new ones, adapted to contemporary life-styles. In addition, space syntax is used to form a parallel description grammar to guarantee that designs with a suitable functional organisation are generated. The resulting compound grammar is proposed as a way of developing and encoding a methodology for housing rehabilitation that can easily be explained to, and applied by, architects.

The use of a transformation grammar as an integral part of the rehabilitation methodology speeds up the decision-making process by providing a clearly defined framework for the work (Duarte, 2007: 275). In this sense, the grammar enables the way on which decisions are made to be structured so that, in using it, designers can understand how to alter the dwellings according to the data in question. In this context the transformation grammar enables rehabilitation to be customised because it responds to specific requirements and may propose several hypotheses for dwelling layouts.

The transformation grammar is structured as a discursive grammar, which includes a shape aspect and a descriptive aspect that evolve in parallel to ensure that an appropriate dwelling design can be obtained from the description contained in the functional programme for the dwelling.

Contributions

As summarised in the Introduction to this thesis the research carried out resulted in a varied set of contributions:

1. A characterisation of the "rabo-de-bacalhau" building type.

   The "rabo-de-bacalhau" building type was chosen for the study mainly because its topology is very representative of the period in which it was built (1940s/60s) and it features prominently in the city.

Despite the significant presence of these buildings in the city, this building type has not been the subject of any specific study, although it has been referenced by various authors in general works on housing and/or the 1940s/50s/60s.

In this thesis, these buildings are characterised with the aim of understanding the design principles behind the building type in order to decide how they can be used today. It was therefore necessary to study the buildings from the functional, technical/constructional, stylistic and social point of view of the time when they were built. In addition to this study, a diagnosis of the current situation regarding the use of these buildings is also presented, on the basis of a survey of the dwellings and consultation of the plans held by the CML. This diagnosis enabled patterns of use to be identified, as well as the potential and restrictions involved in the use of the buildings.

2. <u>A method for defining the ICAT packs to be integrated into the housing, according to family profiles</u>.

   Smart homes should address residents' demands and needs. However, the small percentage of domotic equipment in multi and single family residential buildings has been incorporated in a manner that does not consider either the technologies implemented or the real user needs in an integrated way. This is because home automation is usually installed without the previous knowledge of the end-users or without understanding the exact needs of residents.

   To ensure that an efficient method was proposed it was considered necessary to define certain premises for the definition of the ICAT packs in advance. These premises concern the definition of family profiles, the real needs of individuals and the technology generation, all of which influence the choice of domotics options. In addition to current resident characteristics, the method also anticipates future family needs and activities within the home.

   It was considered necessary to define different levels of ICAT integration that would meet the real needs of residents, taking into account the evolution of their requirements and hence the need to upgrade infrastructures. These levels allow for a scalable incorporation of ICAT, starting with the basic pack and allowing for easy upgrading of the system, culminating in a complete domotic home.

3. <u>The conception of a rehabilitation methodology based on a rigorous process: a general and a specific methodology</u>

   Unlike traditional rehabilitation processes executed on an individual case basis for each family/dwelling combination, this thesis proposes a methodology to support a process which clarifies decision-making and speeds up the project. Various rehabilitation methodologies have been defined for working with buildings of important heritage value and for buildings which form part of the general urban fabric.

   The benefit of the proposed methodology, intended for the first phases of the rehabilitation project, is its ability to impose a very precise and systematic form of intervention.

   Several phases are defined to complete the intervention, each with specific inputs and outputs from the client/resident following the rehabilitation assumptions defined – functional reorganisation and integration of ICAT.

This methodology includes both the architect's knowledge and knowledge acquired from previous experiences of rehabilitation work in the form of principles and rules. These rules are used to transform dwellings and incorporate substance and knowledge and are assumed to represent the architect's knowledge from a wider perspective.

The use of a transformation grammar as a tool for transforming existing dwellings enables shape transformation to be managed within dwellings to create a systematic and methodical process that can encompass all the valid transformation rules for a given dwelling. The transformations respond to functional and technical requirements as well as constructional requirements.

The methodology developed is a general rehabilitation methodology because it can be used in different building types by applying the main steps of the methodology. When all the steps of the methodology are applied it is a rehabilitation methodology specific to the "rabo-de-bacalhau" building type.

4. <u>The development of a transformation grammar</u>

Within the context of research into shape grammar theories, this thesis proposes a new approach to their use in architectural rehabilitation processes.

The grammar proposed in this thesis is called a transformation grammar, as it aims to transform dwellings in order to adapt them to contemporary user needs.

Existing works on shape grammar explore the possibilities of generating designs based on rules using both an analytical approach (to understand existing design languages) and a generative approach (to generate new design languages). This work proposes a different approach, in that it aims not to generate the design of the dwellings in the study or their design after transformation, but the rules that enable them to be adapted to new lifestyles. The transformation grammar is used as part of a proposed methodology that can be used to rehabilitate existing dwellings.

In the current research the grammar is parametric because of substantial differences in the shape and dimensions of the rooms in the dwellings. This grammar is also a compound grammar since it uses several representations of shapes in the rules. Other shape grammar formalisms such as weights and labels are also used. The transformation grammar is structured as a discursive grammar, which includes a shape aspect and a descriptive aspect that evolve in parallel. In order to evaluate the functional conditions of the dwellings in the case study (the original and the rehabilitation proposals), space syntax theories are used in combination with the transformation grammar.

Future lines of research

Ideas for future work which may be developed within the scope of this thesis can be grouped into three categories which are related to the themes that have been covered, namely transformation grammar, the integration of domotics and housing rehabilitation.

Within transformation grammar, future lines of research focus on four essential areas:

Developing a computerised transformation grammar

The transformation grammar defined in this thesis proposes a formalism for its structure, the sequence of steps to be followed in its application and the rules it contains. The grammar was tested through various derivations but in this phase absolute verification of its feasibility and correction of any anomalies would involve computerisation. In addition to testing and correcting the grammar, this would enable it to be used in a rehabilitation design context and, in a second phase, to incorporate rules inferred from other types of buildings in order to develop a general transformation grammar.

Developing a more general transformation grammar

This thesis proposes both a general methodology that can be applied to different building types as well as a specif methodology developed from the previous one but specific for the "rabo-de-bacalhau". The methodology developed is a general rehabilitation methodology because it can be used in different building types by applying the main steps of the methodology. Although, when all the steps of the methodology are applied it is a specific methodology appliable to the "rabo-de-bacalhau" building type.

In the definition of the transformation grammar rules were divided into different groups according to the nature of the work involved – demolishing walls, adding walls, assigning functions, among others. These groups of rules were used for "rabo-de-bacalhau" buildings. Nevertheless, they reflect all the types of actions involved in rehabilitation works which means that all the major aspects of rehabilitation works are already implemented in the grammar.

A generalization of the grammar would begin by the use of the same general framework of rules and then integrate specificities of different building types – considering different construction constrains, different functional organizations, among other parameters.

The development of a more general transformation grammar is done by extracting from the "rabo-de-bacalhau" grammar its methodological structure and rule types and using this information in the definition of a more general grammar that can be applicable in the development of other specific transformation grammars.

Developing the grammar for the third rehabilitation strategy

The transformation grammar was developed for rehabilitation strategies 1 and 2 and was only outlined for strategy 3, which involves dividing the dwellings into two separate units. With a view to achieving typological diversity within the building using the grammar transformation tool, it will be necessary to develop rules that enable dwellings to be divided and add these to any future computerised implementation.

Completing the grammar for the incorporation of ICAT in order to enable these technologies to be fully integrated using the grammar. This task would imply that the grammar covered a level of detail in the design that was not the objective of the current research. The full development of this grammar and its extension to other types of buildings would enable the grammar to be used autonomously both in rehabilitation projects and new construction work and with any building morphology.

Within the context of the integration of ICT and, in particular, home domotics, future lines of research focus on two essential aspects:

Developing a computerised system for the process of selecting ICAT according to family profile, similar to the one produced by Duarte (2001) using the PAHPA programming grammar for the housing functional programme. As previously stated, this option would make the process of choosing services, functions and domotics components more efficient and flexible and better informed.

Carrying out a more detailed study of the integration of domotics, focussing specifically on the elderly and disabled population. The present Portuguese demographic context shows a trend towards a growing elderly population and it is therefore important to study hypotheses for integrating ICAT into housing as a complement and, in some cases, an alternative to assisted health care and residential systems. In this sense, it would be important to extend the study to a national context that would allow for an analysis of the acceptance of technologies by these groups and of socio-economic strategies, so that the latter can be incorporated into housing through support from the public sector.

In terms of housing rehabilitation, it would be important, given the national context, to pursue the following lines if research:

Increasing the typological diversity of the rehabilitation strategies by incorporating other emerging types of housing, such as typologies with shared services (kitchen. laundry), or shared communal areas (kitchen, laundry, dining areas) for single, young or elderly people. This analysis would increase the viability of rehabilitation work for the building type studied, promoting a response within the housing sector to various sections of society.

Studying "rabo-de-bacalhau" buildings from the point of view of constructional rehabilitation, diagnosing the current situation in these areas and proposing measures to complement those presented in terms of energy efficiency (passive measures) and structural, acoustic, thermal, fire safety and restricted mobility access rehabilitation measures, amongst others.

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LIST OF ILLUSTRATIONS

All the figures sources are listed in their caption.
SE stands for Sara Eloy
AC stands for André Cruz