NOVA IMS Information Management School

MGI

Mestrado em Gestão de Informação
Master Program in Information Management

DESIGN OF A SMART HOME TOOLBOX:

AN IOT IMPLEMENTATION GUIDE TO COMMON CITIZENS

Ana Catarina Mena Adelino

Dissertation presented as a partial requirement to obtain the Master's degree in Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

LOMBADA MGI

2021

Título:

Subtítulo:

Nome Completo
do Aluno

MGI

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

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by

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Dissertation presented as a partial requirement to obtain the Master's degree in Information Management with a specialization in Marketing Intelligence

Advisor: PhD Vítor Duarte dos Santos

July 2021

ACKNOWLEDGEMENTS

I would like to start by thanking my thesis advisor, Professor Doctor Vítor Duarte dos Santos for his guidance, availability, and time. His support not only has contributed to the development of this master's thesis, as also challenged my working methods and way of thinking. His influence on this thesis' theme was crucial as he was already eager to investigate it. Hence, I could not feel more honored and grateful for sharing with him the interest in this subject.

I would also like to appreciate the curiosity and availability of the ones who participated in this study's validation. Their knowledge and enthusiasm played a key part in this investigation. They are Prof. Dr. João Cortez (professor and co-founder of Inspired Blue), Nuno Gonçalves, (CEO of Emitu) Joel Reis (CEO of Life Emotions), Inês Cabanas (Manager at Life Emotions*)*, Luísa Mendes (video editor), and Guilherme Dias (surf instructor).

Finally, I also want to thank my family, especially my mother, who supported me when time seemed to be too short to work and study simultaneously. Also, my friends, who have encouraged me to never lose track of what is important in education: the capability of surpassing our boundaries and contribute to our society.

ABSTRACT

Smart Homes' technology is no longer a new theme as it's becoming more available and accessible to the public. However, its fast expansion may undermine the public's perception of what type of devices currently exist and how to install them. This study addresses the need of getting common citizens closer to Smart Homes' technology. Thus, a Toolbox is proposed to help non-technical people transforming their homes by sharing with them recommendations regarding different technologies and their setup.

Conducting this study required a clear definition of Smart Home: a home where comfort and convenience can be enhanced through technology, by offering several potentialities such as elderly assistance, energy efficiency, devices' control, security, entertainment, wellness, and others. A theoretical overview is performed over concepts such as IoT and Domotics, and a systematic literature review allowed the disclosure of the current applications and technologies. Findings suggest that elderly assistance is one of the main applications being developed today, while comfort enhancement and tasks' optimization represent common desires to the user experience.

Interviews have confirmed the usefulness of the artifact and the possibility of getting citizens more aware of Smart Homes' technology. Regardless concerns on privacy issues, the feedback suggested the improvement of users' autonomy in selecting devices. The increased awareness of the public may stimulate designers and vendors to develop a better knowledge on users' preferences and deliver more appropriate features to their needs, in the future. By adding new meaning to Smart Homes' access, it's also expected an increase of users' acceptance and further technological progress.

KEYWORDS

Smart Home; Domotics; IoT; Home Automation; User Experience

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LIST OF ABBREVIATIONS AND ACRONYMS

AI	Artificial Intelligence
API	Application Program Interface
APP	Application
DID	Device ID
DIY	Do-It-Yourself
DSR	Design Science Research
FSR	Force-Sensitive Resistor
GSR	Galvanic Skin Response
ICT	Information and Computing Technology
IoT	Internet of Things
LCD	Liquid Crystal Display
LED	Light-emitting Diode
LPG	Liquid Petroleum Gas
M2M	Machine-To-Machine
MPU	Microprocessor
NLP	Natural Language Processing
SBC	Single Board Computer
SMS	Short Message Service
PIN	Personal Identification Number
PIR	Passive Infrared
PM	Particulate Metter
VOC	Volatile Organic Compounds

1. INTRODUCTION

The following introduction will contextualize this investigation by providing insights on its background and problem definition, specific objectives, and structure.

1.1. BACKGROUND AND PROBLEM IDENTIFICATION

The 21st century brought numerous technological advancements that allowed us to experience our daily lives through Internet. Internet users have expanded and, today, engaging with connected devices that respond to our needs is not only possible but a growing trend (Miori & Russo, 2014; Nikou, 2018). One of the many applications of these devices is embedded in Smart Homes. As modern houses equipped with smart interconnected objects, they have been upgrading the domestic environment of many citizens in many fields, such as energy efficiency and elderly care (Sovacool & Furszyfer Del Rio, 2020).

Smart Homes have become new alternatives to compete in the market for Information and Computing Technology (ICT) companies (Shin et al., 2018). The authors considered the Internet of Things (IoT) a contribution to this trend by promoting the connection between home appliances, such as refrigerators, and services, such as lights' control. Although high prices have been undermining Smart Homes' expansion according to Balta-Ozkan et al. (2014), it's now easier and less expensive to find Smart Homes' technology at stores, online, and in advertising (Wright & Shank, 2019). An increasing interest for these devices is thus being registered, but their diffusion is still not matching expectations (Hong et al., 2020; Shuhaiber & Mashal, 2019). Authors perceive the limited know-how of the citizens regarding Smart Homes and related technologies as a great factor undermining their expansion, along with the vast diversity of devices in the market (Mocrii et al., 2018).

A growing number of people have soon realized the many benefits embedded, but still miss the expertise to proceed further selection and setup of technologies (Mocrii et al., 2018; Wright & Shank, 2019). The authors realize Smart Homes as a future reality to many, thus granting its basic knowledge to common citizens represent the focus of this research. A user-friendly Toolbox coupled with recommendations on how to properly setup an intelligent home can be key inputs to narrow the gap between the general public and Smart Homes' Technology. Recommendations regarding the current types of devices and their installation setup details will, expectedly, help citizens transforming their traditional home into a smart one.

1.2. Specific Objectives

The purpose of this work is the design of a ToolBox capable of guiding, and simplifying, the implementation of IoT systems in domestic environments. It's also expected the acknowledge of how different types of sensors can be used to enhance traditional homes' capabilities, except from the assembled products, end-used products, or smart packages. These aggregated technologies will not be considered to this investigation given the markets' diversity, hence only types of devices will be further exhibited. Efforts will be made only to include some of the most requested technologies in a typical Smart Home, without mentioning specific product names or brands. Additionally, the communication between sensors is also excluded from the objectives of this research as it would widen its scope.

To achieve this investigation's goal, some intermediate objectives were defined as following:

1. Study of the conceptual and applicational state-of-the-art of Smart Homes, Domotics, and IoT fields.
2. Study of the current technologies being used in Smart Homes and their most relevant applications.
3. Study of the most relevant Smart Homes' technologies and users' experience (installation).
4. Design of the ToolBox.
5. Validation of the ToolBox.

1.3. Structure

This investigation encompasses five chapters, each one mentioning a different topic.

The first chapter presents an Introduction, including the background and problem identification, specific objectives, and structure of this study. An overview and brief state-of-the-art of Smart Homes are made to provide some context to the investigation. Furthermore, the research focus is stated as well as the motivation to pursue it and achieve the proposed objectives.

Afterwards, the chosen Methodology for this study is presented. The Design Science Research (DSR) method was selected to be adapted to the problem in hands with the contributions of Hevner et al. (2004) and Peffers et al. (2007). A brief explanation of each stage is given, and their adaptation to this study is also included in the chapter.

According to the selected methodology, a Literature Review is performed and divided into two sections: firstly, a theoretical overview of Smart Homes is done (i.e., Smart Home's Concept and

Applications, and IoT), so that a Systematic Literature Review can disclosure the current developments in academia, regarding Smart Homes' applications and technologies.

Considering the previous information and the output of the Systematic Literature Review, the Smart Homes' Toolbox Framework can be presented. Hence, the steps of the process are clarified, and evaluated by technical and non-technical audiences.

The final chapter encompasses the conclusions of this investigation, its limitations, and future improvements to scientifical and academical contributions.

2. METHODOLOGY

As the desired output of this study to be the design of a Smart Home Toolbox that helps a "non-engineer" to understand Smart Homes' Technology, a Design Science Research (DSR) Methodology was chosen to conduct this investigation.

The DSR refers to a research approach that emphasizes the development of a solution, to a given problem, while striving for its utility (Cleven et al., 2009; Hevner et al., 2004; March & Smith, 1995). It balances scientific rigor, relevance, and practical application, by developing an artifact capable of solving a problem in an innovative way and purposeful way (Hevner et al., 2004). Artifacts differ in their nature, as they can be tangible, such as objects or products, or intangible, such as constructs, methods, models, or instantiations (March & Smith, 1995).

Therefore, the proposed Toolbox will constitute an artifact due to its tangible quality and potential to address this investigation's problem. The chosen methodology will expectedly unlock useful contributions to the technology world by exposing the utility of the proposed artifact.

2.1. Design Science Research (DSR) Methodology

A variety of steps are suggested in the literature to solve identified problems. Nevertheless, the developments made by Hevner et al. (2004) and Peffers et al. (2007) will be adapted to this research. Thus, five important steps will be mentioned: Problem Identification and Motivation, Objective Definition, Design and Development, Evaluation, and Communication.

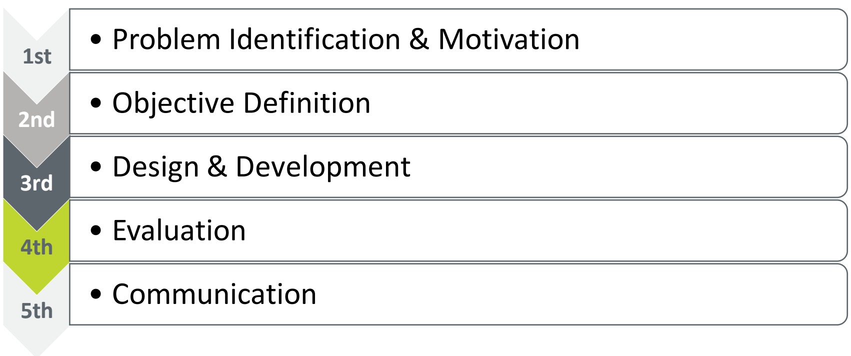

Figure 1 – DSR Method Adaptation (Hevner et al., 2004; Peffers et al., 2007).

These stages will be adapted to this investigation, yet a brief explanation of each step will be given beforehand.

Problem Identification and Motivation

A research problem is specified and used to develop the artifact. Its value will be validated by the researcher aiming to motivate himself and the audience to understand the problem and accept its solution's outcome (Peffers et al., 2007).

Objective Definition

Once the problem is identified, its solution objectives (quantitative or qualitative) need to be defined among what is possible and feasible (Peffers et al., 2007).

Design and Development

In this stage, the artifact is created. Decisions concerning function and form should be made so that requirements are set to the artifact. A clear understanding of the solutions' outcome needs to be achieved, hence research on the problems' state-of-the-art and theoretical background is needed (Peffers et al., 2007). Knowledge on current solutions and their efficiency and efficacy can help designing the solution regarding utility issues and overcome current problems (Hevner et al., 2004).

Evaluation

This stage reflects the degree to which the solution matches the value that is expected. Feedback is given on the artifact itself, but also to its construction process. Attributes such as performance, reliability, or usability can be criticized to perform comparisons between what was initially proposed and what was made (Hevner et al., 2004). A variety of evaluation approaches are available in the literature (Cleven et al., 2009), but the approach selection must be coherent with the artifact and its evaluation metrics (Hevner et al., 2004).

If the evaluation process returns the need to improve the artifact, researchers may choose to revise the process or leave those improvements to other projects, moving on to the final step (Peffers et al., 2007).

Communication

Finally, the problem and its relevance are communicated to the audience along with the artifact and respective attributes (Peffers et al., 2007). Enough detail must be given so that the audience can understand the solution and its application, as well as its construction and evaluation processes (Hevner et al., 2004).

2.2. Methodology Implementation

Problem Identification and Motivation

Reducing the knowledge gap between common citizens and Smart Home's technology could be possible through the construction of a Toolbox and its further application on technologies' deployment. Limited know-how of citizens may turn them dependent on vendors, increasing costs and time (Balta-Ozkan et al., 2014). Thus, this artifact could provide more autonomy to its users, which will be further validated in this investigation.

Objective Definition

Defined the problem and motivation, objectives can be prompted. The proposed artifact should constitute an easy way to understand Smart technology and how different sensors can be used to transform a traditional home into a smart one. Also, having access to different technology parameters should help common users to select the most appropriate technological changes they want in their house.

Some products in the market may represent assembled products, including a set of aggregated sensors and software. Due to the diversity of available options in this regard, these products along with end-use products or smart packages (i.e., including technology aggregation) are not considered in this study. Hence, the communication between sensors is also excluded from the objectives of this research.

Design and Development

An overview of concepts such as Domotics and IoT is performed to understand the scope of the study and the necessary requirements to develop the Toolbox.

The retrieved knowledge of the mentioned domains allowed the development of a Systematic Literature review. The state-of-the-art of the Smart Homes' technologies is reviewed and the selection of the most common types of devices is made. Convenient market information regarding technologies' setup (i.e., knowledge, time, training, and budget required, and site preparation) is given to provide quality insights on the complexity of different devices' setup.

After this detailed research, conditions are met to build the purposed Toolbox. Development requirements, in function and form, are defined.

Evaluation

Among the plethora of evaluation approaches in the literature (Cleven et al., 2009), conducting research interviews seemed to be the most coherent choice to get validation and feedback regarding the artifact's performance, reliability, usability, and usefulness. As this process to be a way to gather insights on a specific topic (Gill et al., 2008), it'll expectedly collect interviewees' views of the (technology) world.

Given the purpose to be directly linked to non-technical people, the interviewing process will also include non-expert people, rather than exploring the theme only among technical people. By doing so, it's expected a technical and non-technical validation.

Communication

The scientific release of this investigation is a possible way to communicate the proposed artifact to the public, so that development details can be shared, and other improvements suggested.

2.3. Research Interviews

A research interview can be defined as a qualitative method that provides the researcher a clear understanding of the participants' experiences, points of view and insights of a specific subject (Gill et al., 2008). It's one of the most used methods for collecting data (Qu & Dumay, 2011), requiring verbal interaction between interviewer and interviewee (Rowley, 2012).

Semi-structured interviews are one of the most common types of research interviews (Rowley, 2012) and will also be used in this investigation. Their wide acceptance is given to their flexibility, accessibility, and capability to cover human and organizational behavior, allowing interviewees to share their thoughts in their own words (Qu & Dumay, 2011). It involves ready questioning that help defining topic areas so that interviewee and interviewer can dive into the detail of questions (Gill et al., 2008).

The interest in the discussion can be influenced by the type and length of the queries made, according to Gill et al. (2008). Regarding type, open-ended questions are mostly used as they help collecting more information, while being impartial and logical in nature. Considering length, it may vary according to the participants' availability. The authors also believe that the richness of the interview also depends on the selection of the participants as it should not be random, but focused on their backgrounds, experiences, and beliefs.

Research interviews not only involve a set of skills, such as listening and questioning, to reveal the social world and views of the interviewees, but also requires careful planning (Qu & Dumay, 2011). The authors also state that gaining expertise on the discussed subject may enhance the interviews' data quality and help choosing the most adequate participants. However, they only represent a few aspects worth planning, hence a more complete plan (Figure 2) is traced and adapted from McGrath et al. (2019).

Figure 2 – Interviews' Plan Adaptation (McGrath et al., 2019).

Background Preparation

Understanding the scope of the research questions is one step towards the success of an interview's process. This requires the study of the available literature for the topic in discussion, but also the acknowledgement of how to conduct the interview. The space and time of the discussion should also be considered so that participants feel comfortable. Recording devices should be tested to avoid conflicts during the event (McGrath et al., 2019).

Participants' Identification

Having suitable participants in the interviewing process may enhance the quality of the insights, as diverse experiences, backgrounds, and roles may generate more interesting findings to the investigation (Rowley, 2012). The author also recommends revealing the interviewee's profile (e.g., their academic and professional background) to provide more authority to their feedback; also, a credible invitation should be done to access their agenda. The participants should be informed about the investigation's scope and share their consent on being recorded (McGrath et al., 2019).

Interview Guide & Testing

Developing an interview guide can help in the interviews' conduction stage. Having as much information as possible regarding the interviews' subject may help designing the guide (McGrath et al., 2019). Questions should be prepared according to the research questions as it turns easier to extract and analyze the findings (Rowley, 2012). They should also be as open-ended, clear, and impartial as possible (Gill et al., 2008; McGrath et al., 2019). The authors also recommend the conduct of pilot interviews to enhance the interviewers' skills and the data collection process.

Interview Conduction

According to McGrath et al. (2019), listening and questioning are two of the most fundamental skills while conducting interviews, along with a neutral attitude and use of silence. Thus, the researcher should not be a passive player in the event, but rather contribute with his/her knowledge to the interviews' insights. A careful attention should be given to ensure a positive relationship between the actors involved and avoid possible bias in the collected data (Gill et al., 2008). The interviews should be recorded so the next stage is done properly.

Interviews' Transcription

The process of writing down recorded data to be analyzed can be very time-consuming but, if done properly, it allows the researcher to dive into the data and validate it. Recommendations are made so that the transcription occurs as soon as possible after interviews completion (McGrath et al., 2019).

3. LITERATURE REVIEW

3.1. Theoretical Overview

To a better understanding of this study's subject, a theoretical overview is necessary. Therefore, a review of some important concepts in the Smart Homes' area will be further exhibited. The following sections will be considered: Smart Homes' concept and application areas, Domotics, and IoT.

3.1.1. Smart Homes

3.1.1.1. Concept

In the current society we live in, the Smart Home's concept is no longer a new theme. These intelligent environments have recently become more available to the great public and their benefits are being progressively embraced and translated into more interest (Wright & Shank, 2019).

Smart Home's notion started in 1930, in America, as a synonym of luxury and modern living, thus only available to wealthy individuals (Strengers, 2013). At the time, the idea of having new services and less effort while performing daily activities seemed to trigger peoples' attention, according to the author, but as computing power began to be more accessible, several other designations started to conquer space over the literature (Darby, 2018).

According to Robles & Kim (2010), a Smart Home can also be considered as a building that is founded on wires which connection can provide remote control of devices and their tasks' setting. A similar Smart Home's designation is shared by Balta-Ozkan et al. (2014), who advocates smart environments as the ones where a communication network lies on to connect sensors, appliances, and devices, that can be monitored and controlled remotely to fulfill users' needs.

However, to what this study concerns, the contribution made by Marikyan et al. (2019) presents a more suitable explanation of the term: a home embedded by smart technologies capable of providing independent and quality living to their residents, while offering them tailored services. This approach illustrates the transaction of the literature focus on the user's behalf, whilst the research emphasis has been on the technological challenges of these systems (Hargreaves et al., 2018; Marikyan et al., 2019; Wilson et al., 2015).

Wilson et al. (2015) attempted to explain the increasing research and development in Smart Homes by evoking three different views on the concept: the functional view, that emphasizes the potential of Smart Homes to manage routine demands through technology; the instrumental view, as they can help users to reach specific goals related to further benefits (e.g., Energy Efficiency), and the socio-technical view, that categorize Smart Homes as the next big step towards a digitalized world, thus potentially transforming social practices and householders' experiences.

Being "Smart" imply specific characteristics, according to Lê et al. (2012), as "automation" or the act of performing independent functions, "multi-functionality" or the performing of a great number of tasks, "adaptability" or the adjustment to users' needs, "interactivity" or the interaction between system and user, and "efficiency" or the act of saving time and money while performing activities. Behind these traces stands a common feature between all smart environments: the ability of all appliances to exchange information with each other (Mocrii et al., 2018). This intercommunication can be done, for instance, by switches that function with a specific devices' location and respond to a signal in the homes' network (Chen, 1997; Robles & Kim, 2010).

In these switches lies the main difference between a conventional home and a Smart Home: whereas a traditional home switches a device by changing its electrical connection, a smart environment switches a device by sending a signal throughout the network, where it's received and translated to a message (Chen, 1997). Also, according to Keith Edwards & Grinter (2001), home intelligence depends on whether the environment can assess the current state of the world through sensors and act upon it considering several factors at the same time. For instance, the number of people in a room may have to be considered as it may indicate a group activity or other similar situation. The authors also state the environment should be able to predict users' intentions and the desired action from them. As an example, the system can turn on the lights if the user is walking through the hallway (Mocrii et al., 2018).

These interactions are usually mediated through an Internet connection, a gateway, and several end devices (Bejarano et al., 2016; Kim & Kim, 2014). This configuration dynamics allows a variety of potentialities further explored in the next section.

3.1.1.2. Application Areas

Smart Homes' applications are unlimited and evolving, as this market is expected to grow to USD 151.4 billion[1], in 2024 (Hong et al., 2020). ICT companies are seeking new revenue streams by introducing new Smart Homes' services and products, thus revolutionizing the marketplace, and widening its access to more people (Shin et al., 2018).

[1] 1 billion USD correspond to 1 thousand million Euros.

Recent developments have been made and have become very attractive to users, especially in areas such as Elderly Assistance, Energy Efficiency, Security, and Entertainment (Balta-Ozkan et al., 2013; Marikyan et al., 2019; Sovacool & Furszyfer Del Rio, 2020).

Elderly Assistance

A growing need for elderly assistance resulted from the aging phenomenon of the population, leading to new developments in IoT to address this problem (Pal et al., 2018). According to the authors, Smart Homes can revolutionize the way elderly people have access to healthcare services, by gathering and analyzing residents' health details and report irregularities. Thus, research has focused on areas such environment monitoring and activity detection, being inherent to them the collection, processing and analysis of data and its transfer to specialized entities to monitor their patients (Pal et al., 2018).

Energy Efficiency

Research shows an increasing interest regarding achievements such as "zero energy buildings" (Marszal et al., 2011), as an attempt to reduce the energy used in buildings by using smart technologies. But the desire to save energy is transferred to Smart Homes according to Sovacool & Furszyfer Del Rio (2020). In their study, feedback collected from multiple users exposed an increasing interest in better managing their energy consumption and becoming more aware of their expenditures. That can be done as real-time consumption information can be displayed and appliances can be scheduled by the consumers (Zhou et al., 2016).

Security

Smart Homes' features can also assure the safety of the residents (Nath et al., 2018; Robles & Kim, 2010). The authors argue that advanced surveillance systems allow inhabitants to, not only monitor activity in every room of the house, but also to be more relaxed over intruders as they can see, in real-time, what is happening to their belongings. Also, when equipped with fire alarm systems, some devices can detect the start of a fire and avoid tragedies (Saeed et al., 2018). Smoke, rising heat and gas leak detection are other common applications, mentioned by the author, that residents can use to assure their protection.

Entertainment

IoT developments are continuously made to improve our lives, not only to make it easier and more convenient (Hargreaves et al., 2018; Miori & Russo, 2014), but also more joyful as home entertainment capabilities continue to evolve to provide, for instance, better television and multimedia experiences (Gavrila et al., 2021). Virtual reality is another entertainment trend today thanks to IoT (Zhang & Yin, 2021). Their study presented a new form of interaction between human and computer in order to control a Smart Home and improve user's experience. Atzori et al. (2010) also envisions users' experience, but in a game's sphere, stating that Smart Homes can provide a better game environment by sensing residents' location or heartbeat throughout the challenges they face while they are playing.

Our homes have welcomed smart technology through the rise of Internet and mobile communications, thus research on Domotics and how it improves appliances' capabilities has intensified (Bolzani et al., 2006; Ruta et al., 2011).

3.1.2. Domotics

The term "Domotics" typically relates to the term "Home Automation", as the use of smart technology to control appliances inside a home and provide benefits for their users (Mathew & Mahanta, 2020; Miori & Russo, 2014). Other designations can be found over the literature, such as "Home and Building Automation" as an attempt to make structures more controllable and comfortable (Ruta et al., 2011) – a definition that can easily recall Smart Homes. The fact is that both concepts are strongly related as Domotics' projects rise and are linked to Smart Homes and, consequently, their technologies.

By Smart Home technologies it's typically implicit all connected devices and appliances (e.g., sensors) that can enhance the lives of their users by responding to their needs (Cook, 2012). Their appearance may be recent for some of us, but history defy those perceptions (Sovacool & Furszyfer Del Rio, 2020).

According to Chen (1997), the average house already interacts with some electronic devices, such as the telephone or the cable TV, which interaction requires its own wiring structure. Accordingly, the different types of signals turn these devices completely independent from each other affecting their communication. Moreover, the initial cost, difficulty in replacing devices and lack of mobility represent obstacles to wiring solutions (Mocrii et al., 2018).

As a solution to this wired connection, Chen (1997) evoked the need of having a more versatile home network embedding digital connections between the devices. The expression "wireless home networks" was then used by Fujieda et al. (2000) who proved its viability in their study. They also promoted the development of other conclusions: devices should offer easy installation, whether in new homes or in existing ones, to be sold in the market. Hence, Bluetooth soon conquered its popularity among wireless technologies as a low-cost alternative, easy to use and install, and flexible enough to connect new devices (Mocrii et al., 2018).

Despite the mentioned advantages that wireless connection brings, challenges including privacy, safety and reliability started to emerge among users (Balta-Ozkan et al., 2013). Aiming to face such problems and turn Smart Homes more appealing, developers attempt to launch more products according to users' needs, thus revealing a user-centered vision that starts to replace exclusive system-centered perspectives (Wilson et al., 2015). Current technology leaders already deliver a plethora of IoT devices for many types of functions (Hong et al., 2020).

3.1.3. IoT

We generally call Internet of Things to the infrastructure that connects the virtual and the physical world, triggering services through technologies (Patel et al., 2016). Both worlds interact and exchange data anytime, to anyone, providing benefits for its users through the communication of each "thing" with each other to reach a final end (Akpakwu et al., 2017; Atzori et al., 2010).

Patel et al. (2016) also proposed a classification of IoT into three different categories: people to people; people to machine/things; things/machine to things/machine. Common characteristics to all the groups were also exposed: interconnectivity, or the ability of interconnecting anything in the network, heterogeneity, or the interaction between different hardware devices, changes' dynamics, or the flexibility on devices' status, safety, or the guarantee that data is secured while moving across the network, and, finally, connectivity, or the network's access grant to all devices.

Other designations refer to IoT as a generic term used to describe the internetworking of physical devices, that is in expansion and will continue to expand in the future (Nikou, 2018). As its first appearance recall for decades from now, a lot of time was dedicated to cover some of the already mentioned application areas (Sovacool & Furszyfer Del Rio, 2020). Today, cars, washing machines and other familiar objects are connected by IoT, whereas wireless technology, including Wi-Fi and Bluetooth, connect these devices to Internet and to each other. Once data is collected by them, cloud services can also store the information to actively make it available to users' decisions and commands (Cook, 2012; Mocrii et al., 2018).

The IoT has dramatically changed our lives (Atzori et al., 2010) and will continue to do so in the future (Ericsson, 2016). The author forecasts that around 28 billion of smart devices will be connecting our world by 2021, whereas more or less than 15 billion refer to machine-to-machine (M2M) communications and 7 billion to devices connected by 2G, 3G, 4G technologies (Akpakwu et al., 2017).

These networks are still evolving to meet future IoT applications, proof of that development is the release of 5G. The fifth-generation network boosts IoT connection of smart devices and allows data sharing and interaction without human interference. Thus, communication between devices can be improved and users' needs satisfied in fields such as Smart Homes (Costanzo & Masotti, 2017).

3.2. Systematic Literature Review

3.2.1. Method

The previous overview of concepts defined the scope of this investigation and specified suitable keywords for the scientific matter request. Hence, a systematic review was performed to understand the most recent developments in the Smart Homes' literature, regarding applications and technologies. Research questions were formulated to conduct this process:

RQ1:	What are the most relevant Smart Homes' applications?
RQ2:	What technologies are currently being used in Smart Homes?
RQ3:	What technologies could be recommended to a common citizen to deploy a Smart Home?

Table 1 – Systematic Review's Research Questions.

Answering these questions required a selection of the most relevant studies. Therefore, keywords were carefully chosen (Table 2) aiming to revise the available literature and proceed to a responsible selection of articles. Terms as "Smart Home" and "Home Automation" were treated as synonyms, as well as "Smart Technologies" and "Smart Appliances", "User" and "User Experience", and "Smart Living" and "Connected Living". Even though concepts such as IoT and Domotics were explored in the overview stage, they were not included as keywords, given their diversified nature and the risk of widen the scope of this study.

Keywords	Title
Smart Home	Home Automation
Smart Technologies	Smart Appliances
User	User Experience
Smart Living	Connected Living

Table 2 – Systematic Reviews' Keywords and Synonyms.

Boolean queries were designed to include, at least, one of the above expressions in the abstracts, titles, or keywords of the searched articles. This condition guaranteed the collection of relevant data related to our domain. Only scientific documents were considered before December 5th, 2020, and between 2015 and 2020, attempting to cover the latest developments in the Smart Home's field.

The query string was prepared as followed: ("Smart Home" OR "Home Automation") AND ("Smart Technologies" OR "Smart Appliances") AND ("User" OR "User Experience") AND ("Smart Living" OR "Connected Living"). The resources considered to this research are reflected in Table 3. Given Scopus and Web of Science to be general databases, a technical resource such as IEEE Xplore was selected to give a more specific contribution.

Resources	Domain
Scopus	https://www.scopus.com/
IEEE	https://www.ieee.org/
Web of Science	https://www.webofknowledge.com/

Table 3 – Systematic Reviews' Resources and Domains.

Aiming to select the most relevant articles for this study, inclusion and exclusion criteria were defined as mentioned in Table 4.

<table>
<tr><th>Inclusion Criteria</th><th>Exclusion Criteria</th></tr>
<tr><td rowspan="4">Evidence of Smart Homes' technologies and applications, and their users' experience</td><td>Publications before 2015</td></tr>
<tr><td>Language different than English</td></tr>
<tr><td>Articles that review/overview</td></tr>
<tr><td>Non-Academic Papers (e.g., magazine's reports, newspapers)</td></tr>
</table>

Table 4 – Systematic Reviews' Inclusion and Exclusion Criteria.

Some articles were removed by attending the exclusion criteria, and by being duplicated or unable to be accessed. The remained articles' abstracts were analyzed and removed if not relevant for this study (e.g., Smart Homes' privacy and security issues) or out of its scope (e.g., Smart Cities, Wearables). Even though it's important to understand the risks behind technological developments, the authors agreed to combine efforts among the most used Smart Homes' technology and not necessarily its drawbacks. Wearable technology is also out of the scope of this investigation as it may not be installed in the homes, but rather on users' body. However, some of the retrieved articles included wearable sensors, such as pulse sensor or other health status' devices, which functional characteristics were valuable inputs to understand other sensors. For this reason, these devices will be mentioned as part of some of the articles but will not move further to the Toolbox conception.

The final step is the analysis of the remained articles as they should be the most relevant ones to conduct this study.

It's worth to mention that only three information resources were accessed to revise the most important information in Smart Homes' literature, whereas only English articles were selected. Therefore, despite of the extensive and careful search, some articles may not have been analyzed given the application of such filters.

3.2.2. Results

The previous section announced the tools that will be used in further analysis and selection, based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method (Moher et al., 2009).

The initial search on the three mentioned databases retrieved 567 articles (Identification Phase). This step and others were organized into a flowchart (Figure 3).

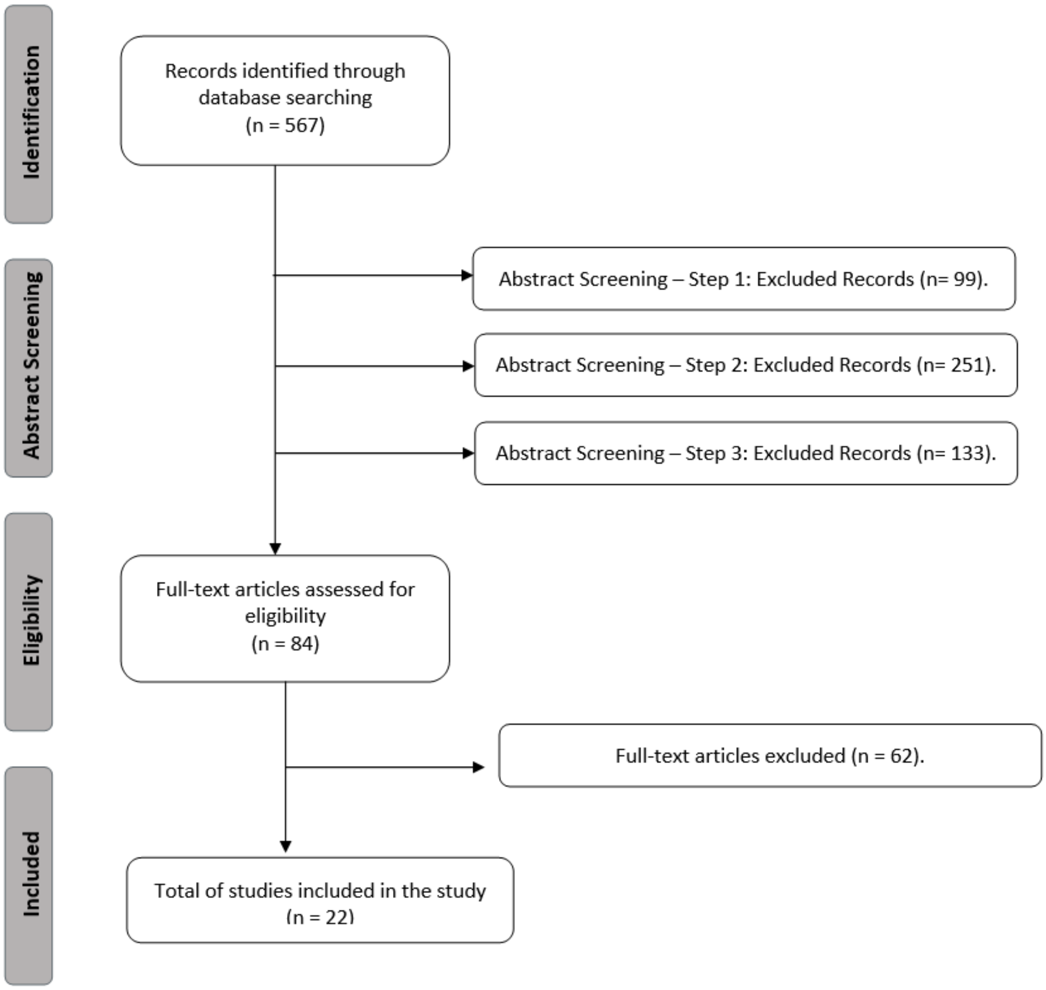

Figure 3 – PRISMA Flowchart.

After the removal of the duplicates in Step 1 (n=99), the remained articles (n=468) were analyzed. Hence, in Step 2, a total of 251 articles were excluded by their non-relevant abstracts (n=185), such as Smart Homes' challenges, overviews, or acceptance rates, or by their "outside of the scope" abstracts (n=66), such as Smart Cities or Big Data issues.

The remained abstracts (n=217) were screened in Step 3 to find some evidence of technologies in the field and their users' experience. The articles where this evidence was lacking were also excluded (n=133).

A total of 84 full-text articles was eligible to be assessed for this investigation. However, some were excluded after careful reading (n=62), by not mentioning users' experience or by approaching similar technologies better prompted in other selected articles.

Hence, this method retrieved 22 articles to be included in this study, whereas 14 were conferences' papers and 8 were published in scientific journals. These studies were divided by Smart Home applications: Elderly Assistance (n=5), Energy Efficiency (n=2), Devices' Control (n=4), Monitoring (n=4), Security (n=2), Entertainment (n=1), Wellness (n=1) and Other Applications (n=3). Even though some of the articles may serve more than one purpose simultaneously, such as Devices' Control and Security, a careful emphasis was given to authors' focus in the article. Thus, if the article focuses more on Devices' Control than Security purposes, the retrieved application of the article will be the control of the devices.

Elderly Assistance is one of the biggest trends in the Smart Homes' field. A lot of development is being registered concerning elderly care and possible ways to provide more autonomy to the aged people. Kong & Yeo (2018) proposed "Eldersense", a solution for caregivers or family members to be notified and assist elderlies who live alone. Motion sensors such as the Passive Infrared (PIR) sensor provide information on the daily movement of aged people around the house and detect anomalies, triggering alarm notifications to the several users. A single-board computer (SBC), as an inexpensive and small computer, allows the connectivity among the sensors and the delivery of important information to users. A smartphone application worked as an interface for the display of this information. The authors' solution exposed positive results, as it could detect movement and, when in the lack of it, alert different users. Enhancing the quality of life was also a goal for Grgurić et al. (2019). Their "SmartHabit" system learns about elderlies' behavioral pattern without invading their privacy. Affordable and off-the-shelf sensors such as smart plugs, door/window sensors and others that measure light, temperature, and humidity, were used to send data to a cloud platform where it's stored and used for pattern recognition. Then, notifications are sent to users. The technological cost was kept as low as possible and included the use of Wi-Fi and an SBC given its low cost and computer functionalities (i.e., memory, input and output capabilities, and microprocessor). Results demonstrated the easy transformation of a typical home to a smart one. However, the study also recognizes some challenges regarding the devices such as their batteries' autonomy or the complexity inherent from an expansion in number. Susnea et al. (2019) also used affordable sensors like the PIR, the temperature sensor and contact sensor to spot abnormal movements. These, when triggered (e.g., persons' movement) can activate a specific source of virtual pheromones in a particular place. These substances can be diffused in the air and form an activity map, helping to better understand users' interaction with the environment. This map shall be compared with a reference map so that conclusions can be drawn over a specific interval. This method constitutes a way to gather richer information from the sensors' data. However, the authors admit that a panic button would be a useful feature along with fall detection devices to help assisting elderly people in their homes. In this sense, Hughes et al. (2019) improved the idea of having a smart carpet where floor-based sensors were constructed to detect falls and movements by walking on the carpet. Sensors' data is scanned and sent to the cloud, where it's processed, and analyzed. Algorithms are also developed to detect movements from older adults. Different users' experiments were performed using different types of shoes providing an information accuracy of 86%. Casciaro et al. (2020) also contributed to the aging population by proposing a medication dispenser that notifies users, via smartphone APP, about the release of their medication. Electronical components such as a servomotor actuator are responsible for opening the lid and drop the pill, while light-emitting diode (LED), smart lights and speakers announce it. A contact sensor detects the take of the pill and, just like the previous components, is connected to a microcontroller (MCU). This component can manage all the others while being linked to an SBC, responsible for fulfilling operations. Results confirmed the usability of this tool by several users and admitted future work regarding displays that show relevant medication information.

Other trends include Energy Efficiency. Al-Kuwari et al. (2018) proposed an IoT based sensing and monitoring system for controlling the house energy powered by solar panels. Sensors' data regarding temperature, humidity, light intensity and $C0_2$ levels are acquired by a MCU and stored in the cloud. A smartphone APP is also used to display the data to users. Results show that sensors' data can successfully be stored in the cloud allowing a better control and efficiency of the house energy conditions. Future work would be to include Artificial Intelligence (AI) to learn more from users' behaviors. Smart plugs are another way to reduce power consumption according to Oh (2020), who studied their application on more than a hundred households. Users voluntarily installed the equipment – smart plugs and smart switches – and received guidelines. Results found that households used around 5% less energy when compared to traditional homes. More installed smart plugs mean higher reduction rate, but also mean higher costs constituting a limitation of this study and an opportunity for future improvements.

Concerning the control of Smart Homes' appliances, a few developments are being made regarding voice assistance. Shin & Jun (2015) have suggested a user authentication method by voice recognition where only authorized users can control devices. A login in a smartphone APP is necessary through a specific device ID (DID) and a personal identification number (PIN). Registering voice is the next step to match it with the DID and the PIN. The specific voice commands need to be inputted into a smartphone and a database. Thus, the user must acknowledge what types of commands does the APP recognizes, otherwise no voice data is saved, nor command is done. Mithil et al. (2018) also proposed eliminating the physical control of devices. The control of devices was the authors' focus, even though security features are also mentioned. Therefore, home devices could also be managed by voice commands and, if they are not clear to the system, it shall search their meaning on the Internet. A fingerprint scanner, a pulse sensor, and a temperature sensor are used among other hardware devices such as LED smart lights, fans, camera, servomotor actuator and microphone. All the mentioned devices are ran by a microcontroller and targeted by Natural Language Processing (NLP) to process input text before inserting it into computers. Results showed that a higher rate of accuracy can still be achieved, and the used face detection algorithm can be improved in the future. Eye tracking is another way to control Smart Home devices, according to Bissoli et al. (2019). A low-cost eye-tracker is used in a software APP that detects the eyes' gaze so actions can be prompted, such as following the eyes' gaze until it ceases movement at a given point and triggers an event. No new software is further needed besides an Internet browser and an Application Program Interface (API) to collect the eyes' gaze coordinates, which are stored in the cloud and communicated to a MCU so that commands can be executed. The effectiveness of the system and its usability were validated by testing several participants. Devices can also be controlled when gardening. Sheth & Rupani (2019) introduced a smart gardening automation to control water supply in gardens or farm fields. A soil moisture sensor, that measures soil wetness, and temperature and humidity sensors are used to verify soil conditions and act upon it. The information is gathered through an MCU, and the status of the soil is displayed on a mobile APP where users can adjust threshold values to keep their fields irrigated and productive. Real-life results confirmed the interaction ability between users and sensors to guarantee water supply.

Monitoring home conditions is another attractive field nowadays. Shahadat et al. (2019) proposed a liquefied petroleum gas (LPG) concentration monitoring system capable of detecting different toxic gases, such as petroleum gases and carbon-based gases, and notify users about it. Besides using gas sensors with specific threshold values, temperature and humidity sensors are also used to identify anomalies. The gas sensor shares information regarding the gas concentration, then it's transferred to other devices and to the cloud via Wi-Fi, Bluetooth, or Ethernet. Once transferred to an MCU, calculations are made to analyze the gas' intensity. If the intensity value crosses a reference threshold, an alert is sent and displayed in a smartphone APP GUI (Graphical User Interface). Twenty trials were completed to analyze system performance and obtain a 95% efficiency rate. Monitoring temperature and humidity was also important to Rao & Prema (2018) who suggested a way to display real-time data on these two metrics. Data from sensors (i.e., temperature and humidity sensors) are collected through an SBC and stored in the cloud where it's analyzed by an online API. Also, LED smart lights are used to notify users when temperature levels go beyond the defined thresholds. The authors recognize that other parameters can be developed in the future by following the same logic, such as light intensity or toxic gases.

Monteriù et al. (2018) also suggested environment monitoring by integrating other sensors and devices: thermostat for temperature monitoring, PIR motion sensor for presence control, electrical consumption meters for electric power measurement, an actuator for light status' control, and health status devices' such as oximeters and thermometers. Additionally, a smart fridge and an air quality control device are deployed to collect more data to the cloud, which conclusions are also shown in a smartphone APP. Authors made possible the monitoring of users and their environment, however, improvements in the machine learning algorithm can be useful to trigger alarms on abnormal activities regarding users' routines. Indoor air quality was also considered by Fang et al. (2016) that proposed a sensing system capable of detecting air pollution and recommending solutions to the residents regarding their households' activities. Sensors such as temperature sensor, humidity sensor, VOC (Volatile Organic Compounds) sensor and PM 2.5 sensor (Particula Matter) are used. Parameters are selected to define thresholds and identify abnormal pollution values and sources and forecast air quality values. The sensed data is uploaded to the cloud via Ethernet, where it's stored, and analyzed so that the sources of pollution can be identified. A forecast is made regarding the air pollution exposure values and suggestions are displayed to users on a smartphone APP to help them raising awareness and act upon the toxic air values. Real-life trials in families confirmed the measurement of air pollution within the households and the identification of its sources. However, the authors admit some improvements such as increasing the number of sources to be considered in this analysis, since it only examined three of them: cooking, smoking and spraying pesticides.

Regarding security features, Jain et al. (2017) suggested a Smart Homes' surveillance system to protect the residents' values when they are not at home. Instead of recording continuously, the system only records when in presence of human activity, measured by a PIR sensor. Video cameras are also used to stream live video and record it for future views. Both devices are connected to an SBC which is connected to a server capable of triggering an alarm notification when a specific place in the house is accessed. The recorded information is encrypted which enhances cyber security and privacy. Future improvements are mentioned such as including face detection for familiar and non-familiar faces. Javare et al. (2017) also announced a smart door lock system by using Bluetooth to access doors. Motion and vibration sensors are used to detect movement and vibration, which in turn sends a signal to a cloud server that will try to identify the user through his/her id. If it matches with the database, an actuator indicates the movement of unlocking the door and a microcontroller performs it; if it doesn't match, a video camera is activated. Notifications are sent simultaneously to a smartphone APP allowing users to interact with the appliances and see live recording of the door status. The authors mentioned the installation process as an easy one, as simple and inexpensive to employ at home, in many areas. However, improving the APP may represent a step further within this investigation.

Advances in Virtual Reality motivated Eckstein et al. (2019) to present a prototype of substitutional reality for games and other applications inside the house such as social interaction. User and object trackers are used, and environmental data is provided through sensors – temperature, light, and air quality sensors – to provide a virtual context and stimuli to users. Microphones are used and so are actuators, that control the electrical status of devices. Smart plugs and lights allow the remotely control of some devices in the room (e.g., fans). Validation tests reflected the successful execution of tasks within a virtual environment, where tension and pressure among users were very low during the experiences. However, only a limited type of objects can be tracked by the system which is one of the improvements that authors admit in the future, together with hand tracking to expand users' interaction with the virtual environment.

Wellness features are also gaining importance. Hesse et al. (2017) presented a connected chair whereas sensors, actuators, and Internet connection together can provide relaxation, health training, and assistive functions. Sensors such as the galvanic skin response (GSR) for relaxation mode, a radar sensor for heart and respiration rates' measurement, and force sensitive resistors (FSR) for presence detection were used among actuators, responsible for seating adjustment. They are controlled by a microcontroller and their data can be transmitted wirelessly. Users' posture can also be analyzed, and simple tasks can be done through the buttons in the armchair, such as switching TV channels or controlling games. The step forward will be to connect the chair to the house environment and develop new features and applications.

Other ways to simplify our lives are mentioned forehead. Shweta (2017) proposed an intelligent refrigerator capable of counting ingredients and calculate their expiration date. It can also notify users concerning old products within the interior, via SMS (Short Message Service), through users' phone. The main objective is to monitor the food stock and list the items that might have to be purchased soon. The fridges' content is evaluated through a video camera that takes pictures of each ingredient so that an algorithm can calculate its age, by comparing the day of the product loading to the current day. A microprocessor (MPU) treats the data and sends a voice signal to the user regarding the age of the fridge's content and what is not being eaten at a regular basis. This prototype can be a good way to keep track of nutrition values more easily by users.

Regarding the same goal – keeping life simple –, Garcia et al. (2017) proposed a smart mirror capable of optimizing the time of its users in terms of getting information and preparing their day. The assembly requires a reflective glass together with a LCD monitor, an SBC, a camera, a smartphone, Internet connection, and cloud computing. Facial authentication is one of the ways to use the tool since it collects data from a smartphone APP and display it in the mirror. Therefore, date and time data, weather information, personalized news (through a news recommendation algorithm), mail, calendar, music, facial recognition, and speech recognition can be displayed. Users' validation confirmed the match between the news displayed and each profile interests. Other applications are introduced by Leonidis et al. (2019) mainly in the transformation of a traditional living room into a smart one with different devices: smart lights, smart locks, blinds, and humidity sensors. The authors proposed a smart sofa as one of the possible changes to be made in a living room. FSR and load sensors are connected to a microcontroller to detect user presence, posture, and position. Motion sensors are installed so that users can interact with the environment by using gestures. A smart TV (AmITV) is also presented aiming to entertain users and keep them informed. A motion sensor located on the top of the TV records users' presence and track their movements, but also allows their interaction with the space without using a remote control. For instance, a user can lock/unlock the TV or pause the movie by moving his hands. The "AugmenTable", also proposed by the authors, is a small table that projects secondary information from the ceiling. It can have a touch-enabled surface and identify objects on it. Vibration can be set under the table to alarm users when necessary – for example, when in home delivery situations. The display of information can also be adapted according to users' posture. Finally, the "SurroundWall" acts as an alternative way to present information, by comprising a projector. Although it has no touch feature, it can add information to the programs users are seeing, such as a summary of a match or lives from other channels. Ambient facilities (e.g., aromas) can be activated according to user's context. User experience shown to be very positive during the validation tests, where small usability issues were detected but also resolved. Most users admitted using these smart technologies in their routines.

4. FRAMEWORK FOR A SMART HOME TOOLBOX

4.1. Assumptions

4.1.1. Smart Homes' Applications' Assumptions

The systematic literature review allowed the acknowledge of the main Smart Home applications and currently existing in academic ground. They are reflected in Table 5 and include Elderly Assistance, Energy Efficiency, Devices' Control, Monitoring, Security, Entertainment, Wellness, and others too specific to be included in the previous categories. Objectives can also be listed, accordingly with each application. The rise of wireless technology and Internet connectivity enhanced Smart Homes' capabilities, by allowing an easy setup of devices to different types of residents (Table 6).

Smart Homes' Applications							
Elderly Assistance	**Energy Efficiency**	**Devices' Control**	**Monitoring**	**Security**	**Entertainment**	**Wellness**	**Other**
Smart Homes' Objectives							
Daily movement and anomaly detection through notifications (Kong & Yeo, 2018)	Controlling house energy consumption (Al-Kuwari et al., 2018)	Controlling through Voice assistance and user authentication (Shin & Jun, 2015)	Real time information on Toxic Gases' Concentration (Shahadat et al., 2019)	Protection and surveillance of values when users are not at home (Jain et al., 2017)	Substitutional reality for games and other applications (Eckstein et al., 2019)	Relaxation, health, training, and assistance (Hesse et al., 2017; Shweta A.S, 2017)	Groceries' Restock and shopping assistance (Shweta A.S, 2017)
Behavioural patterning without privacy invasion (Grgurić et al., 2019)	Reducing house energy consumption. (Oh, 2020)	Controlling through Voice-commands and their search on the Internet (Mithil et al., 2018; Rao & Prema, 2018)	Real time information on Temperature and Humidity. (Rao & Prema, 2018)	Access confirmation /denial of users to the door (Javare et al., 2017)			Information and Time Optimization (Garcia et al., 2017)
Behaviour patterning through activity map and statistical analysis (Susnea et al., 2019)		Controlling water supplies in gardens/farms (Sheth & Rupani, 2019)	Real-time information on users' health and environment status (Monteriù et al., 2018)				Living Room that can entertain, inform, and interact according to context (Leonidis et al., 2019)
Fall Detection (Hughes et al., 2019)			Real-time information on indoor air pollution (Fang et al., 2016)				
Medication Control (Casciaro et al., 2020)		Controlling through eye tracking (Bissoli et al., 2019a)					

Table 5 – LR Identified Smart Homes' Application.

		Residents' Typology						
		By Age			By Family Members		Other	
		Elderly	Adults between 20y-60y	Adults between 18y-29y	Family Members (only adults)	Family Members (including children)	Disabled People	Farmers
Smart Homes' Applications	**Elderly assistance**	(Kong & Yeo, 2018); (Grgurić et al., 2019); (Susnea et al., 2019); (Hughes et al., 2019); (Casciaro et al., 2020)						
	Energy Efficiency	(Oh, 2020)	(Oh, 2020)		(Al-Kuwari et al., 2018)			
	Devices' Control	(Mithil et al., 2018); (Shin & Jun, 2015)	(Mithil et al., 2018); (Shin & Jun, 2015)	(Mithil et al., 2018); (Shin & Jun, 2015)	(Mithil et al., 2018); (Shin & Jun, 2015)	(Bissoli et al., 2019a); (Mithil et al., 2018); (Shin & Jun, 2015)		(Sheth & Rupani, 2019); (Mithil et al., 2018); (Shin & Jun, 2015)
	Monitoring	(Monteriù et al., 2018); (Shahadat et al., 2019); (Rao & Prema, 2018)	(Shahadat et al., 2019); (Rao & Prema, 2018);	(Shahadat et al., 2019); (Rao & Prema, 2018)	(Shahadat et al., 2019); (Rao & Prema, 2018)	(Shahadat et al., 2019); (Rao & Prema, 2018)	(Shahadat et al., 2019); (Rao & Prema, 2018)	(Shahadat et al., 2019); (Rao & Prema, 2018)
	Security	(Jain et al., 2017); (Javare et al., 2017)	(Jain et al., 2017); (Javare et al., 2017)	(Jain et al., 2017); (Javare et al., 2017)	(Jain et al., 2017); (Javare et al., 2017)	(Jain et al., 2017); (Javare et al., 2017)	(Jain et al., 2017); (Javare et al., 2017)	(Jain et al., 2017); (Javare et al., 2017)
	Entertainment			(Eckstein et al., 2019)				
	Wellness	(Hesse et al., 2017)	(Hesse et al., 2017)	(Hesse et al., 2017)	(Hesse et al., 2017)	(Hesse et al., 2017)	(Hesse et al., 2017)	(Hesse et al., 2017)
	Other	(Shweta A.S, 2017)	(Shweta A.S, 2017)	(Shweta A.S, 2017)	(Shweta A.S, 2017)	(Shweta A.S, 2017); (Leonidis et al., 2019)	(Shweta A.S, 2017)	(Shweta A.S, 2017)

Table 6 – LR Identified Residents' Typology.

4.1.2. Smart Homes' Technology's Assumptions

Smart Homes' technologies are becoming more available and affordable (Mare et al., 2019; Mano et al., 2016). Nowadays, a plethora of devices can be found to fulfill different Smart Homes' applications (Sovacool & Furszyfer Del Rio, 2020). A set of technologies can be drawn from the literature review and are included in Table 7.

The Hardware category can be defined as the physical parts and components of a computer, such as its monitor or keyboard (Ugah et al., 2018). In the Smart Homes' context, the mentioned sensors in the previous chapter would fall into this category. Data from these sensors can be managed and stored in the cloud by making use of Cloud Services (e.g., API) through different data transmission modes like the Wi-Fi, Bluetooth, or Ethernet.

Smart Homes' Technologies		
Hardware	**Data Management & Storage**	**Data Transmission**
Input Devices	Cloud Services	Wi-Fi
Input/Output Devices		Bluetooth
Output Devices		Ethernet

Table 7 – LR Identified Smart Homes' Technologies.

However, with respect to this study, a focus on the Hardware category is made. Table 8 clusters a plethora of devices, divided into 3 categories: Input devices that collect information regarding the physical environment (such as sensing devices), Output devices that include any demonstration or transformation to the physical environment (such as a display screen), and devices that can serve Input and Output purposes providing way for users to perform a given task. For instance, scrolling through a document with a mouse, as Input, to see a displayed graph, as Output (Hinckley et al., 2004).

Each category was carefully fulfilled with the retrieved data from the Systematic Literature Review thus respecting the articles' purposes for the devices. Devices' prototypes (i.e., devices' first version) were also included as they provide a future perspective of Smart Homes' technology.

Smart Homes' Technologies (Hardware)									
Input Devices				**Input & Output Devices**			**Output Devices**		
Motion Sensor	Temperature Sensor	Humidity Sensor	Floor-Based Sensor*	Smart Plugs	Smart Switch	Video Camera	Smart Lights	Smart Speakers	Fans
Air Quality Sensor	User/Object Tracker	Contact Sensor	Radar Sensor	Smart Blinds	Smart Locks	Smart TV	Smart Fridge	LCD Monitor	Smart Mirror*
FSR	Soil Moisture Sensor	Gas Sensor	GSR	Consumption Meter	Solar Panels	Actuator	Smart Carpet*	Smart Table*	Smart Sofa*
Vibration Sensor	Microphone	Eye-Tracker	Fingerprint Scanner	Microcontroller		Smartphone[a)]	Smart Refrigerator*		
Thermostat	Light Sensor	Load Sensor		Microprocessor			Projector		

*Articles' Prototypes; a) Installation not applicable to homes.

Table 8 – LR Identified Smart Homes' Technologies (Hardware).

4.1.3. Smart Homes' Assumptions' Correlation

Regarding the systematic review's output, some conclusions can be draw:

- Elderly Assistance showed to be the most explored Smart Home's application in comparison to others.
- Enhancing comfort and optimizing tasks is a common goal to all areas of application.
- The temperature and humidity sensors are quite adaptable to satisfy several Smart Homes' applications.
- The focus on the user experience represents a trend among scientific developments.

The previous assumptions can be organized to provide richer insights to this investigation. Thus, a combination between the most requested Smart Homes' applications and the most required technologies (hardware) was performed (Table 9).

			Smart Homes' Applications							
			Elderly Assistance	Energy Efficiency	Devices' Control	Monitoring	Security	Entertainment	Wellness	Other
Smart Homes ' Technologies	Input Devices	Motion Sensor	**X** (Kong & Yeo, 2018) (Grgurić et al., 2019) (Susnea et al., 2019)			**X** (Monteriù et al., 2018)	**X** (Jain et al., 2017) (Javare et al., 2017)			**X** (Leonidis et al., 2019)
		Thermostat				**X** (Monteriù et al., 2018)				
		Temperature Sensor	**X** (Grgurić et al., 2019) (Susnea et al., 2019)	**X** (Al-Kuwari et al., 2018)	**X** (Sheth & Rupani, 2019) (Mithil et al., 2018)	**X** (Shahadat et al., 2019) (Rao & Prema, 2018)		**X** (Eckstein et al., 2019)		
		Light Sensor	**X** (Grgurić et al., 2019)	**X** (Al-Kuwari et al., 2018)		**X** (Monteriù et al., 2018)		**X** (Eckstein et al., 2019)		
		Humidity Sensor	**X** (Grgurić et al., 2019)	**X** (Al-Kuwari et al., 2018)	**X** (Sheth & Rupani, 2019)	**X** (Shahadat et al., 2019) (Rao & Prema, 2018) (Fang et al., 2016)				
		Floor-based Sensor*	**X** (Hughes et al., 2019)							
		Air Quality Sensor		**X** (Al-Kuwari et al., 2018)		**X** (Fang et al., 2016)		**X** (Eckstein et al., 2019)		
		User/Object Tracker						**X** (Eckstein et al., 2019)		
		Load Sensor								**X** (Leonidis et al., 2019)
		Contact sensor	**X** (Casciaro et al., 2020) (Grgurić et al., 2019) (Susnea et al., 2019)							
		Radar Sensor							**X** (Hesse et al., 2017)	
		Force-Sensitive Resistor (FSR)							**X** (Hesse et al., 2017)	**X** (Leonidis et al., 2019)
		Soil Mosture Sensor			**X** (Sheth & Rupani, 2019)					
		Gas sensor				**X** (Shahadat et al., 2019)				
		Galvanic Sking Response (GSR)							**X** (Hesse et al., 2017)	
		Vibration Sensor					**X** (Javare et al., 2017)			

	Microphone			**X** (Mithil et al., 2018)			(Eckstein et al., 2019)		
	Eye-Tracker			**X** (Bissoli et al., 2019b)					
	Fingerprint Scanner			**X** (Mithil et al., 2018)					
Input & Ouput Devices	Smart Plugs	**X** (Grgurić et al., 2019)	**X** (Oh, 2020)				**X** (Eckstein et al., 2019)		
	Smart Switches		**X** (Oh, 2020)						
	Video Camera			**X** (Mithil et al., 2018)		**X** (Javare et al., 2017) (Jain et al., 2017)			**X** (Shweta A.S, 2017) (Garcia et al., 2017)
	Smart Blinds								**X** (Leonidis et al., 2019)
	Smart Locks								**X** (Leonidis et al., 2019)
	Smart TV								**X** (Leonidis et al., 2019)
	Consumption Meter				**X** (Monteriù et al., 2018)				
	Actuator	**X** (Casciaro et al., 2020)		**X** (Mithil et al., 2018)	**X** (Monteriù et al., 2018)	**X** (Javare et al., 2017)	**X** (Eckstein et al., 2019)	**X** (Hesse et al., 2017)	
	Microprocessor								**X** (Shweta A.S, 2017)
	Microcontroller	**X** (Casciaro et al., 2020)	**X** (Al-Kuwari et al., 2018)	**X** (Mithil et al., 2018) (Bissoli et al., 2019b) (Sheth & Rupani, 2019)	**X** (Shahadat et al., 2019)	**X** (Javare et al., 2017)		**X** (Hesse et al., 2017)	**X** (Leonidis et al., 2019)
	Single Board Computer (SBC)	**X** (Kong & Yeo, 2018) (Grgurić et al., 2019) (Casciaro et al., 2020)			**X** (Rao & Prema, 2018)	**X** (Jain et al., 2017)			**X** (Garcia et al., 2017)
	Solar Panels		**X** (Al-Kuwari et al., 2018)						
Output Devices	Smart Lights	**X** (Casciaro et al., 2020)		**X** (Mithil et al., 2018)	**X** (Monteriù et al., 2018)		**X** (Eckstein et al., 2019)		**X** (Leonidis et al., 2019)
	Smart Speakers	**X** (Casciaro et al., 2020)							
	Fans			**X** (Mithil et al., 2018)					
	Smart Table*								**X** (Leonidis et al., 2019)
	LCD Monitor								X (Garcia et al., 2017)

		Smartphone [a)]	**X** (Casciaro et al., 2020) (Kong & Yeo, 2018)	**X** (Al-Kuwari et al., 2018)	**X** (Shin & Jun, 2015)	**X** (Fang et al., 2016) (Shahadat et al., 2019) (Monteriù et al., 2018)	**X** (Javare et al., 2017)			**X** (Shweta A.S, 2017)
		Smart Mirror*								**X** (Garcia et al., 2017)
		Smart Sofa*								**X** (Leonidis et al., 2019)
		Smart Carpet*	**X** (Hughes et al., 2019)							
		Smart Fridge				**X** (Monteriù et al., 2018)				
		Smart Referigerator*								**X** (Shweta A.S, 2017)
		Projector								**X** (Leonidis et al., 2019)

*Articles' Prototypes; a) Installation not applicable to homes.

Table 9 – LR Technologies and Applications' Assumptions.

4.2. Framework for a Smart Home's Toolbox

Conditions are met to propose a framework for an IoT implementation guide, or Toolbox, to help common citizens transforming their traditional home into a smart one. This framework will help to select the most adequate technologies to be recommended.

This process requires some steps, which are also reflected in Figure 4:

i) Context Identification (Step 1).

ii) Requirements' Definition (Step 2).

iii) Technology Selection (Step 3).

iv) Evaluation (Step 4).

The detail of the first three stages can be reviewed in Figure 5.

This chapter also includes a Users' Guide to help, in real time, the prosecution of the previously mentioned process. To simplify the reading, only the initial part of this guide is presented in Table 10, while the complete guide is available in Appendix 1. The instructions given will expectedly support the execution of the process.

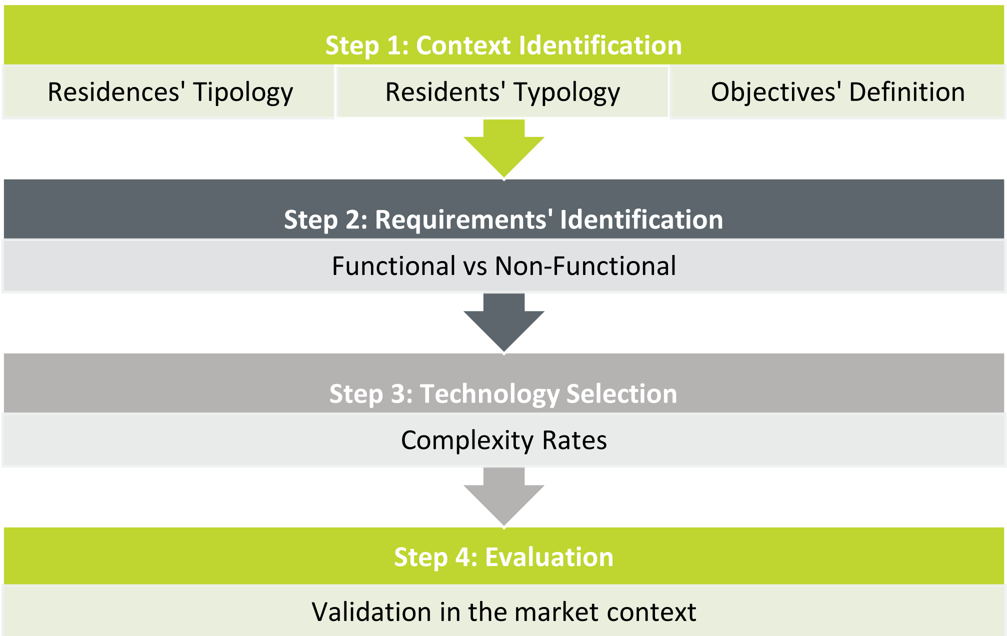

Figure 4 – Toolbox Framework Steps.

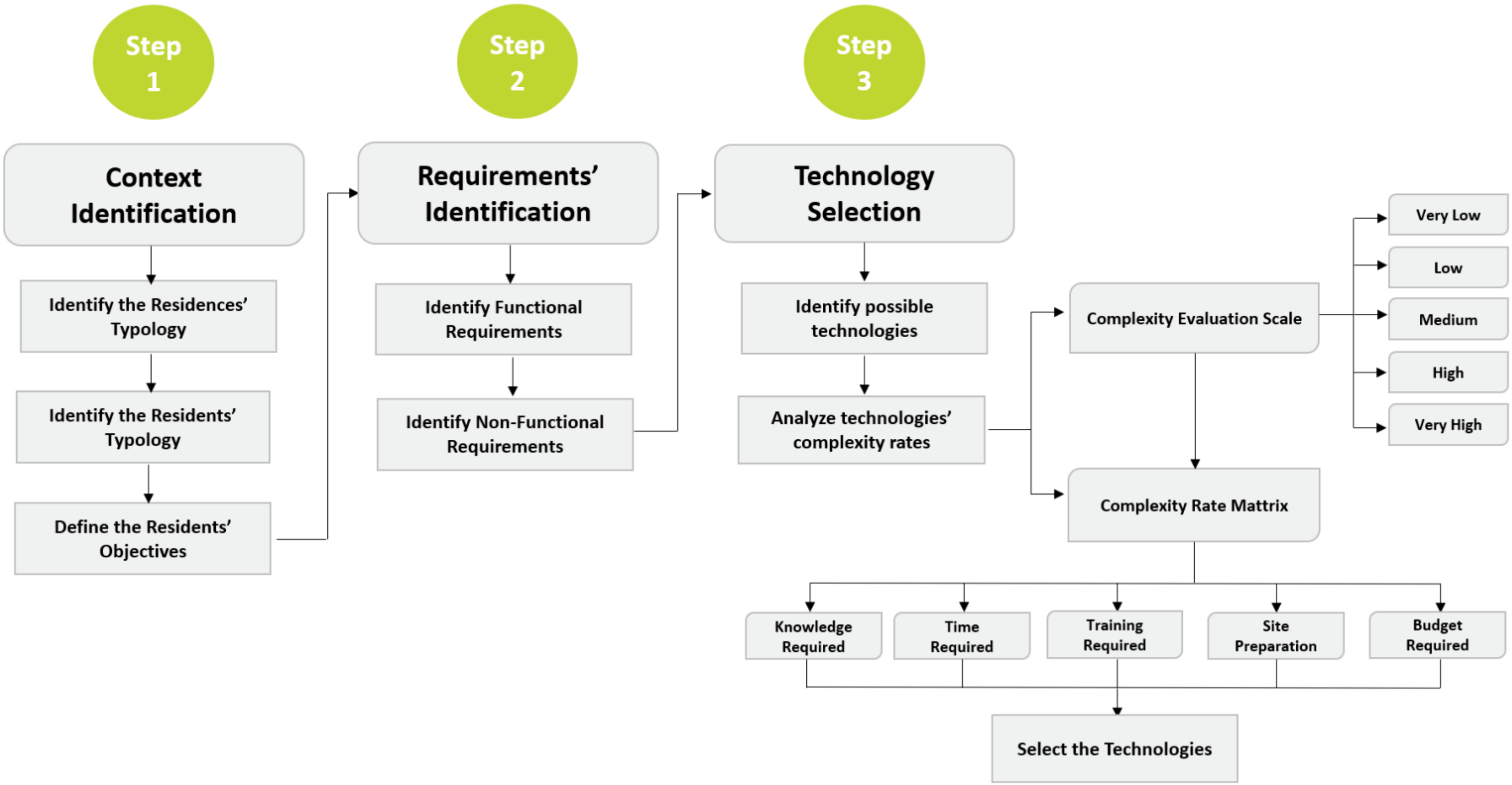

Figure 5 – Framework's Primary Steps.

Steps			Description		Procedure
Step 1: Context Identification			Which resident are you? (Choose **one** type)		Go to A. Apartment **or** B. House
A. Apartment			**B. House**		
By Age	**Select (X)**	**Procedure**	**By Age**	**Select (X)**	**Procedure**
A.1. Elderly		Proceed to C. a)	B.1. Elderly		Proceed to C. b)
A.2. Adults between 20y-60y		Proceed to C. a)	B.2. Adults between 20y-60y		Proceed to C. b)
A.3. Adults between 18y-29y		Proceed to C. a)	B.3. Adults between 18y-29y		Proceed to C. b)
By Family Members	**Select (X)**	**Procedure**	**By Family Members**	**Select (X)**	**Procedure**
A.4. Family Members (only adults)		Proceed to C. a)	B.4. Family Members (only adults)		Proceed to C. b)
A.5. Family Members (including children)		Proceed to C. a)	B.5. Family Members (including children)		Proceed to C. b)
Other	**Select (X)**	**Procedure**	**Other**	**Select (X)**	**Procedure**
A.6. Disabled People		Proceed to C. a)	B.6. Disabled People		Proceed to C. b)
A.7. Farmers		Proceed to C. a)	B.7. Farmers		Proceed to C. b)
C. Objectives' Definition			What is the objective of your Smart Home? Select (X)		Choose **one** objective
a) **Apartment**	**Select (X)**	Procedure	b) **House**	**Select (X)**	Procedure
a.1) Elderly Assistance		Proceed to Stage 2. A.1.	b.1) Elderly Assistance		Proceed to Stage 2. B.1.
a.2) Energy Efficiency		Proceed to Stage 2. A.1.	b.2) Energy Efficiency		Proceed to Stage 2. B.1.
a.3) Devices' Control		Proceed to Stage 2. A.1.	b.3) Devices' Control		Proceed to Stage 2. B.1.
a.4) Monitoring		Proceed to Stage 2. A.1.	b.4) Monitoring		Proceed to Stage 2. B.1.
a.5) Security		Proceed to Stage 2. A.1.	b.5) Security		Proceed to Stage 2. B.1.
a.6) Entertainment		Proceed to Stage 2. A.1.	b.6) Entertainment		Proceed to Stage 2. B.1.
a.7) Wellness		Proceed to Stage 2. A.1.	b.7) Wellness		Proceed to Stage 2. B.1.
a.8) Other		Proceed to Stage 2. A.1.	b.8) Other		Proceed to Stage 2. B.1.

Table 10 – Users' Guide Instantiation Example.

4.2.1. Step 1: Context identification

The first step of this process consists of identifying the context where the proposed artifact will be employed. The type of household is an important factor to be considered, as it's the foundation to the next stages. It may vary regarding size and living area, which can influence the nature of the devices to deploy. For this reason, residences need to be qualified before the beginning of the process itself.

Being the residents the major focus of the proposed Toolbox, their typology should also be considered when deploying different technologies. Residents can either be families with only adults or families with children, or even elderly living alone. The list of the different personas can be reviewed in Table 6.

Finally, defining the residents' objectives allows the adjustment between the technologies' capabilities and users' expectations. As an example, elderly users may need elderly assistance in their "new" homes. The objectives can also be revised in Table 5.

This stage can be reflected in a flowchart, by the mentioned steps.

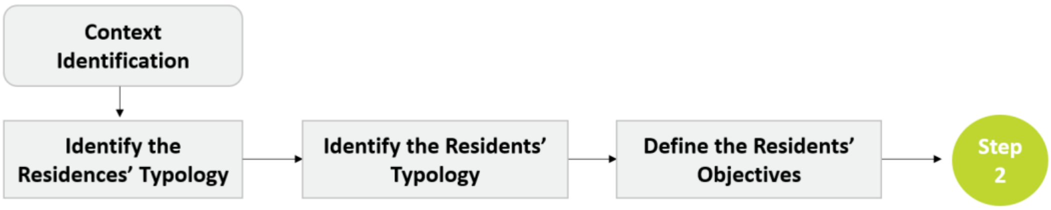

Figure 6 – Frameworks' Implementation (Step 1).

The output of the first stage should be similar to the one reflected in Table 11.

Context Identification		
Residences' Typology	**Residents' Typology**	**Residents' Objectives**
Apartment	Elderly	Elderly Assistance

Table 11 – Example of Context Identification (Step 1).

4.2.2. Step 2: Requirements' Identification

The second stage is focused on the requisites definition to attend users' objectives and specific needs, such as disability needs. Once the context is identified, users' requirements are collected to fulfill their Smart Homes' expectations. Requirements can be classified as Functional Requirements (FR), expressing system functions, or non-functional requirements (NFR), reflecting system properties (Kurtanovic & Maalej, 2017). Commonly used requirements found on the literature review can be found in Table 12.

Smart Home's Application	FSR#	Functional Requirements (FR)	Non-Functional Requirements (NFR)	References
Elderly Assistance	FSR1	Daily Movement and Anomaly Detection	Interoperability; Privacy; Reliability	(Kong & Yeo, 2018) (Susnea et al., 2019)
	FSR2	Behavioral Patterning	Privacy; Adaptability; Safety; Scalability	(Grgurić et al., 2019)
	FSR3	Fall Detection	Adaptability; Interoperability; Safety	(Hughes et al., 2019)
	FSR4	Medication Control	Interoperability; Adaptability	(Casciaro et al., 2020)
Energy Efficiency	FSR5	Energy Consumption Control & Reduction	Usability; Availability; Interoperability; Scalability	(Al-Kuwari et al., 2018) (Oh, 2020)
Devices' Control	FSR6	Voice Assistance	Interoperability; Adaptability; Reliability; Safety	(Shin & Jun, 2015) (Mithil et al., 2018)
	FSR7	Eye-Tracking Control	Usability; Interoperability; Availability	(Bissoli et al., 2019a)
	FSR8	Water Supplies' Control	Interoperability; Usability; Adaptability	(Sheth & Rupani, 2019)
Monitoring	FSR9	Toxic Gases' Monitoring	Performance; Adaptability; Interoperability; Reliability	(Shahadat et al., 2019)
	FSR10	Temperature & Humidity Monitoring	Interoperability; Adaptability; Availability; Reliability; Usability	(Rao & Prema, 2018) (Shahadat et al., 2019)
	FSR11	Health & Environment Status	Availability; Adaptability; Interoperability; Usability	(Monteriù et al., 2018)
	FSR12	Indoor Air Pollution Monitoring	Reliability; Adaptability; Interoperability; Usability; Performance	(Fang et al., 2016)
Security	FSR13	Protection & Surveillance	Privacy; Safety; Interoperability	(Jain et al., 2017)
	FSR14	Home Access Control	Interoperability; Usability; Safety; Privacy	(Javare et al., 2017)
Entertainment	FSR15	Entertainment	Adaptability; Interoperability; Performance; Usability	(Eckstein et al., 2019)
Wellness	FSR16	Health Training & Assistance	Interoperability; Adaptability; Availability	(Hesse et al., 2017)
Other	FSR17	Groceries' Re-stock	Interoperability; Usability; Availability	(Shweta A.S, 2017)
	FSR18	Information & Time Optimization	Interoperability; Usability; Performance; Availability	(Garcia et al., 2017)
	FSR19	Room Comfort	Interoperability; Adaptability; Reliability	(Leonidis et al., 2019)

Table 12 – LR Functional and Non-Functional Requirements.

This step can also be organized as follows:

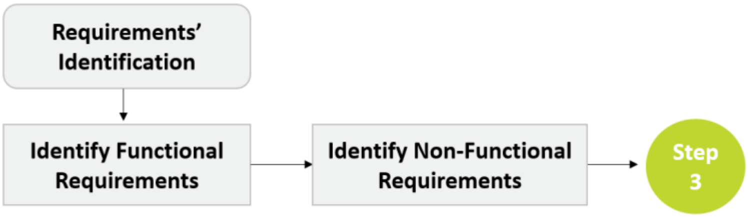

Figure 7 – Frameworks' Implementation (Step 2).

<table>
<tr><th colspan="3">Context Identification</th><th colspan="2">Requirements' Identification</th></tr>
<tr><th>Residences' Typology</th><th>Residents' Typology</th><th>Residents' Objectives</th><th>Functional Requirements</th><th>Non-Functional Requirements</th></tr>
<tr><td rowspan="4">Apartment</td><td rowspan="4">Elderly</td><td rowspan="2">Security</td><td>Home Access Control</td><td rowspan="2">Privacy</td></tr>
<tr><td>Protection & Surveillance</td></tr>
<tr><td rowspan="2">Elderly Assistance</td><td>Fall Detection</td><td rowspan="2">Interoperability</td></tr>
<tr><td>Medication Control</td></tr>
</table>

Table 13 – Example of Requirements' Identification (Step 2).

4.2.3. Step 3: Technology's Selection

Regarding the information collected from the previous stages, the selection of Smart Homes' technology can now be conducted.

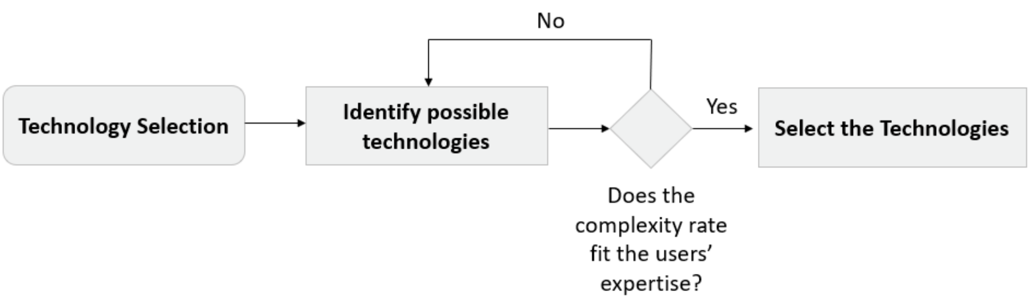

Figure 8 – Frameworks' Implementation (Step 3).

The identification of possible technologies to be used foresees the analysis of their complexity rate and former correspondence to users' expertise. Hence, a matrix was developed to analyze each devices' setup regarding the following factors: "Knowledge Required" or the necessary know-how for deployment, "Time Required" or the amount of time needed, "Training Required" as the amount of training needed to the setup, "Site Preparation" as the necessary changes to the environment, and "Budget Required" or the necessary amount of money a common citizen would expect for the device's setup (Figure 14).

Setup Process / Devices	Knowledge Required	Time Required	Training Required	Site Preparation	Budget Required	Complexity Rate (Average)	Complexity Rate (Final Result)
A							
B							
C							

Table 14 – Technologies' Complexity Matrix.

To a better understanding and a more accurate output, a complexity scale was defined through the assignment of specific points (from 1 to 5) to each factor. Factors such as "Time Required" or "Budget Required" followed more restrictive scales (Table 15).

Time Required Scale	Budget Required Scale	General Scale
<= 10m = Very Low (1)	<= 20€ = Very Low (1)	Very Low (1)
10m < X <= 20m = Low (2)	20€ < X <= 50€ = Low (2)	Low (2)
20m < X <= 30m = Medium (3)	50€ < X <= 100€ = Medium (3)	Medium (3)
30m < X <= 1h = High (4)	100€ < X <= 500€ = High (4)	High (4)
> 1h = Very High (5)	> 500€ = Very High (5)	Very High (5)

Table 15 – Evaluation Scale Used in Complexity's Rate Matrix.

Table 19 comprises the current information from different retailers and manufacturers whereas distinct designs and deployments may influence setup practices, as instructions made for users' assistance. They were retrieved from the manufacturers' available data, which included installation manuals, users' reviews and forums and setup videos (Table 16; Attachments 1 and 2). Three distinct manufacturers and retailers were selected to each device; hence, the same technology appears three times on the matrix, yet with different values. Hence, each row represents the output from one manufacturer. Efforts were made to include well-known companies from different countries; thus, dollar values are converted to euros.

Access Date	Source	Manufacturers	Retailers	Product's Name	Devices' Typology
xxxx-yy-zz	https://www.xyz.com	A	1	X	Air Quality Sensor
xxxx-yy-zz	https://www.xyz.com	B	2	Y	Air Quality Sensor
xxxx-yy-zz	https://www.xyz.com	C	3	Z	Air Quality Sensor

Table 16 – Example of Complexity Rates' Industry Input.

According to the different setup practices, an average was made upon each row to present an accurate result regarding the devices' setup (Table 17; Attachments 1 and 2).

<table>
<tr><th>Setup Practices</th><th>Knowledge Required</th><th>≅ Knowledge Required</th><th>General Scale</th><th>Time Required</th><th>≅ Time Required</th><th>Time Required Scale</th></tr>
<tr><td>APP configurations; Location Setting (Manufacturer A)</td><td>Low</td><td>2</td><td rowspan="3">2,0</td><td>≅ 10m</td><td>1</td><td rowspan="3">1,7</td></tr>
<tr><td>APP configurations; Location Setting Calibration (Manufacturer B)</td><td>Low</td><td>2</td><td>≅ 20m</td><td>2</td></tr>
<tr><td>Wall mounting; Location Setting (Manufacturer C)</td><td>Low</td><td>2</td><td>≅ 20m</td><td>2</td></tr>
</table>

Table 17 – Example of Factors' Complexity Calculations.

The output of the previous calculations is the average of each factor, for each group of devices, providing a final complexity value that will accurately judge the difficulty in installing a certain technology (Table 18; Attachments 1 and 2).

Total General Scale	Total Time Required Scale	Total General Scale	Total General Scale	Total Budget Required Scale		
Knowledge Required	Time Required	Training Required	Site Preparation	Budget Required	Complexity Rate	Final Complexity Rate
1,0	1,0	1,0	1,0	2,0	1,2	1

Table 18 – Example of Factors' Final Calculations.

Some of the devices hereafter exposed are still prototypes in the articles, hence they may appear differently in the matrix (i.e., with letters instead of numeric values). Regarding a specific device such as the "Smart Refrigerator", although it's an existent device, it may appear as a prototype because the retrieved article made some developments on it.

Additionally, the obtained analysis was also presented to four specialists in IoT and Smart Homes' areas, through whom the veracity of the data was confirmed. As time goes by, these records will require an update that, for instance, could be held by consumer protection associations. However, except from the technological breakthroughs, it's expected that the combination between setup and types of devices remains stable, adding to this data a predictable durability.

Setup Process / Devices	Knowledge Required	Time Required	Training Required	Site Preparation	Budget Required	Complexity Rate (Average)	Complexity Rate (Final Result)
Actuator	Very high (5)	High (4)	High (4)	High (4)	Low (2)	3,9	High (4)
Air Quality Sensor	Low (2)	Low (2)	Low (2)	Low (2)	Medium (3)	2,1	Low (2)
Consumption Meter	High (4)	Medium (3)	Low (2)	Medium (3)	Medium (3)	3,1	Medium (3)
Contact Sensor	Very low (1)	Very low (1)	Very low (1)	Very low (1)	Low (2)	1,3	Very low (1)
Eye-Tracker	High (4)	High (4)	High (4)	Medium (3)	Very high (5)	4,1	High (4)
Fans	Very high (5)	Very high (5)	Medium (3)	Very high (5)	High (4)	4,3	High (4)
Fingerprint Scanner	High (4)	High (4)	Medium (3)	Medium (3)	Medium (3)	3,5	High (4)
Floor-Based Sensor*	a)	a)	a)	a)	a)	a)	N/A
Force-Sensitive Resistor (FSR)	Very hight (5)	Medium (3)	High (4)	Medium (3)	Very low (1)	3,1	Medium (3)

Galvanic Skin Response (GSR)	High (4)	Very high (5)	High (4)	Very low (1)	Medium (3)	3,5	High (4)
Gas Sensor	Medium (3)	Low (2)	Medium (3)	Medium (3)	Low (2)	2,6	Medium (3)
Humidity Sensor	Medium (3)	Low (2)	Low (2)	Medium (3)	Medium (3)	2,5	Medium (3)
LCD Monitor	Medium (3)	Medium (3)	Low (2)	Low (2)	High (4)	2,9	Medium (3)
Light Sensor	Low (2)	Low (2)	Low (2)	Low (2)	Low (2)	2,2	Low (2)
Load Sensor	Very high (5)	Very high (5)	Very high (5)	High (4)	Very low (1)	4,0	High (4)
Microcontroller (MCU)	Very high (5)	Very high (5)	Very high (5)	Very high (5)	Very low (1)	4,3	High (4)
Microphone	Very low (1)	Very low (1)	Very low (1)	Very low (1)	Low (2)	1,2	Very low (1)
Microprocessor (MPU)	Very high (5)	Very high (5)	High (4)	Medium (3)	Very low (1)	3,6	High (4)
Motion Sensor	Very low (1)	Very low (1)	Very low (1)	Very low (1)	Low (2)	1,2	Very low (1)
Projector	Medium (3)	High (4)	High (4)	High (4)	Very high (5)	3,9	High (4)
Radar Sensor	Very high (5)	Very high (5)	Very high (5)	Very high (5)	Very low (1)	4,1	High (4)
Single-Board Computer (SBC)	Very high (5)	Very high (5)	Very high (5)	High (4)	Low (2)	4,1	High (4)
Smart Blinds	Medium (3)	Medium (3)	Low (2)	Low (2)	High (4)	2,7	Medium (3)
Smart Carpet*	a)	a)	a)	a)	a)	a)	N/A
Smart Fridge	Very high (5)	Very high (5)	Very high (5)	Very high (5)	Very high (5)	5	Very high (5)
Smart Lights	Very low (1)	Very low (1)	Very low (1)	Very low (1)	Low (2)	1,1	Very low (1)
Smart Locks	High (4)	High (4)	High (4)	High (4)	Medium (3)	4,0	High (4)
Smart Mirror*	a)	a)	a)	a)	a)	a)	N/A
Smart Plugs	Very low (1)	Very low (1)	Very low (1)	Very low (1)	Low (2)	1,4	Very low (1)
Smart Refrigerator*	a)	a)	a)	a)	a)	a)	N/A
Smart Sofa*	a)	a)	a)	a)	a)	a)	N/A
Smart Speakers	Low (2)	Low (2)	Medium (3)	Low (2)	Medium (3)	2,2	Low (2)
Smart Switches	Very high (5)	Very high (5)	Low (2)	Very high (5)	Medium (3)	3,9	High (4)
Smart Table*	a)	a)	a)	a)	a)	a)	N/A

Smart TV	Low (2)	Medium (3)	Medium (3)	Medium (3)	High (4)	3,1	Medium (3)
Smartphone	c)	c)	c)	c)	c)	c)	N/A
Soil Moisture Sensor	High (4)	High (4)	Medium (3)	High (4)	Very low (1)	3,3	Medium (3)
Solar Panels	b)	b)	b)	b)	b)	b)	N/A
Temperature Sensor	Very low (1)	Very low (1)	Very low (1)	Very low (1)	Medium (3)	1,5	Low (2)
Thermostat	High (4)	High (4)	High (4)	Medium (3)	High (4)	3,7	High (4)
User/Object Tracker	High (4)	Medium (3)	Medium (3)	Medium (3)	High (4)	3,3	Medium (3)
Vibration Sensor	Low (2)	Low (2)	Very low (1)	Very low (1)	Medium (3)	1,8	Low (2)
Video Camera	Very low (1)	Very low (1)	Very low (1)	Very low (1)	Medium (3)	1,7	Low (2)

* Articles' prototypes; N/A – Not Applicable; a) Information not available as the device/project to be a prototype yet; b) Factors' information depends on the size of the residence; c) Installation not applicable to homes.

Table 19 – Example of Complexity's Rate Matrix.

The presented framework attempts to guide the final users to a rational choice of technologies regarding their interests and needs. Aside from the different questions that are made during the process, a series of steps can be consulted in Users' Guide, located in the final section of this investigation (Appendix 1).

4.2.3.1. Continuous Improvements

The selected methodology can be very dynamic, allowing future improvements to it. These improvements can be fed by users' feedback during, and after, the implementation and usage of this method. Hence, through a small questionnaire regarding specific performance indicators (Table 20) it's possible to collect insights from users' experience and learn from it.

Devices' Typology	**<insert data>**	
Performance Indicators	**Users' Input**	
	Select (x)	
Please select "Yes" or "No"	YES	NO
A. Presence in the Market Are the technologies available in the market?		
B. Availability to the user Are the technologies accessible to you?		
C. Users' Expertise Do the technologies match your expertise?		

Table 20 – Feedback Questionnaire Instantiation Example.

4.2.4. Step 4: Evaluation

The proposed framework for technology selection was evaluated, attempting to recognize its utility, improvement suggestions, and validation. Therefore, and according to the selected methodology, interviews were made to specialists and common citizens to seize technical and non-technical insights on the framework. The performed literature review served as a foundation to the questioning content during the interviews. They were made on-line through a video communications' platform with record technology embedded.

To validate this investigation's framework, specialists from IoT, Smart buildings, and Smart Homes were selected: Prof. Dr. João Cortez (**JC**), professor at NOVA IMS and co-founder of Inspired Blue, Nuno Gonçalves (**NG**), CEO of Emitu – a digital transformation startup focused on IoT solutions for companies, Joel Reis (**JR**), founder and CEO of Life Emotions – a specialized company in designing and developing smart solutions for companies and private homes, and Inês Cabanas (**IC**), operations' manager at Life Emotions.

Also, two non-specialists were nominated to share feedback on the framework: Guilherme Dias (**GD**), a surf instructor with no available background regarding these technologies, and Luísa Mendes (**LM**), a video editor with a growing curiosity in IoT.

After a brief presentation of the framework (Attachment 4), the participants were prompted with some questions, as an attempt to collect their insights, knowledge, and constructive feedback (Table 21).

Q1	Do you consider the proposed framework to be useful to common citizens?
Q2	What recommendations/suggestions would you consider improving the proposed framework?
Q3	Do you have any comments on the proposed framework?

Table 21 – Validation Questions.

These questions allowed the acknowledge of the frameworks' utility among the citizens, the overall acceptance from the public, and relevant improvements for future work.

Additionally, given the extended contribution of the interviewees, only the answers to the questions above were included in this section. But considering the importance of the interviews, a complete transcript, in Portuguese, can be accessed in Attachment 3.

To avoid biased information, the transcription process occurred immediately after the interviews' conclusion.

Regarding Q1, the answers were the following:

JC: For academic purposes, this makes sense. The democratization of IoT, academically, has lots of potential. However, it's necessary to understand how to transpose this from an academical potential to an economical one. These types of questions need to be in the center of the discussion and must be approached.

It makes sense to me that the framework can aggregate several requirements that already exist in the market so that users can have a participant role. But are they able to select the technologies that makes more sense to him/her? The given example of an apartment for an old person is valid, but I don't expect an old person to have the capability to understand the technological complexity of this process (…). Regarding young people, it's easier to use this framework and understand what types of technologies interests them the most, older people would have more difficulty (…).

Nevertheless, I think this framework can be useful. As any technology, it appears in an ad-hoc format and, at some point, it must be framed out. In my opinion, this framework profiles the sensing technology and turns it more familiar to the public. It's necessary to consider the general lack of understanding by common citizens in this field, which can be explained by several factors, being the advertisement one of them (…). Nowadays, it's more common to encounter ads mentioning trivial technology, such as smartphones, than ads of sensors. So, honestly, the framework makes all sense to me.

NG: In my opinion, and bearing in mind my experience in IoT fields, I think that IoT is a concept that has been presented for a while, especially in the Smart Homes' area, but never got massified. One explanation could be the vast dispersion regarding technologies and solutions, and the competition between them. Sometimes, there are technologies' versions that compete for the same solution, letting users confused about where their investments should be done. For instance, having a version A, B, and C of a certain technology, probably means that one of them will be better than the others. Here lies the uncertainty and the frustration of not knowing to distinguish which one will be obsolete in the future. In this sense, there is this technology dispersion that made IoT to never be massified. So, in my opinion, this framework would help simplifying consumers' navigation in this technologies' maze to satisfy their objectives. If peoples' effort in choosing technologies can be reduced by this framework, then, I consider it very useful as it does something that technology, in general, should do – simplifying peoples' lives.

JR & IC: The idea is very useful. Now, the big challenge would be to align the complexity and diversity of the IoT devices with the citizens' comprehension of them. Having a frameworks that, through filters, can guide them to the right device it's not impossible, but it's difficult, plus the challenge of having several products in the market that don't have much usefulness.

I would apply this framework because it would help me selecting devices for the needs I want to solve. For instance, if I'm cold during the winter maybe a thermostat would warm my house or even a mattress would solve the problem without spending much energy. But this only happens if a good story is told and if I, as a customer, can make a draft of what I want in my home.

GD: I consider the framework very useful because, in my opinion, there is a lack of information regarding the Smart Homes' world, or even disinformation. And this [the framework] would be an important step to turn this area a bit more familiar to people. For people who are not aware of these technologies, such as me, they wouldn't have a clue of what devices are out there, or their purposes. It would be easier to identify what is currently available in the market, and its purpose, with this framework (…). Regarding skeptical people like me, that, sometimes, fear these technologies, I think this framework would let them more comfortable because it would give some control to what is done to their homes. In that sense, I would use this framework. I think that others with more interest in these technologies would see it [the framework] as an extra tool to turn them more accessible.

LM: Technology is becoming more useful and helpful to people. I don't look at technology as something that takes peoples' jobs away, but rather as something that creates new ones. However, people are becoming more and more rigorous with technology, so, whatever it's done, it must be well done (…).

In terms of utility, this framework seems very useful to me, if well implemented (…). In a citizen's perspective, I must be sure that I can control my home and don't need to worry about hackers or other similar problems regarding wireless and Internet technologies. Now, this seems an interesting idea. It serves older people whether in medication monitoring, or emergencies, or fall detection, and families with children… So, it's transversal to different population groups, mainly the most vulnerable ones. But, once again, as long as it does not interfere with my privacy as a citizen, I think it [the framework] is an interesting tool, as long as knowledge and security remain embedded in order to recommend and install the right technologies.

Regarding Q2, the answers were the following:

JC: As in every academic work, there is an inherent economic potential. How is this framework going to serve people and be economically viable? I think this must be mentioned somewhere. Today, we already have solutions with significant economic potential, such as Google Home, Alexa, or Apple TV.

Another question is regarding the technology selection. In my opinion, it should not be common users' responsibility because of their lack of knowledge in the area. This can cause some problems, being the intercommunication between devices one example of them. In IoT we can use different protocols to communicate, for example LoRa, Sinfox, and NBA IoT. Each protocol has different ways to communicate and different scope, batteries' life and communication speeds. How will different devices be included in the same framework while working with different protocols? The framework has a conceptual design, but, in reality, the common citizens don't even know the existence of such protocols. How will people understand the subject in-hands when the vast majority is used to get the solutions from us? Also, in most situations, the price tends to win above all other products' characteristics or, in this case, the setup factors.

Therefore, this framework could have an alternative to the technology selection stage. Perhaps by having a way to recommend technologies through someone who already analyzed the citizens' situation and could guide them through a set of possible solutions. The market is full of technologies and giving to people the freedom to choose them can, not only undermine the problem's resolution, but create others. In my opinion, this is an aspect in the framework I still can't transpose to real life.

NG: Regarding all the applications and software that exist in the market, along with the different sensors and protocols (…) I comprehend the difficulty in choosing the best deal possible. To simplify this delivery process for users, one alternative would be focusing on sensors that are already associated with an APP, such as smart lights, and leaving behind the software and protocols issue as they are too complex to a common person to dive into (…).

Nowadays, giving the pandemics context we live in, home sensors' data turned out to be even more important. We show some interest in understanding whether, for example, the air quality of our homes – which is the place we have spent more time lately – is acceptable. With these types of sensors, associated to a simple APP and simple deployment, we can assure that our home is safe in that way. Maybe by going this way, it'll be easier to relate technologies and applications without diving too deep on software and other complex matters.

The development of this solution could also include several vendors and platforms' software partners as, for example, those who develop Smart Home solutions. If we involve these people, and each one contributes with their parts, we should probably end up with a critical information data set enough for this framework to be successfully used. Its outcome will perhaps depend on this information ingestion regarding devices, solutions, and technologies so that the right value could be given to the common citizens.

JR: There are three or four ideas very interesting in this framework. The identification of the context may be very appealing to the user. Artificial Intelligence (AI) embedded would be even nicer to have so that any type of residence could be easily filtered. But, if the framework would only have the context identification and then the residents' objectives organized in product families, such as lighting or audio, maybe it probably would be easier to present solutions to the people. Otherwise, I can imagine how difficult could be to recommend specific things.

The complexity rate matrix is also very interesting, but I think it's not matching reality in some aspects. The "Time Required" factor is, usually, longer than what is demonstrated in the matrix. Less than 10 minutes for configuration it's difficult to find in a device; usually, the minimum is 20 or 30 minutes. The "Budget Required" factor could also be revised. Nowadays, it's still very difficult to find products being sold for less than 20 euros, in a Smart Homes' context (…). Also, the difference between the "Budget Required" from other devices is, in my opinion, small. So, my suggestion would be to get this information as closest to reality as possible (…). However, by looking closely to the rest of the factors, every sensor in the table seems accurate to me, except from the eye-tracker, which seems a bit more complicated to install.

Additionally, who should be responsible to qualify the end user regarding their expertise level? How do I know my knowledge rate? Maybe, it would be interesting to create some step that would determine users' expertise level. Allowing them to evaluate their know-how to install these devices can be inaccurate. An alternative to this would be asking questions and conclude a certain expertise level from the answers. For instance, asking users how much time they need to change a light bulb or similar questions related to electricity or informatics, since todays' solutions relate to these domains. Users need more help to understand their level in Do-It-Yourself (DIY) technology (e.g., beginner, level 1/level 2, etc.). I think this detail could be improved in this framework.

IC: I would suggest trying to simplify the whole process. From my point of view, the framework is trying to cover many areas, some of them very complex, and I think that if it could be filtered to basic sensors and explore them, for example, instead of trying to get into more topics superficially, it would be simpler to the final user. Also, I think the "Installation Time" factors' name seems vast. I would change the name to other word a bit more tangible.

JR: Furthermore, I think the scope can be revised. Is the framework only for people with some DIY embedded or is it for the use of common mortals? This will drastically change the development process. If it's for any citizen, I think there must be some filter regarding electricity because the majority of people don't have enough know-how on the subject. Maybe, by applying this filter, the framework would only mention sensors that provide data from our homes with devices everyone could act upon, such as smart lighting, which does not require an extraordinary knowledge regarding electricity.

GD: As a recommendation, I would say to try to simplify the process, so that it can be more accessible to everyone. For example, I think older people would have more difficulty in understanding this framework. My grandmother would not understand some of the things mentioned here [the presentation]. Maybe explaining a bit more about each device, such as their purpose and benefits, in the easiest way possible, would be a good improvement. In my understanding, this process must be easier for older people. At least for the current older generation, because in a few years I believe generations will be much more prepared to deal with technology.

LM: A recommendation, in my opinion, would be related to the safety warrantee to people. As a citizen, I want to make sure that this project works with no problems or hackers' attacks, whether I decide to install technology A, B or C. A careful treatment must be given to these technologies, during the recommendations' process, because it's a sensible subject.

For example, regarding the monitoring of older people, the switch of medication can result in serious problems. Guaranteeing the technology security would be a recommendation I would made, or, at least, it should be mentioned in the process.

Another improvement would be expanding this idea beyond Domotics and approaching other areas related to social areas like justice, such as prevention mechanisms (…). But, maybe, that would deviate from the scope of this project.

However, within the scope, would be interesting the creation of a step where users could define the timestamp dimension of some technologies. For example, users could only want a certain technology for a specific period, such is the case for temporarily surveillance. This timestamp could be added to the process so that the residents enjoy more control of their homes in that range of time. Another improvement would be to expand the residences' typology to include, for example, buildings and other technologies such as more intelligent doorbells or elevators. Installing smart technology in buildings, would probably be less expensive and available to more citizens. Then (…), other forms of residence could be explored such as boats and caravans, as many people also live in them and should also be included in this framework.

Regarding Q3, the answers were the following:

JC: Yes, regarding the dependency on vendors and their know-how again. A new business model is positioning in the market – platforms that sell technologies from different manufacturers and, every day, ads new devices from other vendors. They stopped being concentrated in their know-how, to allow other vendors to use their platforms, which also helps expanding the brand. However, most companies still try to sell their products on their own, focusing on creating dependencies over their customers. For instance, a smart solution can be marketed at a low price but, most likely, will guarantee some payment dependency over the user (…). An understanding of these commercial issues is needed because companies need to survive (…).

Regarding the complexity matrix, it makes sense to me (…). It's obvious we should try to translate these technology factors to numbers and perform calculus. Every sensor represented in the column seem right to me, as a sample of the several sensors in the market. Overall, the framework makes all sense, to me.

NG: The framework has several steps that makes sense for me. Firstly, the identification of the context allows us to understand the type of users and what their objectives are, so that they can be translated in the next stage – the requirements' identification. This step is not always that obvious, sometimes different providers offer many solutions letting common citizen feeling confused about them and their match with personal goals (…). From my understanding, the idea of this framework is to help the user, in a logical and structured way (…) to select the right technology through several filters, until a set of solutions can be presented regarding their specific objectives. Then, the user will select them regarding some factors, such as the time to install, the budget required, and the related benefits.

Therefore, I consider this framework a good navigation tool among technologies (…) to answer to peoples' needs while, simultaneously, reduces their cognitive effort of having to study these technologies alone. Technology, in general, should do this – reduce peoples' effort and easing their lives – so, I assume this framework as a technology that simplifies peoples' lives in IoT selection.

As a final note, I think it's important to implement this and use it, in fact. If we have a framework that simplifies the technology navigation process and further selection, it should be used. It does not make sense creating a framework and then ignoring it, and don't use it. The most important, in my opinion, is that we start from theoretical solutions to end up into practical ones.

JR & IC: Overall, the framework seems subjective, given the manufacturers and retailers from where calculus was based (…). This information needs to be based on websites where common citizens navigate. It's also important to acknowledge that products will vary in price and stock, regarding their geographical location. There are manufacturers and retailers that only focus on the America's market, rather than on the Europeans' (…).

This framework's path is to democratize the IoT concept, in terms of marketing. It has been on the table for a while now, and vendors also help in this process of getting people to know what IoT is. In IoT there is one characteristic: manufacturers, usually, have very concrete and closed projects, so it's difficult for a vendor to commercialize, for instance, tracking sensors and quality sensors, simultaneously. (…) In general, products' families are very segmented. Everything appears in different "islands", sometimes with no connection between them. This represents another challenge while talking about technologies or solutions so that users can better understand the complexity of this world.

Again, I would use this framework if the storytelling showed to be effective. Understanding if I am building a home, or an apartment, and what am I looking for to enhance my life would help me draft what I want to solve my problems. If we offer solutions, in an appropriate end user language, I think this framework could be a useful tool.

GD: Overall, I think it [the framework] is a good idea. It would be interesting to have a brief explanation of each sensor before recommending it, because, even if it's easy to some to identify what a specific sensor can do, to others it may not be. In my case, and I think I can speak for younger generations, I can recognize all sensors here [in the complexity rate matrix]. But perhaps having an overview of what each can do would turn this information more intuitive. Maybe explaining how the sensor sends the information, from where it's taken… But, by doing this, there is also a downside: it becomes more complex, and maybe some people would lose motivation on this tool. However, if I had to buy smart technology, this [the framework] would be something I would use because it seems to me less invasive than some other technologies out there. I think I would be in control with it. I would also say this could be more interesting for young people rather than to old people. For my generation I think this is very accessible, there is nothing here I can't decode.

But, overall, I think this [the framework] is a very good idea given the market tendencies right now. Soon enough we will have much more devices embedded in our lives, to do so much more things than they already do today. In my perspective, it will become a matter of habits and trends, so we need to be aware of it.

LM: Overall, I think this [the framework] is very clear; there is nothing that I didn't understand in the process. The difficult part will probably be the selling of this idea because the framework must be well explained, credible, and safe. A single mistake can result in trust issues to users.

The framework's steps make sense to me. Having two selection phases and a last one of recommendation seems to be a good strategy, where the context and deployment conditions are inquired to, then, recommend something to the user. To me, this is interesting since it reaches all society groups, including the most vulnerable ones such as older people and children. In this aspect, this is, per se, an achievement, enhanced if cost-price relation is accessible.

4.3. Discussion

After the evaluation of the artifact, a careful analysis of the given feedback is made in this section. This discussion has its focus on the artifacts' utility, possible improvements, and general observations of the participants during the interviews.

Regarding the utility of the artifact, all participants agreed on the usefulness of this framework for common citizens that are getting more rigorous about technology. The need for democratizing IoT among the public seemed to be a shared concern among all specialists and non-specialists, that agreed on the general lack of understanding on IoT and, consequently, Smart Homes' technology. Simplifying consumers lives and reducing their effort on reaching their objectives were the most mentioned benefits.

However, all participants recognized some challenges inherent to the framework, such as: the economical challenge (how to transform the academical potential into an economical one and be aware, at the same time, of the companies' economic interests), the complexity challenge within users (how to guarantee that all users, including older ones, understand the technological process), the technology market variety (how to ensure selection of the right devices or the best deals among so many options in the market), and the security warrantee (how to ensure the safety of the smart technology's users).

Considering improvements and recommendations, there is an overall concern regarding users' responsibility over technology selection. Most of the participants agreed that this idea could create some conflict because users lack the necessary know-how to select the right technology to their needs. Therefore, alternatives were given such as having a more technical person in the process, capable of evaluating each situation and properly recommend a set of solutions, or even simplifying the process itself, so that it is accessible to most of the people, including older generations. Focusing on a specific set, or family, of devices and detail them a bit better seemed to be a solution for some of the participants, to avoid approaching devices too superficially.

Within the presented devices some recommendations were also done. The match with reality could be improved, by selecting more familiar sources. Even though brands, or devices' models, can't be mentioned throughout the investigation, these should be as much adapted to what users usually access so that installation factors such as "Time Required" or "Budget Required", or even Complexity Rate, appear as accurate as possible. Other suggestions were to focus on specific types of devices, such as the simple ones, or the ones controlled by an APP, to avoid complex matter such as software and communication protocols. A brief explanation of each device's function was another improvement idea given in the evaluation phase.

Still regarding suggestions, some were related to the process stages. The addition of a new step was discussed as a bridge between users and their qualifications to define their expertise level. It would thus include more questions regarding topics such as informatics and electricity. Other steps were suggested regarding the timestamp of this technologies in users' lives, or even the expansion of the residences' typology in the process. Including a range of time on the installation of some products and other buildings or other residences' formats, such as boats, were mentioned.

Also, improving the residents' objective stage was suggested to better assist users when identifying their goals, since product families could be aggregated (e.g., lighting and sound). Expectedly it would be more intuitive for users to identify their needs and better accept recommendations. Adding AI to the process would help filtering the type of residents and possibly consuming less time and resources.

The final suggestion given by the participants was regarding the development of the framework. Including several vendors and platforms' software partners would probably aggregate critical information to enhance the process of selecting technologies.

Finally, concerning overall comments to the proposed framework, all the interviewees expressed their support to upgrade this tool to the practical world, and use it as an answer to common citizens' needs. Some determinants to this would be the effective storytelling of the process, the functional connection between communication protocols, and the accuracy of devices' information. Allowing citizens to idealize a draft of what they want in their homes, understanding how different devices can communicate with each other, and guaranteeing the recommended devices are based in accessible vendors to citizens are "must haves" to the usability of this framework. Also, non-specialists assumed the privacy issue as something that should be considered in the process.

Additionally, some participants shared outputs from the IoT field today, as an attempt to contextualize the framework in the future. The geographical location, according to the feedback, will play an important role to the technology selection stage, as products can vary in price, and availability, from country to country. The democratization of IoT can be triggered by the framework, but vendors will give an important contribution to this phenomenon, since they are the ones who launch products in the market. Finally, some products will represent a challenge, as they may appear completely isolated from others, with no available connection between them. However, some recognize that Smart Homes' technology will soon become a trend with products doing much more than they already do today.

5. CONCLUSIONS

This chapter concludes the developed work of this dissertation by reflecting the most important conclusions, limitations, and future work. It also allows a global understanding of whether the specified objectives were achieved or not. Therefore, and considering the collected feedback at the evaluation stage, we can acknowledge the initial objectives were fulfilled, and the proposed artifact can ensure common citizens' awareness and autonomy during their home transformation process.

5.1. SYNTHESIS OF DEVELOPED WORK

Conducting this investigation endorsed the overview of different subjects from the Smart Homes' concept and application areas, to IoT and Domotics. Gathering knowledge on these areas made possible the design of a framework that support common citizens in their Smart Homes' setup. The framework was validated by technical specialists and common citizens to verify its utility in the market.

5.2. LIMITATIONS

This investigation had some limitations regarding the validation of the framework. Even though it was approved by a technical and non-technical audience, the number of participants could have been higher and, consequently, provide a more credible, and universal, validation. Given the pandemics' context that was active during the conduct of this investigation, the availability of several participants was reduced.

Attempting to not include extensive information regarding the existent technologies, the number of devices and applications was limited to the articles' information. Therefore, the complexity analysis matrix may also be limited to the devices present in the articles.

Efforts were made to include manufacturers and retailers from global locations turning these devices accessible to everyone, however, and according to the type of devices retrieved from the literature, some locations were not mentioned, thus limiting the geographical boundaries of the investigation.

Additionally, due to the shortage of time, the communication stage previously scheduled in the selected methodology of this study was not fulfilled. Consequently, the real application of the proposed framework was also compromised, leaving other interesting findings to reveal. The practical application would also test more scenarios and, possibly, collect more insights to widen the framework's scope.

It is also important to mention that technology is always evolving and what is used and available today may not be in the future. Therefore, obsolete technologies constitute the most significant limitation to the conduct of this investigation.

5.3. Future Work

Regarding future work, the validation process could be improved by gathering more insights from a larger number of people, thus turning the framework as much universal and accessible as possible. Different users should be interviewed to collect information from as many scenarios as possible.

Considering the diversity of technologies and their rapid growth and update in the market, a good improvement would be the continuous update of new technologies and devices that are launched in the market. As IoT is always innovating, new products will be inevitably launched, thus a follow-up of them would be recommended to future work. Also, including a larger sample of devices in the complexity matrix would catalogue as much devices as possible and analyze them through users' optics and expertise.

This investigation would also benefit from a public communication and a field application to study and test different scenarios, types of users and technologies. The retrieved data from that operation would represent an important input to the enhancement of this work.

Finally, turning this investigation available to the academic world through, for instance, a publication, would also made it more accessible to the public and allow the arise of other investigations.

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APPENDIXES

APPENDIX 1: USERS' GUIDE

Steps			Description		Procedure
Step 1: Context Identification			Which resident are you? (Choose **one** type)		Go to A. Apartment **or** B. House
A. Apartment			B. **House**		
By Age	**Select (X)**	**Procedure**	**By Age**	**Select (X)**	**Procedure**
A.1. Elderly		Proceed to C. a)	B.1. Elderly		Proceed to C. b)
A.2. Adults between 20y-60y		Proceed to C. a)	B.2. Adults between 20y-60y		Proceed to C. b)
A.3. Adults between 18y-29y		Proceed to C. a)	B.3. Adults between 18y-29y		Proceed to C. b)
By Family Members	**Select (X)**	**Procedure**	**By Family Members**	**Select (X)**	**Procedure**
A.4. Family Members (only adults)		Proceed to C. a)	B.4. Family Members (only adults)		Proceed to C. b)
A.5. Family Members (including children)		Proceed to C. a)	B.5. Family Members (including children)		Proceed to C. b)
Other	**Select (X)**	**Procedure**	**Other**	**Select (X)**	**Procedure**
A.6. Disabled People		Proceed to C. a)	B.6. Disabled People		Proceed to C. b)
A.7. Farmers		Proceed to C. a)	B.7. Farmers		Proceed to C. b)
C. Objectives Definition			What is the objective of your Smart Home? Select (X)		Choose **one** objective
a) Apartment	**Select (X)**	**Procedure**	**b) House**	**Select (X)**	**Procedure**
a.1) Elderly Assistance		Proceed to Stage 2.A.1.	b.1) Elderly Assistance		Proceed to Step 2.A.2.
a.2) Energy Efficiency		Proceed to Stage 2.A.1.	b.2) Energy Efficiency		Proceed to Step 2.A.2.

a.3) Devices' Control		Proceed to Stage 2.A.1.	b.3) Devices' Control		Proceed to Step 2.A.2.
a.4) Monitoring		Proceed to Stage 2.A.1.	b.4) Monitoring		Proceed to Step 2.A.2.
a.5) Security		Proceed to Stage 2.A.1.	b.5) Security		Proceed to Step 2.A.2.
a.6) Entertainment		Proceed to Stage 2.A.1.	b.6) Entertainment		Proceed to Step 2.A.2.
a.7) Wellness		Proceed to Stage 2.A.1.	b.7) Wellness		Proceed to Step 2.A.2.
a.8) Other		Proceed to Stage 2.A.1.	b.8) Other		Proceed to Step 2.A.2.
Step 2: Requirements' Identification			Which are your requirements for your Smart Home?		Go to A. Functional Requirements, **then** B. Non-Functional Requirements
A. Functional Requirements (FRS)			Which FSR would you like to have in your Smart Home?		1st: Choose your identified context. 2nd: Select your FSR (Choose **one,** from Table 10)

1. Apartment

Context	**FSR**																			**Procedure**
	Elderly Assistance				Energy Efficiency	Devices' Control			Monitoring				Security		Entertainment	Wellness	Other			
	FSR1	**FSR2**	**FSR3**	**FSR4**	**FSR5**	**FSR6**	**FSR7**	**FSR8**	**FSR9**	**FSR10**	**FSR11**	**FSR12**	**FSR13**	**FSR14**	**FSR15**	**FSR16**	**FSR17**	**FSR18**	**FSR19**	
1.1 Apartment + Elderly																				Proceed to 2. B. 1.1.1.
1.2 Apartment + Adults 20y-60y																				Proceed to 2. B. 1.1.2.

1.3 Apartment + Adults 18y-29y																				Proceed to 2. B. 1.1.3.
1.4 Apartment + Family Members (only adults)																				Proceed to 2. B. 1.1.4.
1.5 Apartment + Family Members (including children)																				Proceed to 2. B. 1.1.5.
1.6 Apartment + Family Members (only adults)																				Proceed to 2. B. 1.1.6.
1.7 Apartment + Disabled																				Proceed to 2. B. 1.1.7.
1.8 Apartment + Farmers																				Proceed to 2. B. 1.1.8.
2. House																				
Context	**FSR**																			**Procedure**
	Elderly Assistance				Energy Efficiency	Devices' Control			Monitoring				Security		Entertainment	Wellness	Other			
	FSR1	**FSR2**	**FSR3**	**FSR4**	**FSR5**	**FSR6**	**FSR7**	**FSR8**	**FSR9**	**FSR10**	**FSR11**	**FSR12**	**FSR13**	**FSR14**	**FSR15**	**FSR16**	**FSR17**	**FSR18**	**FSR19**	
2.1 House + Elderly																				Proceed to 2. B. 2.1.1.
2.2 House + Adults 20y-60y																				Proceed to 2. B. 2.1.2.
2.3 House + Adults 18y-29y																				Proceed to 2. B. 2.1.3.
2.4 House + Family																				Proceed to 2. B. 2.1.4.

Members (only adults)																				
2.5 House + Family Members (including children)																				Proceed to 2. B. 2.1.5.
2.6 House + Family Members (only adults)																				Proceed to 2. B. 2.1.6.
2.7 House + Disabled																				Proceed to 2. B. 2.1.7.
2.8 House + Farmers																				Proceed to 2. B. 2.1.8.

B. Non- Functional Requirements (NFRS)	Which NFSR would you like to have in your Smart Home?	1st: Choose your identified context 2nd: Select your NFSR (Choose **one**, from Table 10)

1. Apartment

Context	NFRS								Procedure
	Interoperability	**Privacy**	**Reliability**	**Adaptability**	**Safety**	**Scalability**	**Usability**	**Performance**	
1.1 Apartment + Elderly									Proceed to Step 3.
1.2 Apartment + Adults 20y-60y									Proceed to Step 3.
1.3 Apartment + Adults 18y-29y									Proceed to Step 3.
1.4 Apartment + Family Members (only adults)									Proceed to Step 3.

1.5 Apartment + Family Members (including children)									Proceed to Step 3.
1.6 Apartment + Family Members (only adults)									Proceed to Step 3.
1.7 Apartment + Disabled									Proceed to Step 3.
1.8 Apartment + Farmers									Proceed to Step 3.
2. House									
Context	**NFRS**								**Procedure**
	Interoperability	**Privacy**	**Reliability**	**Adaptability**	**Safety**	**Scalability**	**Usability**	**Performance**	
1.1 House + Elderly									Proceed to Step 3.
1.2 House + Adults 20y-60y									Proceed to Step 3.
1.3 House + Adults 18y-29y									Proceed to Step 3.
1.4 House + Family Members (only adults)									Proceed to Step 3.
1.5 House + Family Members (including children)									Proceed to Step 3.
1.6 House + Family Members (only adults)									Proceed to Step 3.
1.7 House + Disabled									Proceed to Step 3.

1.8 House + Farmers									Proceed to Step 3.

Step 3: Technology Selection	Which devices fit you better?	Select your device.

Apartment/House						
Context		**Objective**	**FSR**	**NFSR**	**Device**	**Complexity Rate**
Apartment/House	Elderly	Elderly Assistance	FSR1	Interoperability Privacy Reliability	Motion Sensor	Very Low
					Smartphone	c)
					Temperature Sensor	Low
	Adults 18y-29y				Single-Board Computer	High
			FSR2	Privacy Adaptability Safety Scalability	Temperature Sensor	Low
	Family Members (only adults)				Humidity Sensor	Medium
					Single-Board Computer	High
					Contact Sensor	Very Low
					Light Sensor	Low
	Family Members (including children)		FSR3	Adaptability Interoperability Safety	Floor-Based Sensor*	a)
					Smart Carpet*	a)
	Disabled		FSR4	Interoperability Adaptability	Smart Lights	Very Low
					Actuator	High
	Farmers				Smart Speakers	Low
					Single-Board Computer	High
					Contact Sensor	Very Low
	Elderly	Energy Efficiency	FSR5	Usability Availability Interoperability	Temperature Sensor	Low
	Adults 20y-60y				Humidity Sensor	Medium
					Air Quality Sensor (CO_2 sensor)	Low
	Adults 18y-29y				Smart Plugs	Very Low
	Family Members (only adults)				Smart Switches	High
					Solar Panels	b)

Apartment/House	Family Members (including children)			Scalability	Light Sensor	Low
	Disabled				Smartphone	c)
	Farmers				Microcontroller	High
	Elderly	Devices' Control	FSR6	Safety Interoperability	Temperature Sensor	Low
					Microphone	Very Low
	Adults 20y-60y				Fans	High
					Actuator	High
					Smartphone	c)
	Adults 18y-29y				Fingerprint Scanner	High
					Smart Lights	Very Low
					Single-Board Computer	High
	Family Members (only adults)				Video Camera	Low
			FSR7	Usability Availability Interoperability	Eye-Tracker	High
					Microcontroller	High
	Family Members (including children)		FSR8	Interoperability Usability Adaptability	Soil Moisture Sensor	Medium
					Temperature Sensor	Low
	Disabled				Humidity Sensor	Medium
	Farmers				Microcontroller	High
	Elderly		FSR9	Performance Adaptability Interoperability Reliability	Gas Sensor	Medium
					Temperature Sensor	Low
					Humidity Sensor	Medium
					Microcontroller	High
	Adults 20y-60y		FSR10	Interoperability Adaptability Availability Reliability Usability	LED	Low
	Adults 18y-29y				Temperature Sensor	Low
					Humidity Sensor	Medium
					Gas Sensor	Medium
					Microcontroller	High
			FSR11		Thermostat	High

Apartment/House

	Family Members (only adults)	Monitoring		Availability Adaptability Interoperability Usability	Smartphone	c)
	Family Members (including children)				Motion Sensor	Very Low
					Consumption Meter	Medium
					Light Sensor	Low
					Smart Lights	Very Low
					Health Status Devices	Medium
					Smart Fridge	Very High
	Disabled		FSR12	Reliability Adaptability Interoperability Usability Performance	Temperature Sensor	Low
					Humidity Sensor	Medium
					Smartphone	c)
	Farmers				Air quality Sensor (VOC Sensor)	Low
					Air quality Sensor (PM 2.5 Sensor)	Low
Apartment/House	Elderly	Security	FSR13	Privacy Safety Interoperability	Motion Sensor	Very Low
	Adults 20y-60y				Video camera	Low
	Adults 18y-29y				Single Board Computer	High
	Family Members (only adults)					
	Family Members (including children)		FSR14	Interoperability Usability Safety Privacy	Smart Lock	High
					Microcontroller	High
	Disabled				Vibration Sensor	Low
					Smartphone	c)
	Farmers				Motion Sensor	Very Low
	Elderly	Entertainment	FSR15	Adaptability Interoperability Performance Usability	User/Object Tracker	Medium
	Adults 20y-60y				Light Sensor	Low
	Adults 18y-29y				Temperature Sensor	Low
	Family Members (only adults)				Actuator	High
					Microphone	Very Low
	Family Members (including children)				Air Quality Sensor	Low
					Smart Lights	Very Low
	Farmers				Smart Plugs	Very Low

Apartment/House	Elderly	Wellness	FSR16	Interoperability Adaptability Availability	Galvanic Skin Response (GSR)	High
	Adults 20y-60y					
	Adults 18y-29y				Radar Sensor	High
	Family Members (only adults)					
	Family Members (including children)				Force-Sensitive Resistor (FSR)	Medium
					Actuator	High
	Disabled				Microcontroller	High
	Farmers					
	Elderly	Other	FSR17	Interoperability Usability Availability	Video Camera	Low
					Smartphone	c)
					Microprocessor	High
					Smart Refrigerator*	a)
	Adults 20y-60y		FSR18	Interoperability Usability Performance Availability	LCD Monitor	Medium
					Single Board Computer	High
					Smart Mirror*	a)
	Adults 18y-29y				Video Camera	Low
Apartment/House	Family Members (including children)		FSR19	Interoperability Adaptability Reliability	Smart Lights	Very Low
					Force-Sensitive Resistor (FSR)	Medium
					Load Sensor	High
					Smart Locks	High
	Disabled				Smart Blinds	Medium
					Motion Sensor	Very Low
					Humidity Sensor	Medium
	Farmers				Smart TV	Medium
					Smart Sofa*	a)
					Smart Table*	a)

					Microcontroller	High
					Projector	High

ANNEXES

ANNEX 1: COMPLEXITY RATES' MATRIX: CALCULATIONS (PART I)

Timestamp	Source	Manufacturers	Retailers	Products' Name	Devices Typology	Practices	Knowledge Required	≈Knowledge Required	GENERAL SCALE	Time Required	≈Time Required	TIME REQUIRED SCALE	Training Required	≈Training Required	GENERAL SCALE	Site Preparation	≈Site Preparation	GENERAL SCALE	Budget Required	≈Budget Required	BUDGET REQUIRED SCALE
2021-06-18	https://www.p	Mauser	Ptrobotics	Tower Pro SG90 Serv	Actuators	Electrical Wiring; Programming settings; Location Setting; Wall Mounting;	Very High	5		≈1h	4		High	4		High	4		€3,57	1	
2021-06-19	https://www.a	Homend	AMAZON	DC12V 12inch Stroke	Actuators	Electrical Wiring; Programming settings; Location Setting; Wall Mounting;	Very High	5	5,0	≈1h	4	4,0	High	4	4,0	High	4	4,0	€38,73	2	2,3
2021-06-19	https://www.d	BTICINO	dmlights	light status F411/4	Actuators	Electrical Wiring; Programming settings; Location Setting; Wall Mounting;	Very High	5		≈1h	4		High	4		High	4		€126,75	4	
2021-06-19	https://www.e	Eve Home	Eve Home	Eve Room	Air Quality Sensors	APP configurations; Location Setting;	Low	2		≈10m	1		Low	2		Medium	3		€99,95	3	
2021-06-19	https://www.a	AIRTHINGS	AIRTHINGS	Wave Mini indoor air	Air Quality Sensors	APP configurations; Location Setting; Calibration	Low	2	2,0	≈20m	2	1,7	Very Low	1	1,7	Very Low	1	2,0	€67,42	3	3,0
2021-06-19	https://www.e	ECOWITT	ECOWITT	WH0290 Air quality r	Air Quality Sensors	Wall Mounting; Location Setting;	Low	2		≈20m	2		Low	2		Low	2		€64,05	3	
2021-06-08	https://www.e	Eve Home	Eve Home	Eve Energy Smart Plu	Consumption Meter	APP configurations;	Very Low	1		≈5m	1		Very Low	1		Very Low	1		€39,95	2	
2021-06-08	https://www.d	BTICINO	dmlights	Electrical consumptio	Consumption Meter	Electrical Wiring; Network configuration;	Very High	5	3,7	≈1h	4	3,3	Medium	3	2,3	Medium	3	3,0	€181,80	4	3,0
2021-06-08	https://www.a	Qubino	AMAZON	Smart Meter	Consumption Meter	aPP configurations; Electrical Wiring; Network configuration;	Very High	5		≈1h30m	5		Medium	3		Very High	5		€79,27	3	
2021-06-07	https://www.e	ECOBEE	ECOBEE	Smart Sensor for Doo	Contact sensor	APP configurations; Location Setting;	Very Low	1		≈5m	1		Very Low	1		Very Low	1		€42,13	2	
2021-03-04	https://www.a	Aqara	AMAZON	Aqara Door and Wind	Contact Sensor	APP configurations; Location Setting;	Very Low	1	1,0	≈5m	1	1,0	Very Low	1	1,0	Very Low	1	1,0	€82,34	3	2,3
2021-06-07	https://eu.ring	ring	ring	Alarm Contact Sensor	Contact sensor	APP configurations; Location Setting;	Very Low	1		≈5m	1		Very Low	1		Very Low	1		€25,00	2	
2021-06-07	https://pupil-la	PupilLabs	PupilLabs	Pupil Core	Eye-Tracker	Software configuration; Location Setting; Calibration;	Very High	5		≈1h30m	5		Very High	5		High	4		€2 490,00	5	
2021-06-07	https://www.g	GAZEPOINT	GAZEPOINT	GP3 Eye Tracker	Eye-Tracker	Software configuration; Location Setting; Calibration	Medium	3	3,7	≈1h	4	4,3	High	4	4,3	Medium	3	3,3	€585,79	5	4,7
2021-06-07	https://gaming	Tobii	Tobii	Tobii Eye Tracker 5	Eye-Tracker	Software configuration; Location Setting; Calibration	Medium	3		≈1h	4		High	4		Medium	3		€229,00	4	
2021-06-22	https://www.h	Honeywell	HONEYWELL	Honeywell Carnegie 5	Fans	Wall Mounting; Electrical Wiring; Location Setting;	Very High	5		≈45m	4		Medium	3		Very High	5		€151,41	4	
2021-06-22	https://www.a	Big Ass Fans Store	AMAZON	Big Ass Fans Haiku L S	Fans	Wall Mounting; Electrical Wiring; Network Configurations; Location Setting;	Very High	5	5,0	≈1h30m	5	4,7	Medium	3	3,0	Very High	5	5,0	€672,12	5	4,0
2021-06-22	https://promin	ProminenceHome	PROMINENCEHOME	52" Bolivar, White, Pu	Fans	Wall Mounting; Electrical Wiring; Location Setting;	Very High	5		≈1h	5		Medium	3		Very High	5		€83,30	3	
2021-06-07	https://www.s	SEEED	SEEED	Grove - capacitive fin	Fingerprint Scanner	Network configurations; Software configuration; Programming configuration	Very High	5		≈1h30m	4		High	4		Low	2		€23,09	2	
2021-06-07	https://verifisa	VERIFI	VERIFI	Verifi P5100 Fingerpr	Fingerprint Scanner	Software configuration; Location Setting; Calibration;	High	4	4,3	≈1h	4	4,0	Medium	3	3,3	Low	2	2,7	€117,16	4	3,3
2021-06-07	https://ekeysh	eKey	eKey	Finger Scanner Integr	Fingerprint Scanner	Electrical Wiring; Wall Mounting	High	4		≈1h	4		Medium	3		High	4		€427,46	4	
2021-06-23	a)	a)	a)	a)	Floor-based Sensor*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-06-23	a)	a)	a)	a)	Floor-based Sensor*	a)	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A
2021-06-23	a)	a)	a)	a)	Floor-based Sensor*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-06-07	https://www.s	Sensitronics	Sensitronics	1 Inch ThruMode FSR	Force-sensitive resistors (FSR)	Electrical Wiring; Location Setting	Very High	5		≈20m	2		High	4		Medium	3		€6,74	1	
2021-06-07	https://buyinte	Interlink Eletronics	Interlinks Eletronics	FSR Model 400	Force-sensitive resistors (FSR)	Electrical Wiring; Location Setting;	Very High	5	5,0	≈20m	2	2,7	Medium	3	3,7	Medium	3	3,0	€2,52	1	1,0
2021-06-07	https://www.a	Adafruit	Adafruit	Adafruit Square Force	Force-sensitive resistors (FSR)	Electrical Wiring; Programming Settings; Location Setting;	Very High	5		≈1h	4		High	4		Medium	3		€7,54	1	
2021-06-07	https://www.a	NeuLog	AMAZON	Neulog NUL217 Galva	Galvanic Sking Response Sensor (GSR)	Electrical Wiring; Network configuration;	Medium	3		≈45m	4		High	4		Very Low	1		€84,28	3	
2021-06-07	https://www.s	Seeed	SEEED	Grove - GSR Sensor	Galvanic Sking Response Sensor (GSR)	Electrical Wiring; Software Configuration	Very High	5	4,3	≈1h30m	5	4,7	High	4	4,0	Very Low	1	1,3	€9,19	1	3,0
2021-06-07	https://www.v	Vernier	Vernier	Qubit GSR Sensor	Galvanic Sking Response Sensor (GSR)	Electrical Wiring; Software Configuration	Very High	5		≈1h30m	5		High	4		Low	2		€1 030,82	5	
2021-06-07	https://www.e	ECOWITT	ECOWITT	WH0290 Air quality r	Gas Sensor	Wall Mounting; Location Setting;	Low	2		≈20m	2		Low	2		Low	2		€64,05	3	
2021-06-07	https://www.s	SparkFun Store	SparkFun Store	LPG Gas Sensor MQ-6	Gas Sensor	Electrical Wiring; Programming Settings; Location Setting;	High	4	2,7	≈45m	4	2,3	High	4	2,7	High	4	3,0	€4,17	1	2,3
2021-06-07	https://www.e	Eve Home	Eve Home	Eve Room	Gas Sensor	APP configurations; Location Setting;	Low	2		≈10m	1		Low	2		Medium	3		€99,95	3	
2021-06-19	https://www.e	Eve Home	Eve Home	Eve Room	Humidity Sensor	APP configurations; Location Setting;	Low	2		≈10m	1		Low	2		Medium	3		€99,95	3	
2021-06-19	https://www.h	Honeywell Home	HONEYWELL	T9 Smart Sensor	Humidity Sensor	APP configurations; Location Setting;	Low	2	2,7	≈10m	1	1,7	Very Low	1	2,0	Medium	3	3,0	€33,71	2	3,0
2021-06-19	https://www.e	Ecobee	ECOBEE	ecobee3 lite	Humidity Sensor	Electrical Wiring; Calibration; APP configurations	High	4		≈30m	3		Medium	3		Medium	3		€143,28	4	
2021-06-22	https://www.l	LG	LG	LG 27GL650F-B 27 Inch	LCD Monitor	Electrical wiring; Mounting; Network configurations; Location Setting;	Medium	3		≈1h	4		Low	2		Low	2		€167,47	4	
2021-06-22	https://store.h	HP	HP	HP V22 FHD Monitor	LCD Monitor	Electrical wiring; Mounting; Network configurations; Location Setting;	Medium	3	3,0	≈30m	3	3,3	Low	2	2,0	Low	2	2,0	€105,17	4	4,0
2021-06-22	https://www.d	DELL	DELL	Dell 24 Monitor - S24	LCD Monitor	Electrical wiring; Mounting; Network configurations; Location Setting;	Medium	3		≈30m	3		Low	2		Low	2		€126,20	4	
2021-06-19	https://aeotec	Aotec	Popp/to	MultiSensor 6	Light Sensor	Location Setting;	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€49,52	2	
2021-06-19	https://wiki.se	SEEED	SEEED	Grove - Light Sensor	Light Sensor	Software Configurations; Electrical Wiring; Location Setting	Very High	5	2,3	≈50m	4	2,0	High	4	2,3	High	4	2,3	€3,36	1	2,0
2021-06-19	https://www.f	FIBARO	FNAC	Fibaro Motion Sensor	Light Sensor	APP configurations; Location Setting;	Very Low	1		≈10m	1		Low	2		Low	2		€57,97	3	
2021-06-19	https://www.s	sparkFun Store	SparkFun Store	Load Sensor - 50kg (G	Load Sensor	Programming Settings; Electrical Wiring;	Very High	5		≈2h	5		Very High	5		High	4		€3,33	1	
2021-06-19	https://www.p	Ptrobotics	Ptrobotics	Load Sencor - 50kg	Load Sensor	Electrical Wiring; Calibration	Very High	5	5,0	≈1h30m	5	5,0	Very High	5	5,0	High	4	4,0	€16,54	1	1,0
2021-06-19	https://www.l	SENSOR	AliExpress	Load Cell 1022	Load Sensor	Mechanical Mounting; Electrical Wiring; Calibration	Very High	5		≈2h	5		Very High	5		High	4		€1,17	1	
2021-06-23	https://www.a	Jekewin	AMAZON	ATMega32-16PU 8-bit	Microcontroller	Programming Settings; Software configurations; Network configurations;	Very High	5		≈2h	5		Very High	5		Very High	5		€12,55	2	
2021-06-23	https://esp826	ESP8266 Shop	ESP8266 Shop	NodeMCU-ESP8266	Microcontroller	Programming Settings; Software configurations; Network configurations;	Very High	5	5,0	≈2h	5	5,0	Very High	5	5,0	Very High	5	5,0	€4,51	1	1,3
2021-06-23	https://www.m	Microchip	Microchip	ATSAM4LC4CA-AUR	Microcontroller	Programming Settings; Software configurations; Network configurations;	Very High	5		≈2h	5		Very High	5		Very High	5		€4,97	1	

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ANNEX 1: COMPLEXITY RATES' MATRIX: CALCULATIONS (PART I) – CONT.

2021-04-04	https://www.t	TONOR	TONOR	TONOR G11 Conferen	Microphone	Network configurations;	Very Low	1		≈2m	1		Very Low	1		Very Low	1		€26,96	2	
2021-04-04	https://www.s	SABINETEK	SABINETEK	SmartMike+Wireless	Microphone	APP configurations;	Very Low	1	1,0	≈5m	1	1,0	Very Low	1	1,0	Very Low	1	1,0	€98,75	3	2,0
2021-04-04	https://www.a	TOSHIBA	AMAZON	Toshiba Connect USB	Microphone	Network configurations;	Very Low	1		≈5m	1		Very Low	1		Very Low	1		€10,91	1	
2021-05-10	https://pt.mou	Atmel	Mouser Eletronics	Atmel ATSAMA5D22	Microprocessor	Software Configuration; Network configuration;	Very High	5		≈1h	5		High	4		Medium	3		€5,67	1	
2021-05-10	https://www.a	S-Smart-Home	AMAZON	GY-6500 MPU-6500 6	Microprocessor	Software Configuration; Network configuration;	Very High	5	5,0	≈1h30m	5	5,0	High	4	4,0	Medium	3	3,0	€5,65	1	1,0
2021-05-10	https://pt.alie	Co'zoo Store	AliExpress	STM32F030K6T6 LQF	Microprocessor	Software Configuration; Network configuration;	Very High	5		≈1h	5		High	4		Medium	3		€14,36	1	
2021-05-10	https://www.e	Eve Home	Eve Home	Eve Motion	Motion Sensors	Location Setting; APP configurations	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€49,95	2	
2021-05-10	https://www.s	SAMSUNG	SAMSUNG	SmartThings Motion	Motion Sensors	Wall Mounting; APP configurations	Very Low	1	1,0	≈10m	1	1,0	Very Low	1	1,0	Very Low	1	1,0	€21,00	2	2,0
2021-05-10	https://www.p	PHILIPS	PHILIPS	Motion Sensor	Motion Sensors	Wall Mounting; APP configurations	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€33,60	2	
2021-05-10	https://www.a	ViewSonic	AMAZON	4K UHD Short Throw	Projector	Electrical Wiring; Network Configuration; Location Setting; APP configuration;	Medium	3		≈1h	4		Medium	3		Medium	3		€1 578,74	5	
2021-05-10	https://www.l	LG	LG	LG HU80KA 4K UHD L	Projector	Electrical Wiring; Network Configuration; Location Setting; APP configuration;	Medium	3	3,0	≈1h	4	4,3	High	4	3,7	High	4	3,7	€2 015,17	5	5,0
2021-05-10	https://www.b	BENQ	BENQ	Ultra-Low Input Lag H	Projector	Electrical Wiring; Network Configuration; Location Setting; APP configuration;	Medium	3		≈2h	5		High	4		High	4		€799,00	5	
2021-06-07	https://www.i	Infineon	INFINEON	BGT24MTR12	Radar Sensor	Software Configuration; Location Setting;	High	4		≈1h30m	5		Very High	5		Very High	5		€14,26	1	
2021-06-07	https://www.c	ACONEER	CODICO	A111-001-TY	Radar Sensor	Software Configuration; Location Setting;	Very High	5	4,7	≈2h	5	5,0	Very High	5	5,0	Very High	5	5,0	€7,70	1	1,0
2021-06-07	https://www.a	SEEED	SEEED	5.8GHZ DOPPLER RAD	Radar Sensor	Programming Settings; Location Setting;	Very High	5		≈2h	5		Very High	5		Very High	5		€6,95	1	
2021-06-23	https://www.s	NVIDIA	SiliconHighway	NVIDIA JETSON NAN	Single Board Computer	Software configuration; Electrical Wiring; Programming settings;	Very High	5		≈2h	5		Very High	5		Very High	5		€82,50	3	
2021-06-23	https://www.r	Raspberry Pi	Raspberry Pi	Raspberry Pi 4 Model	Single Board Computer	Software Configuration; Network configuration;	High	4	4,7	≈1h	4	4,7	High	4	4,7	Medium	3	4,3	€29,29	2	2,0
2021-06-23	https://www.s	SEEED	Radxa	Rock Pi S	Single Board Computer	Software configuration; Network configuration; Programming Settings;	Very High	5		≈2h	5		Very High	5		Very High	5		€11,64	1	
2021-06-07	https://www.i	IKEA	APPLE	FYRTUR	Smart Blinds	Wall Mounting; Network configuration	Low	2		≈1h	4		Low	2		Low	2		€108,78	4	
2021-06-07	https://www.a	Yoolax	AMAZON	Yoolax Venetian Blind	Smart Blinds	Wall Mounting; APP configurations	Medium	3	2,7	≈1h	4	3,3	Low	2	1,7	Low	2	2,0	€117,21	4	4,0
2021-06-07	https://eu.som	SOMA	SOMA	SOMA Tilt	Smart Blinds	Wall Mounting; APP configurations	Medium	3		≈15min	2		Very Low	1		Low	2		€119,00	4	
2021-04-04	a)	a)	a)	a)	Smart Carpet*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-04-04	a)	a)	a)	a)	Smart Carpet*	a)	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A
2021-04-'4	a)	a)	a)	a)	Smart Carpet*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-06-22	https://www.s	SAMSUNG	SAMSUNG	27.3 cu. ft. Smart Side	Smart Fridge	Electrical Wiring; Mounting; Network Configuration; Location Setting; APP configu	Very High	5		≈2h	5		Very High	5		Very High	5		€1 665,14	5	
2021-06-22	https://www.l	LG	LG	27 cu. ft. Side-By-Side	Smart Fridge	Electrical Wiring; Mounting; Network Configuration; Location Setting; APP configu	Very High	5	5,0	≈2h	5	5,0	Very High	5	5,0	Very High	5	5,0	€1 261,27	5	5,0
2021-06-22	https://www.b	BOSCH	BOSCH	Benchmark® Built-in F	Smart Fridge	Electrical Wiring; Mounting; Network Configuration; Location Setting; APP configu	Very High	5		≈2h	5		Very High	5		Very High	5		€4 711,03	5	
2021-06-19	https://nanole	Nanoleaf	Nanoleaf	Nanoleaf Essentials A	Smart Lights	APP configurations; Location Setting;	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€23,27	2	
2021-06-19	https://www.p	PHILIPS	PHILIPS	Single Bulb E12	Smart Lights	APP configurations; Location Setting;	Very Low	1	1,0	≈10m	1	1,0	Very Low	1	1,0	Very Low	1	1,0	€42,00	2	1,7
2021-06-19	https://www.i	IKEA	IKEA	TRÅDFRI	Smart Lights	Wall Mounting; Location Setting;	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€19,99	1	
2021-07-08	https://www.a	August	AMAZON	August Smart Lock 3r	Smart Locks	Wall Mounting; APP configurations;	High	4		≈45m	4		Medium	3		High	4		€93,97	3	
2021-07-08	https://store.u	Ultraloq	Ultraloq	UL300	Smart Locks	Wall Mounting; APP configurations; Programmingconfigurations;	Very High	5	4,3	≈2h	5	4,3	Very High	5	3,7	Very High	5	4,3	€420,79	4	3,3
2021-07-08	https://simplis	SimpliSafe	SimpliSafe	SimpliSafe Smart Lock	Smart Locks	Wall Mounting; Programming configuration	High	4		≈45m	4		Medium	3		High	4		€83,28	3	
2021-04-04	a)	a)	a)	a)	Smart Mirror*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-04-04	a)	a)	a)	a)	Smart Mirror*	a)	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A
2021-04-04	a)	a)	a)	a)	Smart Mirror*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-05-10	https://www.A	Wemo	APPLE	Wemo Mini Smart Pl	Smart Plugs	APP configurations; Location Setting;	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€24,95	2	
2021-05-10	https://www.l	PHILIPS	PHILIPS	Hue Smart Plug	Smart Plugs	Location Setting;	Very Low	1	1,0	≈5m	1	1,3	Very Low	1	1,3	Very Low	1	1,3	€29,95	2	2,0
2021-05-10	https://www.a	FIBARO	AMAZON	Fibaro Wall Plug type	Smart Plugs	APP configurations; Location Setting;	Very Low	1		≈20m	2		Low	2		Low	2		€42,00	2	
2021-04-04	a)	a)	a)	a)	Smart referigerator*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-04-04	a)	a)	a)	a)	Smart referigerator*	a)	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A
2021-04-04	a)	a)	a)	a)	Smart referigerator*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-04-04	a)	a)	a)	a)	Smart Sofa*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-04-04	a)	a)	a)	a)	Smart Sofa*	a)	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A
2021-04-04	a)	a)	a)	a)	Smart Sofa*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	

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2021-04-04	a)	a)	a)	a)	Smart Sofa*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-04-04	a)	a)	a)	a)	Smart Sofa*	a)	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A
2021-04-04	a)	a)	a)	a)	Smart Sofa*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-07-22	https://www.a	APPLE	APPLE	APPLE HomePod Mini	Smart Speakers	APP configurations;	Low	2		≈15m	2		Medium	3		Low	2		€83,31	3	
2021-07-22	https://www.a	AMAZON	AMAZON	All-new Echo (4th Ger	Smart Speakers	APP configurations;	Very Low	1	1,7	≈5m	1	1,7	Medium	3	3,0	Very Low	1	1,7	€67,20	3	3,0
2021-07-22	https://store.g	GOOGLE	GOOGLE	Nest Audio	Smart Speakers	APP configurations;	Low	2		≈10m	2		Medium	3		Low	2		€63,10	3	
2021-06-06	https://www.a	FIBARO	AMAZON	WALLI DOUBLE SWITC	Smart Switches	Electrical Wiring+Wall Mounting+Network configuration;	Very High	5		≈1h30m	5		Low	2		Very High	5		€94,31	3	
2021-06-06	https://www.e	ecobee	ecobee	Switch+	Smart Switches	Electrical Wiring+Wall Mounting+APP configuration	Very High	5	5,0	≈45m	4	4,5	Low	2	2,0	Very High	5	5,0	€59,86	3	3,0
2021-06-06	https://www.e	Eve Home	Eve Home	Eve Light Switch	Smart Switches	Electrical Wiring+Wall Mounting+APP configuration	Very High	5		≈45m	4		Low	2		Very High	5		€99,95	3	
2021-04-04	a)	a)	a)	a)	Smart Table*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-04-04	a)	a)	a)	a)	Smart Table*	a)	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A	a)	a)	N/A
2021-04-04	a)	a)	a)	a)	Smart Table*	a)	a)	a)		a)	a)		a)	a)		a)	a)		a)	a)	
2021-04-04	https://www.f	LG	FNAC	Smart TV LG 32LM63C	Smart TV	Electrical Wiring; Network configuration;	Low	2		≈20m	2		Medium	3		Medium	3		€267,77	4	
2021-04-04	https://www.a	SONY	AMAZON	Sony 32-inch 720p Sm	Smart TV	Electrical Wiring; Network configuration;	Low	2	2,3	≈30m	3	2,7	Medium	3	3,0	Medium	3	3,0	€250,37	4	4,3
2021-04-04	https://www.s	SAMSUNG	SAMSUNG	65" TU8500 Smart 4K	Smart TV	Electrical Wiring; Network configuration;	Medium	3		≈30m	3		Medium	3		Medium	3		€899,99	5	
2021-05-10	c)	c)	c)	c)	Smartphone	c)	c)	c)		c)	c)		c)	c)		c)	c)		c)	c)	
2021-05-10	c)	c)	c)	c)	Smartphone	c)	c)	c)	N/A	c)	c)	N/A	c)	c)	N/A	c)	c)	N/A	c)	c)	N/A
2021-05-10	c)	c)	c)	c)	Smartphone	c)	c)	c)		c)	c)		c)	c)		c)	c)		c)	c)	
2021-06-07	https://www.e	ECOWITT	ECOWITT	WH51 Wireless soil m	Soil Moisture Sensor	APP configurations; Location Setting;	Medium	3		≈45m	4		Medium	3		High	4		€14,32	1	
2021-06-07	https://www.b	Holman	Bunnings	Smart Moisture Senso	Soil Moisture Sensor	APP configurations; Network configurations; Location Setting;	High	4	4,0	≈1h	4	4,0	Medium	3	3,3	High	4	4,0	€41,30	2	1,3
2021-06-06	https://www.s	SparkFun Store	SparkFun Store	Soil Moisture Sensor	Soil Moisture Sensor	Electrical Wiring; Programming Settings; Location Setting;	Very High	5		≈1h	4		High	4		High	4		€5,02	1	
2021-04-04	https://www.t	TESLA	TESLA	Solar Roof	Solar Panels	b)	b)	b)		b)	b)		b)	b)		b)	b)		b)	b)	
2021-04-04	https://www.a	PAXCESS Store	AMAZON	120W Portable Solar	Solar Panels	b)	b)	b)	N/A	b)	b)	N/A	b)	b)	N/A	b)	b)	N/A	b)	b)	N/A
2021-04-04	https://www.i	IKEA	IKEA	SOLSTRÅLE	Solar Panels	b)	b)	b)		b)	b)		b)	b)		b)	b)		b)	b)	
2021-04-20	https://www.a	APPLE	APPLE	Aqara Temperature &	Temperature Sensor	Location Setting; APP configurations	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€80,81	3	
2021-04-20	https://www.e	Eve Home	Eve Home	Eve Weather	Temperature Sensor	Location Setting; APP configurations	Very Low	1	1,0	≈20m	2	1,3	Very Low	1	1,0	Low	2	1,3	€69,95	3	2,7
2021-04-20	https://www.a	GOOGLE	AMAZON	Google Nest Tempera	Temperature Sensor	Location Setting; APP configurations	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€38,99	2	
2021-06-19	https://www.b	BOSCH	BOSCH	Smart Radiator Therm	Thermostat	APP configurations; Device configurations; Calibration	High	4		≈1h	4		High	4		Medium	3		€63,80	3	
2021-06-19	https://www.h	Honeywell Home	AMAZON	T9 Smart Thermostat	Thermostat	Electrical Wiring; Calibration; APP configurations	High	4	4,0	≈1h30m	5	4,0	High	4	3,7	Medium	3	3,0	€144,47	4	3,7
2021-06-19	https://www.e	Ecobee	ECOBEE	ecobee3 lite	Thermostat	Electrical Wiring; APP configurations	High	4		≈30m	3		Medium	3		Medium	3		€143,28	4	
2021-06-07	https://optitra	OptiTrack	OptiTrack	Flex 3	User/Object Tracker	Software Configuration; Electrical Wiring; Location Setting;	High	4		≈45m	4		Medium	3		Medium	3		€504,87	5	
2021-06-07	https://www.v	VIVE	VIVE	VIVE Tracker	User/Object Tracker	Software configurations;	High	4	4,0	≈30m	3	3,3	Medium	3	3,0	Low	2	2,7	€83,44	3	3,7
2021-06-07	https://www.c	Ctronics	Ctronics	Ctronics wifi PTZ Cam	User/Object Tracker	Software Configurations; APP configurations; Location Setting;	High	4		≈30m	3		Medium	3		Medium	3		€75,85	3	
2021-04-04	https://www.a	Aqara	AMAZON	Aqara Vibration Sens	Vibration Sensors	APP configurations; Network configurations; Location Setting;	Low	2		≈20m	2		Very Low	1		Very Low	1		€82,34	3	
2021-04-04	https://www.a	SAMSUNG	AMAZON	SmartThings MultiPur	Vibration Sensors	Network configurations; APP configurations	Low	2	1,7	≈20m	2	1,7	Very Low	1	1,3	Very Low	1	1,3	€67,43	3	3,0
2021-04-04	https://www.f	FIBARO	FNAC	Fibaro Motion Sensor	Vibration Sensors	APP configurations; Location Setting;	Very Low	1		≈10m	1		Low	2		Low	2		€57,97	3	
2021-07-06	https://www.e	Eve Home	Eve Home	Eve Cam	Video Camera	Location Setting; APP configurations;	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€149,94	4	
2021-07-06	https://www.h	Honeywell Home	AMAZON	C1 WIFI Security Cam	Video Camera	APP configurations; Network configurations; Location Setting;	Low	2	1,3	≈20m	2	1,3	Low	2	1,3	Very low	1	1,0	€102,31	4	3,3
2021-07-06	https://www.l	Logitech	Logitech	C270 HD WEBCAM	Video Camera	Location Setting; Network configuration	Very Low	1		≈10m	1		Very Low	1		Very Low	1		€23,60	2	

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ANNEX 2: COMPLEXITY RATES' MATRIX CALCULATIONS (PART II)

						TOTAL GENERAL SCALE	TOTAL TIME REQUIRED SCALE	TOTAL GENERAL SCALE	TOTAL GENERAL SCALE	TOTAL BUDGET REQUIRED SCALE		
Timestamp	Source	Manufacturers	Retailers	Products' Name	Devices Typology	KNOWLEDGE REQUIRED	TIME REQUIRED	TRAINING REQUIRED	SITE PREPARATIO N	BUDGET REQUIRED	COMPLEXITY RATE	FINAL COMPLEXITY RATE
2021-06-18	https://www.p	Mauser	Ptrobotics	Tower Pro SG90 Servo	Actuators							
2021-06-19	https://www.a	Homend	AMAZON	DC12V 12inch Stroke l	Actuators	5,0	4,0	4,0	4,0	2,3	3,9	4
2021-06-19	https://www.d	BTICINO	dmlights	light status F411/4	Actuators							
2021-06-19	https://www.e	Eve Home	Eve Home	Eve Room	Air Quality Sensors							
2021-06-19	https://www.a	AIRTHINGS	AIRTHINGS	Wave Mini indoor air (	Air Quality Sensors	2,0	1,7	1,7	2,0	3,0	2,1	2
2021-06-19	https://www.e	ECOWITT	ECOWITT	WH0290 Air quality m	Air Quality Sensors							
2021-06-08	https://www.e	Eve Home	Eve Home	Eve Energy Smart Plug	Consumption Meter							
2021-06-08	https://www.d	BTICINO	dmlights	Electrical consumption	Consumption Meter	3,7	3,3	2,3	3,0	3,0	3,1	3
2021-06-08	https://www.a	Qubino	AMAZON	Smart Meter	Consumption Meter							
2021-06-07	https://www.e	ECOBEE	ECOBEE	Smart Sensor for Door	Contact sensor							
2021-03-04	https://www.a	Aqara	AMAZON	Aqara Door and Windo	Contact Sensor	1,0	1,0	1,0	1,0	2,3	1,3	1
2021-06-07	https://eu.ring	ring	ring	Alarm Contact Sensor	Contact sensor							
2021-06-07	https://pupil-la	PupilLabs	PupilLabs	Pupil Core	Eye-Tracker							
2021-06-07	https://www.g	GAZEPOINT	GAZEPOINT	GP3 Eye Tracker	Eye-Tracker	3,7	4,3	4,3	3,3	4,7	4,1	4
2021-06-07	https://gaming	Tobii	Tobii	Tobii Eye Tracker 5	Eye-Tracker							
2021-06-22	https://www.h	Honeywell	HONEYWELL	Honeywell Carnegie 5:	Fans							
2021-06-22	https://www.a	Big Ass Fans Store	AMAZON	Big Ass Fans Haiku L S	Fans	5,0	4,7	3,0	5,0	4,0	4,3	4
2021-06-22	https://promin	ProminenceHome	PROMINENCEHOME	52" Bolivar, White, Pul	Fans							
2021-06-07	https://www.s	SEEED	SEEED	Grove - capacitive fing	Fingerprint Scanner							
2021-06-07	https://verifisa	VERIFI	VERIFI	Verifi P5100 Fingerpri	Fingerprint Scanner	4,3	4,0	3,3	2,7	3,3	3,5	4
2021-06-07	https://ekeysh	eKey	eKey	Finger Scanner Integra	Fingerprint Scanner							
2021-06-23	a)	a)	a)	a)	Floor-based Sensor*							
2021-06-23	a)	a)	a)	a)	Floor-based Sensor*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2021-06-23	a)	a)	a)	a)	Floor-based Sensor*							
2021-06-07	https://www.s	Sensitronics	Sensitronics	1 Inch ThruMode FSR	Force-sensitive resistors (FSR)							
2021-06-07	https://buyinte	Interlink Eletronics	Interlinks Eletronics	FSR Model 400	Force-sensitive resistors (FSR)	5,0	2,7	3,7	3,0	1,0	3,1	3
2021-06-07	https://www.a	Adafruit	Adafruit	Adafruit Square Force	Force-sensitive resistors (FSR)							
2021-06-07	https://www.a	NeuLog	AMAZON	Neulog NUL217 Galva	Galvanic Sking Response Sensor (GSR)							
2021-06-07	https://www.s	Seeed	SEEED	Grove - GSR Sensor	Galvanic Sking Response Sensor (GSR)	4,3	4,7	4,0	1,3	3,0	3,5	4
2021-06-07	https://www.v	Vernier	Vernier	Qubit GSR Sensor	Galvanic Sking Response Sensor (GSR)							
2021-06-07	https://www.e	ECOWITT	ECOWITT	WH0290 Air quality m	Gas Sensor							
2021-06-07	https://www.s	SparkFun Store	SparkFun Store	LPG Gas Sensor MQ-6	Gas Sensor	2,7	2,3	2,7	3,0	2,3	2,6	3
2021-06-07	https://www.e	Eve Home	Eve Home	Eve Room	Gas Sensor							
2021-06-19	https://www.e	Eve Home	Eve Home	Eve Room	Humidity Sensor							
2021-06-19	https://www.h	Honeywell Home	HONEYWELL	T9 Smart Sensor	Humidity Sensor	2,7	1,7	2,0	3,0	3,0	2,5	3
2021-06-19	https://www.e	Ecobee	ECOBEE	ecobee3 lite	Humidity Sensor							

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ANNEX 2: COMPLEXITY RATES' MATRIX CALCULATIONS (PART II) – CONT.

2021-06-22	https://www.l	LG	LG	LG 27GL650F-B 27 Inc	LCD Monitor							
2021-06-22	https://store.h	HP	HP	HP V22 FHD Monitor	LCD Monitor	3,0	3,3	2,0	2,0	4,0	2,9	3
2021-06-22	https://www.d	DELL	DELL	Dell 24 Monitor - S242	LCD Monitor							
2021-06-19	https://aeotec	Aotec	Popp/to	MultiSensor 6	Light Sensor							
2021-06-19	https://wiki.se	SEEED	SEEED	Grove - Light Sensor	Light Sensor	2,3	2,0	2,3	2,3	2,0	2,2	2
2021-06-19	https://www.f	FIBARO	FNAC	Fibaro Motion Sensor	Light Sensor							
2021-06-19	https://www.s	sparkFun Store	SparkFun Store	Load Sensor - 50kg (G	Load Sensor							
2021-06-19	https://www.p	Ptrobotics	Ptrobotics	Load Sencor - 50kg	Load Sensor	5,0	5,0	5,0	4,0	1,0	4,0	4
2021-06-19	https://www.l	SENSOR	AliExpress	Load Cell 1022	Load Sensor							
2021-06-23	https://www.a	Jekewin	AMAZON	ATMega32-16PU 8-bi	Microcontroller							
2021-06-23	https://esp826	ESP8266 Shop	ESP8266 Shop	NodeMCU-ESP8266	Microcontroller	5,0	5,0	5,0	5,0	1,3	4,3	4
2021-06-23	https://www.m	Microchip	Microchip	ATSAM4LC4CA-AUR	Microcontroller							
2021-04-04	https://www.t	TONOR	TONOR	TONOR G11 Conferen	Microphone							
2021-04-04	https://www.s	SABINETEK	SABINETEK	SmartMike+Wireless	Microphone	1,0	1,0	1,0	1,0	2,0	1,2	1
2021-04-04	https://www.a	TOSHIBA	AMAZON	Toshiba Connect USB	Microphone							
2021-05-10	https://pt.mou	Atmel	Mouser Eletronics	Atmel ATSAMA5D22	Microprocessor							
2021-05-10	https://www.a	S-Smart-Home	AMAZON	GY-6500 MPU-6500 6	Microprocessor	5,0	5,0	4,0	3,0	1,0	3,6	4
2021-05-10	https://pt.aliex	Co'zoo Store	AliExpress	STM32F030K6T6 LQF	Microprocessor							
2021-05-10	https://www.e	Eve Home	Eve Home	Eve Motion	Motion Sensors							
2021-05-10	https://www.s	SAMSUNG	SAMSUNG	SmartThings Motion S	Motion Sensors	1,0	1,0	1,0	1,0	2,0	1,2	1
2021-05-10	https://www.p	PHILIPS	PHILIPS	Motion Sensor	Motion Sensors							
2021-05-10	https://www.a	ViewSonic	AMAZON	4K UHD Short Throw P	Projector							
2021-05-10	https://www.l	LG	LG	LG HU80KA 4K UHD La	Projector	3,0	4,3	3,7	3,7	5,0	3,9	4
2021-05-10	https://www.b	BENQ	BENQ	Ultra-Low Input Lag H	Projector							
2021-06-07	https://www.i	Infineon	INFINEON	BGT24MTR12	Radar Sensor							
2021-06-07	https://www.c	ACONEER	CODICO	A111-001-TY	Radar Sensor	4,7	5,0	5,0	5,0	1,0	4,1	4
2021-06-07	https://www.a	SEEED	SEEED	5.8GHZ DOPPLER RAD	Radar Sensor							
2021-06-23	https://www.s	NVIDIA	SiliconHighway	NVIDIA JETSON NANO	Single Board Computer							
2021-06-23	https://www.r	Raspberry Pi	Raspberry Pi	Raspberry Pi 4 Model	Single Board Computer	4,7	4,7	4,7	4,3	2,0	4,1	4
2021-06-23	https://www.s	SEEED	Radxa	Rock Pi S	Single Board Computer							
2021-06-07	https://www.i	IKEA	APPLE	FYRTUR	Smart Blinds							
2021-06-07	https://www.a	Yoolax	AMAZON	Yoolax Venetian Blinds	Smart Blinds	2,7	3,3	1,7	2,0	4,0	2,7	3
2021-06-07	https://eu.som	SOMA	SOMA	SOMA Tilt	Smart Blinds							
2021-04-04	a)	a)	a)	a)	Smart Carpet*							
2021-04-04	a)	a)	a)	a)	Smart Carpet*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2021-04-'4	a)	a)	a)	a)	Smart Carpet*							
2021-06-22	https://www.s	SAMSUNG	SAMSUNG	27.3 cu. ft. Smart Side	Smart Fridge							
2021-06-22	https://www.l	LG	LG	27 cu. ft. Side-By-Side	Smart Fridge	5,0	5,0	5,0	5,0	5,0	5,0	5
2021-06-22	https://www.b	BOSCH	BOSCH	Benchmark® Built-in F	Smart Fridge							
2021-06-19	https://nanole	Nanoleaf	Nanoleaf	Nanoleaf Essentials A1	Smart Lights							
2021-06-19	https://www.p	PHILIPS	PHILIPS	Single Bulb E12	Smart Lights	1,0	1,0	1,0	1,0	1,7	1,1	1
2021-06-19	https://www.i	IKEA	IKEA	TRÅDFRI	Smart Lights							
2021-07-08	https://www.a	August	AMAZON	August Smart Lock 3rd	Smart Locks							
2021-07-08	https://store.u	Ultraloq	Ultraloq	UL300	Smart Locks	4,3	4,3	3,7	4,3	3,3	4,0	4
2021-07-08	https://simplis	SimpliSafe	SimpliSafe	SimpliSafe Smart Lock	Smart Locks							

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ANNEX 2: COMPLEXITY RATES' MATRIX CALCULATIONS (PART II) – CONT.

2021-04-04	a)	a)	a)	a)	Smart Mirror*							
2021-04-04	a)	a)	a)	a)	Smart Mirror*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2021-04-04	a)	a)	a)	a)	Smart Mirror*							
2021-05-10	https://www.A	Wemo	APPLE	Wemo Mini Smart Plu	Smart Plugs							
2021-05-10	https://www.li	PHILIPS	PHILIPS	Hue Smart Plug	Smart Plugs	1,0	1,3	1,3	1,3	2,0	1,4	1
2021-05-10	https://www.a	FIBARO	AMAZON	Fibaro Wall Plug type	Smart Plugs							
2021-04-04	a)	a)	a)	a)	Smart referigerator*							
2021-04-04	a)	a)	a)	a)	Smart referigerator*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2021-04-04	a)	a)	a)	a)	Smart referigerator*							
2021-04-04	a)	a)	a)	a)	Smart Sofa*							
2021-04-04	a)	a)	a)	a)	Smart Sofa*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2021-04-04	a)	a)	a)	a)	Smart Sofa*							
2021-07-22	https://www.a	APPLE	APPLE	APPLE HomePod Mini	Smart Speakers							
2021-07-22	https://www.a	AMAZON	AMAZON	All-new Echo (4th Gen	Smart Speakers	1,7	1,7	3,0	1,7	3,0	2,2	2
2021-07-22	https://store.g	GOOGLE	GOOGLE	Nest Audio	Smart Speakers							
2021-06-06	https://www.a	FIBARO	AMAZON	WALLI DOUBLE SWIT(	Smart Switches							
2021-06-06	https://www.e	ecobee	ecobee	Switch+	Smart Switches	5,0	4,5	2,0	5,0	3,0	3,9	4
2021-06-06	https://www.e	Eve Home	Eve Home	Eve Light Switch	Smart Switches							
2021-04-04	a)	a)	a)	a)	Smart Table*							
2021-04-04	a)	a)	a)	a)	Smart Table*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2021-04-04	a)	a)	a)	a)	Smart Table*							
2021-04-04	https://www.f	LG	FNAC	Smart TV LG 32LM63(	Smart TV							
2021-04-04	https://www.a	SONY	AMAZON	Sony 32-inch 720p Sm	Smart TV	2,3	2,7	3,0	3,0	4,3	3,1	3
2021-04-04	https://www.s	SAMSUNG	SAMSUNG	65" TU8500 Smart 4K	Smart TV							
2021-05-10	c)	c)	c)	c)	Smartphone							
2021-05-10	c)	c)	c)	c)	Smartphone	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2021-05-10	c)	c)	c)	c)	Smartphone							
2021-06-07	https://www.e	ECOWITT	ECOWITT	WH51 Wireless soil m	Soil Moisture Sensor							
2021-06-07	https://www.b	Holman	Bunnings	Smart Moisture Senso	Soil Moisture Sensor	4,0	4,0	3,3	4,0	1,3	3,3	3
2021-06-06	https://www.s	SparkFun Store	SparkFun Store	Soil Moisture Sensor	Soil Moisture Sensor							
2021-04-04	https://www.t	TESLA	TESLA	Solar Roof	Solar Panels							
2021-04-04	https://www.a	PAXCESS Store	AMAZON	120W Portable Solar P	Solar Panels	N/A	N/A	N/A	N/A	N/A	N/A	NA
2021-04-04	https://www.il	IKEA	IKEA	SOLSTRÅLE	Solar Panels							
2021-04-20	https://www.a	APPLE	APPLE	Aqara Temperature &	Temperature Sensor							
2021-04-20	https://www.e	Eve Home	Eve Home	Eve Weather	Temperature Sensor	1,0	1,3	1,0	1,3	2,7	1,5	2
2021-04-20	https://www.a	GOOGLE	AMAZON	Google Nest Tempera	Temperature Sensor							
2021-06-19	https://www.b	BOSCH	BOSCH	Smart Radiator Therm	Thermostat							
2021-06-19	https://www.h	Honeywell Home	AMAZON	T9 Smart Thermostat	Thermostat	4,0	4,0	3,7	3,0	3,7	3,7	4
2021-06-19	https://www.e	Ecobee	ECOBEE	ecobee3 lite	Thermostat							
2021-06-07	https://optitra	OptiTrack	OptiTrack	Flex 3	User/Object Tracker							
2021-06-07	https://www.v	VIVE	VIVE	VIVE Tracker	User/Object Tracker	4,0	3,3	3,0	2,7	3,7	3,3	3
2021-06-07	https://www.c	Ctronics	Ctronics	Ctronics wifi PTZ Came	User/Object Tracker							
2021-04-04	https://www.a	Aqara	AMAZON	Aqara Vibration Senso	Vibration Sensors							
2021-04-04	https://www.a	SAMSUNG	AMAZON	SmartThings MultiPur	Vibration Sensors	1,7	1,7	1,3	1,3	3,0	1,8	2
2021-04-04	https://www.f	FIBARO	FNAC	Fibaro Motion Sensor	Vibration Sensors							
2021-07-06	https://www.e	Eve Home	Eve Home	Eve Cam	Video Camera							
2021-07-06	https://www.h	Honeywell Home	AMAZON	C1 WIFI Security Cam	Video Camera	1,3	1,3	1,3	1,0	3,3	1,7	2
2021-07-06	https://www.l	Logitech	Logitech	C270 HD WEBCAM	Video Camera							

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ANNEX 3: INTERVIEWS' TRANSCRIPTION (PT)

Interviews' transcription regarding the proposed frameworks' evaluation stage of the present dissertation. In order to strictly respect the original statements of the interviewees, the transcript text preserved the original language.

Specialists' interviews

1. Specialist A: IoT Specialist

Date: Thursday, 15th April 2021

Location: Online Meeting

Interviewee's name: João Miguel de Campos Barbosa Cortez Neves (most known as João Cortez)

Short biography: Prof. Dr. João Cortez has graduated from Informatic Engineering by COCITE, completed his Informatics' postgraduate studies by Faculdade de Ciências de Lisboa, and concluded his masters' degree on Informatic Engineering at Universidade Pontifícia de Salamanca. He has worked as a Software Engineer at TAP Air Portugal, and as a software professor at Instituto Politécnico de Leiria. Prof. Dr. João was an author, and co-author, of several publications and books, while being lecturing Informatics' at Instituto Superior de Biotecnologia, at Universidade Católica. Currently, he is the director of the Informatica course program to the army, and co-founder of Inspired Blue, a company specialized in the creation, development and commercializing of informatic solutions, in the IoT field.

Q1: Considera que a *framework* proposta será útil para um cidadão comum?
A1: Em termos académicos, isso faz todo o sentido. A democratização do *IoT*, academicamente, tem todo o potencial. Porém, é preciso é perceber como é que este potencial académico se pode concretizar num potencial económico. É preciso que estas questões estejam na base da discussão e sejam abordadas.

O que a *framework* pretende é agregar os requisitos que já existem no mercado e isso faz-me todo o sentido para que os utilizadores tenham um papel participativo no processo. Mas serão eles capazes de fazer este tipo de seleção? O exemplo dado era de um apartamento de um idoso e era válido, mas eu não espero que um idoso tenha a capacidade de perceber a complexidade tecnológica. Atualmente, na minha empresa, temos um projeto em mãos que tem sensorização com tecnologia *IoT* para vigilância de idosos à distância. Temos um *control room* que vai permitir o controlo dos diferentes idosos, mas quem vai fazer a seleção da tecnologia para dar suporte a essa situação é um conjunto de pessoas relacionadas com a tecnologia em si e com a questão social. Se estivermos a falar de pessoas jovens é mais fácil chegar a um conjunto final de tecnologias e dizer "isto faz-me sentido, aquilo não", pessoas mais idosas, certamente, terão mais dificuldade.

No entanto, acho que esta *framework* pode ser útil. Como qualquer tecnologia, elas vão surgindo num formato *ad-hoc* e, a determinado momento, têm que ser enquadradas. Na minha opinião, esta *framework* parece-me que enquadra este tipo de tecnologia e leva a torná-las mais familiares às pessoas. É necessário considerar que, hoje em dia, as pessoas têm dificuldade em perceber esta temática o que é explicado por vários fatores, sendo a publicidade um deles. Atualmente, os anúncios, normalmente, são de coisas mais banais, como os telemóveis, e não necessariamente de sensores que tenham para vender. A *framework*, acho que faz todo o sentido, sinceramente.

Q2: Que recomendações/sugestões consideraria para melhorar a *framework* proposta?

A2: Como em qualquer trabalho académico, tem de existir algum potencial económico. Como é que esta *framework* irá servir as pessoas e ser economicamente viável? Penso que isto tenha de ser mencionado algures. Temos hoje um conjunto de soluções com muito potencial económico, tais como o Google Home, a Alexa ou a Apple TV.

Outra questão está relacionada com a seleção de tecnologias. Na minha opinião, esse procedimento não deve ser da responsabilidade do utilizador comum, dado o pouco conhecimento na área. Alguns problemas podem surgir, nomeadamente, na comunicação entre dispositivos. Na tecnologia *IoT* podemos usar, para comunicar, protocolos como o LoRa, Sinfox e o NBA *IoT*. Cada protocolo apresenta formas de comunicar diferentes e alcances, gastos de baterias, velocidades de comunicação também diferentes. Como é que, na mesma *framework*, diferentes dispositivos podem ser incluídos, podendo eles ser compatíveis com protocolos diferentes? A *framework* tem um aspeto concetual, mas na prática, o cidadão comum não percebe de protocolos, nem de tecnologias. Como é que as pessoas irão ter essa capacidade de perceber do tema quando, na sua maioria, estão habituadas a receber soluções da nossa parte? Também, na maioria das situações, a questão do preço condiciona a escolha de tecnologias, ganhando quase sempre sobre todas as outras características dos produtos ou, neste caso, dos fatores de instalação.

Assim, a *framework* podia ter uma alternativa a esta fase de seleção de tecnologias. Talvez tendo a recomendação de alguém que já analisou, fez o levantamento da situação e consegue direcionar para um conjunto de soluções. A oferta no mercado é muita e, talvez, dando essa panóplia de opções às pessoas não se resolve o problema, antes se gera outro. Na minha opinião, é apenas esse aspeto que ainda não consigo transpor para aquilo que seria o papel real da *framework*.

Q3: Existe mais algum comentário a tecer à *framework* proposta?

A3: Sim, em relação à dependência dos vendedores e do seu *know-how*. Existe um modelo de negócio que se está a posicionar no mercado – plataformas que vendem tecnologias de vários fabricantes que, todos os dias, acrescentam novos dispositivos de outros vendedores. Deixaram de estar concentrados no seu *know-how* para permitir que todos os outros vendedores usem a plataforma, permitindo, ao mesmo tempo, a divulgação da sua marca. Está a ganhar terreno, mas a maioria das empresas tenta vender os seus próprios dispositivos de forma independente para criarem laços de dependência para com os seus clientes. Por exemplo, uma solução inteligente pode ser colocada no mercado a um preço mais baixo, mas certamente terá, em contrapartida, uma garantia de dependência para com o utilizador, que vai pagando uma quota para poder usufruir dela.

Há aspetos de ordem comercial, que é preciso abordar. Por exemplo, clarificar a forma como se passa para um modelo em que os utilizadores beneficiem de uma série de tecnologias correspondentes às suas expectativas. É preciso perceber como gerir estes problemas comerciais, porque as empresas precisam disso para sobreviver. Na minha empresa, tenho disponível um *gateway* que funciona com LoRa. O *gateway* consegue fazer a leitura de todos dispositivos que funcionam com este protocolo. Mas, neste caso, eu é que estou a dar a solução ao cliente. Ou seja, importa perceber como é que é dada essa autonomia aos clientes para fazerem a seleção das tecnologias.

Relativamente à matriz de complexidade, ela faz-me todo o sentido. O "Budget Required" para o sensor de qualidade de ar é algo de média complexidade, tal como foi descrito. A matriz faz-me sentido. É óbvio que temos de tentar traduzir os fatores tecnológicos para números. Dentro de todos os sensores que estão representados nas colunas, todos me parecem alinhados, já que são apenas amostras dos vários que existem no mercado. No geral, a *framework* faz-me sentido.

2. Specialist B: Smart Buildings' Specialist

Date: Tuesday, 20th April 2021

Location: Online Meeting

Interviewee's name: Nuno Gonçalves

Short biography: Nuno Gonçalves is an entrepreneur with experience in different areas. He has graduated from Electrical and Computer Engineering at Universidade do Porto, where he also concluded his Renewable Energies' postgraduate studies. Also in the same city, Nuno has concluded an MBA, at Porto Business School. Professionally, he had contributed to several companies in the industrial and services' area, where he led development and operations' teams. Currently, Nuno is the executive director and co-founder of Emitu, a startup which core business is the digital transformation of companies through IoT solutions.

Q1: Considera que a *framework* proposta será útil para um cidadão comum?

A1: Na minha opinião, e tendo em conta a experiência que tenho na área da *IoT*, acho que se fala na *IoT* há bastante tempo, especialmente na área das Smart Homes, mas, na prática, é um conceito que nunca se conseguiu massificar. Uma explicação possível seria a dispersão de tecnologias, soluções, e a sua competição. Por vezes, existem várias versões a competir pela mesma solução, deixando os utilizadores sentirem-se confusos e inseguros em relação aos seus investimentos. Por exemplo, tendo a versão A, B e C de uma determinada tecnologia, à partida, existirá uma melhor do que as restantes. Gera-se a incerteza e a frustração de não se saber distinguir qual ficará obsoleta no futuro. Neste sentido, existe esta dispersão que torna a *IoT* difícil de ser massificada. Por isso, na minha opinião, esta *framework* permitiria simplificar o trabalho dos consumidores a navegar neste emaranhado de tecnologias e soluções para chegar a algo que satisfaça os seus objetivos. Se o esforço das pessoas em selecionar tecnologia é reduzido através desta *framework*, então eu considero-a bastante útil, já que faz exatamente o que a tecnologia deve fazer – simplificar a vida das pessoas.

Q2: Que recomendações/sugestões consideraria para melhorar a *framework* proposta?

A2: Tendo em conta as aplicações e softwares que existem no mercado, em conjunto com os vários sensores e protocolos, compreendo que não seja muito difícil, para ti ou para mim, encontrar todas estas opções [relativamente à matriz de tecnologias] e concatená-las numa tabela como esta. O que é difícil é encontrar o melhor *deal* possível.

De forma a simplificar o processo de entrega de valor para os utilizadores, uma alternativa seria focá-la em sensores que já estão associados a uma APP, por exemplo, as *smart lights*, e deixar para trás a questão dos *softwares* e protocolos, porque são demasiado complexos para uma pessoa comum explorar.

Há muitos sensores, neste momento. Existem sensores de qualidade de ar e soluções que nós próprios já instalamos em casa. E agora, em contexto de pandemia, os dados que estes sensores nos dão interessam ainda mais. Temos interesse em perceber se, por exemplo, a qualidade do ar das nossas casas – que tem sido o local onde temos passado mais tempo – é adequada. Com este tipo de sensores, associados a uma APP simples, de instalação simples, conseguimos assegurar as condições da nossa casa. Talvez indo por este caminho, seja mais fácil relacionar tecnologias e aplicações, sem ir ao detalhe do software e outros temas complexos.

O desenvolvimento desta solução podia até incluir os vários fabricantes e parceiros de plataformas de *software*, como, por exemplo, quem desenvolve as soluções. Se envolvermos todos estes intervenientes e cada qual contribuir com a sua parte, talvez possamos ter uma massa crítica suficiente para que a *framework* pudesse ser utilizada com sucesso. O resultado final provavelmente dependerá da informação que for ingerida, relativamente a dispositivos, soluções e tecnologias, para que possa dar valor às pessoas.

Q3: Existe mais algum comentário a tecer à *framework* proposta?

A3: Aquilo que é a *framework* nos vários passos, faz sentido para mim. Primeiramente, a identificação do contexto permite-nos perceber quem são os utilizadores, os seus objetivos e, daí, fazer a tradução para a fase seguinte – identificação de requisitos. Nem sempre este passo é óbvio; o que acontece é que os diferentes *providers* oferecem muitas soluções, deixando as pessoas confusas e indecisas acerca da correspondência com os seus objetivos pessoais. Se, por exemplo, o tipo de residente for uma família com crianças, certamente irá querer garantir a segurança do quarto das crianças. A meu ver, o objetivo da *framework* é, de uma forma lógica e estruturada, ajudar o utilizador, partindo do seu contexto, passando pelos requisitos, para que, através de um funil, cheguemos a um conjunto de soluções. O utilizador parte deste ponto e escolhe o que prefere e baseia-se, por exemplo, no tempo que vai despender na instalação, no seu orçamento ou nos benefícios que a tecnologia possa oferecer. Por isso, em suma, considero a *framework* uma boa ferramenta de navegação, porque vai funcionar como um filtro, no sentido de chegar às necessidades das pessoas, enquanto reduz a carga cognitiva que a pessoa tem de ter para estudar estas tecnologias sozinha. A tecnologia, no geral, deve fazê-lo – reduzir o esforço das pessoas e facilitar as suas vidas –, por isso, eu assumo a *framework* como uma tecnologia que simplifica a vida das pessoas na seleção de *IoT*.

Como nota final, acho que éimportante implementar isto e usá-lo. Aliás, à luz do que estava a dizer, se temos uma *framework* que simplifica o processo de navegação e seleção de tecnologias, ela deve ser implementada. Não faz sentido nós criarmos uma *framework* e ela depois ficar na prateleira. O mais importante, na minha opinião, é partirmos das soluções teóricas e levarmo-las à prática.

3. Specialists C and D - Smart Homes' Specialists

Date: Wednesday, 21st April 2021

Location: Online Meeting

Interviewee's name: Joel Reis

Short biography: Joel Reis has graduated from Communications' and Information Networks, by Instituto Superior Técnico. Currently, he is founder and CEO of Life Emotions, a specialized company in the design and development of smart integrated solutions, such as temperature control, lighting and blinds, and others. He also founded XSTA LDA, a company focused on electrical solutions, and Welcome Miracle Investimentos, specialized in real estate's operations.

Interviewee's name: Inês Cabanas

Short biography: Inês Cabanas has graduated from Industrial Management by Instituto Superior Técnico (both bachelors' and masters' degree). Currently, Inês is an Operations' Manager at Life Emotions*.*

Q1: Considera que a *framework* proposta será útil para um cidadão comum?
A1: A ideia é muito útil. Agora, é um desafio enorme conseguir que toda esta complexidade e panóplia de soluções seja compreensível para as pessoas comuns. Ter uma *framework* que guie as pessoas através de filtros, para que sejam direcionadas para os dispositivos certos, não é impossível, mas é difícil, sem contar com o desafio de existirem diversos produtos no mercado que não têm muita utilidade.

Eu aplicaria esta *framework* porque me ajudaria a selecionar dispositivos de acordo com as minhas necessidades. Por exemplo, se tenho frio no inverno talvez um termóstato conseguisse aquecer a minha casa ou até um colchão, resolvendo o problema sem despender muita energia. Mas isto apenas é possível se uma boa história for contada e, enquanto consumidor, consiga construir um rascunho daquilo que eu quero na minha casa.

Q2: Que recomendações/sugestões consideraria para melhorar a *framework* proposta?
A2: Há três ou quatro ideias muito interessantes nesta *framework*. A caracterização do espaço pode ser muito apelativa para o utilizador. Fazer uso da Inteligência Artificial (IA) seria ainda mais interessante para que o tipo de utilizador fosse mais rapidamente filtrado. Porém, se a *framework* tivesse a identificação do contexto e os objetivos dos residentes organizados por famílias de produto,

como iluminação ou áudio, talvez fosse mais fácil apresentar soluções às pessoas. Caso contrário, imagino que possa ser difícil recomendar certo tipo de tecnologias que sejam mais específicas.

A matriz de complexidade também é muito interessante, mas acho que não corresponde à realidade nalguns aspetos. O fator "*Required Time*" é, normalmente, mais longo do que o demonstrado na matriz. Por menos de 10 minutos, é difícil configurar qualquer dispositivo que seja; o mínimo são 20 ou 30 minutos. O fator "*Budget Required*" também podia ser revisto. Ainda é muito difícil encontrar produtos que sejam vendidos por menos de 20 euros, num contexto de Smart Homes. Uma lâmpada inteligente custa cerca de 70€, enquanto uma lâmpada normal custa uns 6€. Há uma empresa na Bulgária que vende dispositivos um pouco mais baratos, mas penso que o mínimo serão 30€. Adicionalmente, a diferença entre o orçamento requerido dos vários dispositivos também me parece pequena, na minha opinião. Por isso, a minha sugestão seria aproximar esta informação do contexto real, o quanto possível.

Agora, olhando para a matriz, e desmistificando o papel do sensor: o sensor é algo que não necessita de nada mais para além de energia e conectividade para nos fornecer valores ou dados de um determinado espaço. Por exemplo, um termóstato, em oposição, vai interagir com o resto do ambiente e também será difícil instalar porque vai interagir com outros equipamentos. No entanto, revendo atenciosamente os restantes fatores apresentados, na sua generalidade, todos os sensores apresentados na tabela parecem-me ajustados à realidade, exceto o *eye-tracker*, que me parece um pouco mais complicado de configurar do que o demonstrado.

Adicionalmente, quem dá o certificado de complexidade ao utilizador, consoante o seu nível de experiência? Como é que eu sei o meu grau de conhecimento? Seria interessante, talvez, criar algum passo que ajude os utilizadores a determinar o seu nível. Dar-lhes liberdade para avaliarem o seu *know-how* para instalar certos dispositivos pode gerar informação incorreta. Eu posso dizer que percebo imenso do assunto e não perceber absolutamente nada. Uma alternativa seria colocar algumas questões e concluir o seu nível através das respostas dadas. Por exemplo, perguntar aos utilizadores quando tempo precisariam para mudar uma lâmpada ou algo relacionado com possíveis conhecimentos de eletricidade e informática, já que todas as soluções giram à volta destes domínios. As pessoas precisam de perceber o seu nível, em termos de instalação *Do-It-Youself* (DIY), deste tipo de tecnologia (ex.: iniciante/nível 1/nível 2, etc.). Acho que este detalhe pode ser melhorado na *framework*.

(IC) Eu sugeria tentar simplificar o processo. Parece-me que a *framework* está a tentar alcançar muitas áreas, muitas delas bastante complexas. Acho que se fossem filtrados apenas sensores básicos e fossem explorados, em vez de se tentar abordar muitos tópicos superficialmente, seria mais simples para o utilizador final perceber. Acho que o nome do fator “tempo de instalação” me parece um termo muito vasto. Eu tentaria alterar este nome para outro mais tangível.

(JR) Adicionalmente, acho que o *scope* da *framework* pode ser revisto. É destinada a pessoas com algum DIY embebido nelas ou é para o uso do comum dos mortais? Isso vai alterar drasticamente a forma como é desenvolvido. Se é para qualquer pessoa, há que fazer uma espécie de filtro em tudo o que envolva eletricidade, porque a maioria dos cidadãos comuns não percebe muito do tema. Talvez aplicando este filtro, a *framework* mencionaria apenas sensores que fornecem dados das nossas casas, com dispositivos facilmente usados por todos, como a iluminação inteligente, que não acarreta nenhum conhecimento extraordinário de eletricidade.

Q3: Existe mais algum comentário a tecer à *framework* proposta?

A3: No geral, a *framework* parece subjetiva, dados os fabricantes e revendedores que serviram de base para os cálculos. A questão dos fabricantes é complexa e, se adicionarmos a tecnologia chinesa, ainda mais complexa fica. Estes dados têm de ser retirados dos *websites* onde o cidadão comum navegue. Outro tema importante é que estas tecnologias vão variar em preço e em *stock* consoante a sua localização geográfica. Existem fabricantes e/ou revendedores que apenas se focam no mercado americano e não tanto no europeu; também diferem em termos de preço e em meios de instalação, sendo uns mais intuitivos do que outros. Existem ainda fabricantes cujo sucesso é explicado pela experiência de configuração que oferecem. O *marketing* dos fabricantes, por vezes, passa pela premissa da rapidez da instalação.

O caminho que é traçado nesta *framework* é o de democratizar a *IoT*, em termos de *marketing*. É um conceito do qual se fala há já algum tempo e admite a ajuda dos fabricantes para o difundir. Na *IoT* há uma característica: os fabricantes costumam ter projetos muito concretos e fechados, por isso, torna-se difícil comercializarem, simultaneamente, sensores de *tracking* e sensores de qualidade de ar, por exemplo. Haverá um vendedor que faça sensores de *tracking* e outros de humidade, mas, no geral, as famílias de produto são segmentadas. Surgem em diferentes “ilhas” e, por vezes, não há ligação entre elas. Isto representa outro desafio quando falamos de tecnologias ou soluções para que os utilizadores desmistifiquem a complexidade deste mundo.

Uma vez mais, daria uso a esta *framework* se a história fosse efetiva. Perceber se estou a construir uma casa, ou um apartamento, e o que é que eu procuro para melhorar a minha qualidade de vida, ajudar-me-ia a fazer um esboço daquilo que eu quero para resolver os meus problemas. Se falarmos em soluções, numa linguagem apropriada para o utilizador, acho que a *framework* pode ser uma ferramenta útil.

Non-specialists' interviews

1. Non-specialist A:

Date: Friday, 23rd April 2021

Location: Online Meeting

Interviewee's name: Guilherme Dias

Short biography: Guilherme Dias is graduated in Marketing Management, by ISCTE Business School. He has played marketing roles in several companies, such as Auchan and Vodafone, and was a professional athlete for more than 12 years. Currently, he is a surf and bodyboard instructor in several schools.

Q1: Considera que a *framework* proposta será útil para um cidadão comum?
A1: Considero esta *framework* muito útil porque, na minha opinião, há muita falta de informação sobre o mundo das Smart Homes ou, até, desinformação. E isto [a *framework*] seria um passo importante para familiarizar as pessoas com esta área. Para quem não está a par deste tipo de tecnologias, como eu, não há noção do que existe por aí e das capacidades que advêm disso. Seria mais fácil identificar o que está atualmente disponível no mercado, e o seu propósito, com esta *framework*. Nunca fui muito curioso, a ponto de ter estes dispositivos lá em casa, porque sou cético em relação aos mesmos. Relativamente a pessoas igualmente céticas, que, por vezes, têm receio destas inovações, acho que esta *framework* sugere um conforto, no sentido em que podem ter algum controlo sobre aquilo que fazem nas suas casas. Neste sentido, eu usaria esta *framework*. Acho que para quem tem interesse nestas tecnologias, isto [a *framework*] também seria usado como uma ferramenta extra para as mais acessíveis.

Q2: Que recomendações/sugestões consideraria para melhorar a *framework* proposta?
A2: Como recomendação, diria para se tentar simplificar o processo para que seja acessível a toda a gente. Por exemplo, eu acho que pessoas mais idosas teriam mais dificuldade em perceber esta *framework*. A minha avó teria dificuldade em perceber alguns conceitos mencionados aqui [na apresentação]. Talvez explicando um pouco mais acerca de cada dispositivo, tais como o propósito e os benefícios, da maneira mais simples possível, acho que seria uma boa melhoria. Para pessoas mais idosas, este processo tem de ser mais fácil, a meu ver. Pelo menos na geração idosa atual, acredito que daqui a uns anos esta geração já esteja mais à vontade com a tecnologia.

Q3: Existe mais algum comentário a tecer à *framework* proposta?

A3: No geral, acho que é uma boa ideia [relativamente à *framework*]. Seria interessante ter alguma explicação prévia de cada sensor antes de o recomendar, porque o que pode ser fácil de identificar para mim, pode não o ser para o resto das pessoas. No meu caso, e penso falar em nome da geração mais jovem, consigo reconhecer todos os sensores que aqui estão [na matriz de complexidade]. Mas, talvez, ter uma *overview* do que é que cada dispositivo faz, tornasse a informação mais intuitiva. Talvez, explicando o funcionamento, relativamente ao envio da informação, de onde esta é retirada..., mas, talvez, este procedimento tenha também uma desvantagem: torna tudo mais complexo e, provavelmente, a motivação das pessoas se desvanecesse com isso. No entanto, se eu tivesse que comprar este tipo de tecnologia inteligente, isto [a *framework*] seria algo que eu utilizaria porque sinto que é menos invasiva do que outras tecnologias que andam por aí. Acho que, assim, teria mais controlo. Diria também que isto seria mais interessante para jovens do que para idosos. Para a minha geração, acho que é muito acessível, não há aqui nada que me traga muitas dúvidas.

Também considero que, no geral, [a *framework*] é uma boa ideia, dadas as tendências do mercado, neste momento. Mais cedo ou mais tarde, teremos muitos mais dispositivos nas nossas vidas, capazes de fazer muito mais do que aquilo que já fazem. Na minha perspetiva, é uma questão de hábitos e tendências, por isso, temos de os acompanhar.

2. Non-Specialist B:

Date: Tuesday, 27th April 2021

Location: Online Meeting

Interviewee's name: Luísa Mendes

Short biography: Luísa Mendes é, atualmente, editora de vídeo, tendo experiência em vários cargos relacionados com a tecnologia do mundo do espetáculo. Considera-se, assim, adepta da tecnologia em geral.

Q1: Considera que a *framework* proposta será útil para um cidadão comum?

A1: Cada vez mais, a tecnologia é útil e facilita a vida das pessoas. Não olho para a tecnologia como algo que rouba os empregos das pessoas, mas como algo que cria novos. Porém, as pessoas estão cada vez mais exigentes, por isso, o que quer que seja feito tem de ser bem feito. A meu ver, as casas inteligentes tornam as pessoas mais independentes, no sentido em que já não precisam tanto de ajuda extra, mas também as torna mais ostracizadas dentro de casa. Na minha opinião, uma casa inteligente é meio caminho andado para não saírem de casa.

Em termos de utilidade, a *framework* parece-me muito útil, desde que implementada com peso e medida. A meu ver, o fator de segurança destas tecnologias é o mais importante. Na perspetiva de um cidadão, tenho que ter a certeza que controlo a minha casa e que não preciso de me preocupar com *hackers* ou outros riscos, em sistemas como este, fundados em *wireless* e Internet. Mas isto [a *framework*] parece-me uma ideia interessante. Serve idosos, quer seja na monitorização da medicação, em emergências ou deteção de quedas, serve também famílias com crianças... Ou seja, é transversal a vários grupos da população, nomeadamente os mais vulneráveis. Mas, mais uma vez, desde que não interfira com a minha privacidade enquanto cidadão, acho que isto [a *framework*] tem tudo para ser uma ferramenta interessante, desde que haja conhecimento e segurança do que se está a recomendar e a instalar.

Q2: Que recomendações/sugestões consideraria para melhorar a *framework* proposta?

A2: Uma melhoria, a meu ver, estaria relacionada com a garantia de segurança para com as pessoas. Enquanto cidadão, quero ter a certeza de que este projeto funciona sem problemas e sem risco de ataques de *hackers*, quer eu instale a tecnologia A, B ou C. Tem de ser dado um tratamento mais cuidadoso na recomendação destas tecnologias porque é um tema sensível. Por exemplo, relativamente à monitorização de idosos, a troca da medicação de um idoso pode resultar em vários problemas.

Garantir a segurança destas tecnologias, seria um ponto a melhorar ou, pelo menos, mencioná-lo no processo.

Agora, outra melhoria poderia passar pela expansão desta ideia, para além da área da Domótica, e abordar outras áreas mais sociais, tais como mecanismos de prevenção. Por exemplo, garantir a segurança máxima dentro de casa, como proteção contra algum agressor. Mas isso seria talvez expandir demasiado o *scope* da investigação, por agora, já que só falamos em Domótica.

Porém, dentro do *scope*, a criação de uma fase extra que permitisse ao utilizador definir a dimensão temporal de algumas tecnologias, seria interessante. Por exemplo, o utilizador pode só querer determinada medida em sua casa, durante determinado tempo, como é o caso da videovigilância temporária. O período temporal podia ser adicionado ao processo, para oferecer aos residentes maior controlo da casa naquele período de tempo. Outra melhoria seria talvez expandir a tipologia de residências e incluir, por exemplo, prédios e incluir outras tecnologias, tais como campainhas ou elevadores mais inteligentes. Instalar tecnologia inteligente em prédios, talvez fosse até mais barato e acessível a mais residentes. Depois, e tendo em conta a Internet, é requisito, pois, ao que me parece, é tudo *wireless*, outras formas de residência poderem ser exploradas, tais como barcos e caravanas, uma vez que também há muita gente a viver nestes termos e também deviam ser incluídos nesta *framework*.

Q3: Existe mais algum comentário a tecer à *framework* proposta?

A3: No geral, achei tudo isto [a *framework*] muito claro; não há nada que não tivesse percebido no processo. A dificuldade, provavelmente, estará na venda, porque a *framework* teria de ser bem explicada, credível e segura. O mínimo erro pode implicar a perda de confiança por parte dos utilizadores.

As fases da *framework* fazem-me todo o sentido. Ter duas fases de triagem e uma última de aplicação parece-me uma boa estratégia, que começa com o indagar do contexto e das condições em que a *framework* será utilizada, para depois se proceder às recomendações para cada utilizador. Para mim, isto é interessante, porque atinge todos os grupos sociais, incluindo os mais vulneráveis, como os idosos e as crianças. Neste aspeto, é uma mais-valia por si só; então, se a relação custo-preço for acessível, mais interessante se torna.

ANNEX 4: FRAMEWORKS' PRESENTATION

Problem Statement

01

Current lack of expansion on Smart Home Technology (An increasing demand is being registered, but still not matching expectations).

02

Lack of understanding on Smart Technology by common citizens (e.g., what type of devices are currently in the market, what type of applications are they offering).

03

Lack of understanding on Smart Technology setup by common citizens (e.g., where to install it, how to install it).

04

Current gap between vendors'/designers' products and users' expectations/preferences (Even though the users' experience is becoming more important, there is still the need to refine their preferences and deliver more appropriate features).

Research Objectives

- ✓ Develop a **framework** capable of being **used by common citizens.**
- ✓ The proposed **framework** should support the **technologies' selection** to transform a traditional home into a smart one.
- ✓ The proposed **framework** should be as **customized** as possible to common citizens desires on Smart Home technology.

Framework

01
Context Identification

- Identify the context where the Toolbox will be employed.
- Identify the Residences' Typology.
- Identify the Residents' Typology.
- Identify Residents' Objectives.

02
Requirements' Identification

- Identify the intersections between smart technology and users.
- Collection of users' requirements (functional and non-functional).
- Identify the major features to be employed in the Toolbox.

03
Technology Selection

- Identify possible technologies to be employed.
- Identify the intersection between devices and respective setup.
- Identify and analyze technologies' complexity rates according to different manufacturers/retailers.

Framework

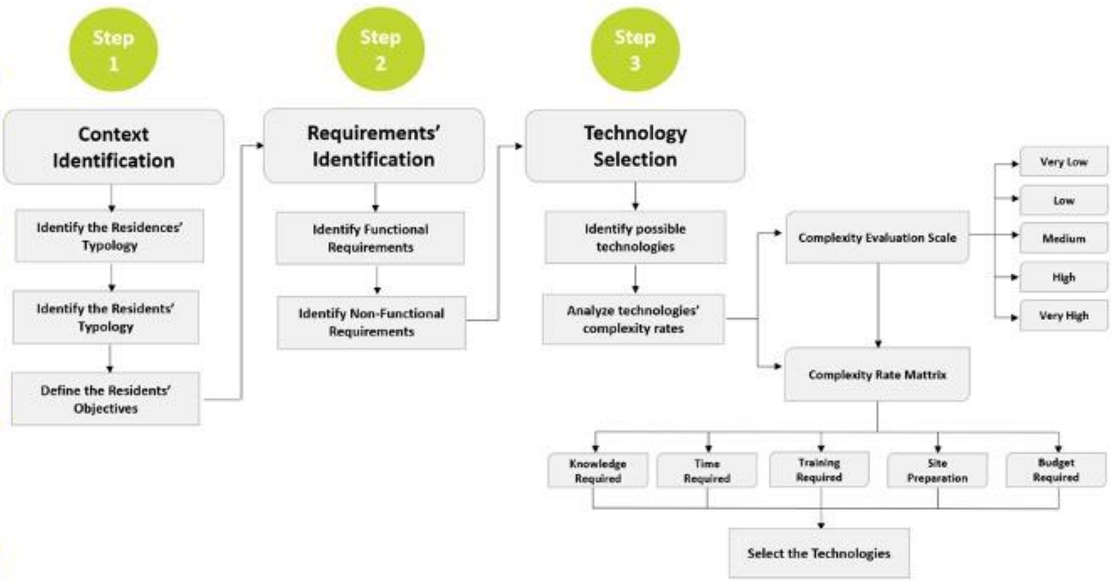


Figure 1 – Framework's Primary Steps.

Note: The next slides will present each step, in detail, with practical examples of expected outputs.

Step 1 – Context Identification

Figure 2 – Frameworks' Implementation (Step 1).

Context Identification		
Residences' Typology	Residents' Typology	Residents' Objectives
Apartment	Elderly	Elderly Assistance

Table 1 – Example of Context Identification (Step 1).

Step 2 – Requirements' Identification

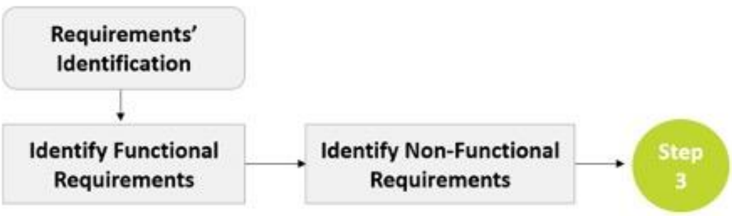


Figure 3 – Frameworks' Implementation (Step 2).

Context Identification			Requirements' Identification	
Residences' Typology	Residents' Typology	Residents' Objectives	Functional Requirements	Non-Functional Requirements
Apartment	Elderly	Security	Home Access Control	Privacy
			Protection & Surveillance	
		Elderly Assistance	Fall Detection	Interoperability
			Medication Control	

Table 2 – Example of Requirements' Identification (Step 2).

Step 3 – Technology Selection

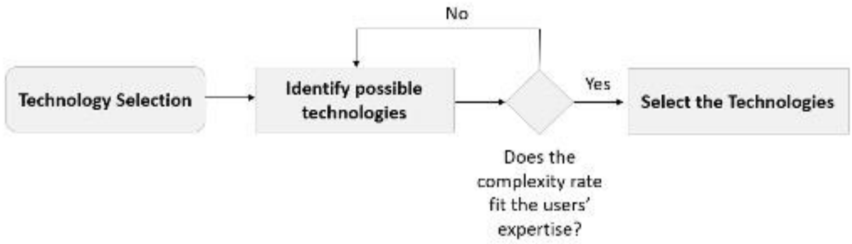


Figure 4 – Frameworks' Implementation (Step 3).

TIME REQUIRED SCALE	BUDGET REQUIRED SCALE	GENERAL SCALE
<= 10m =Very Low (1)	<= 20€ = Very Low (1)	Very Low (1)
10m < X <= 20m=Low (2)	20€ < X <=50€ =Low (2)	Low (2)
20m < X <= 30m =Medium (3)	50€ < X <= 100€ = Medium (3)	Medium (3)
30m < X <= 1h = High (4)	100€ < X <= 500€ = High (4)	High (4)
> 1h = Very High (5)	> 500€ = Very High (5)	Very High (5)

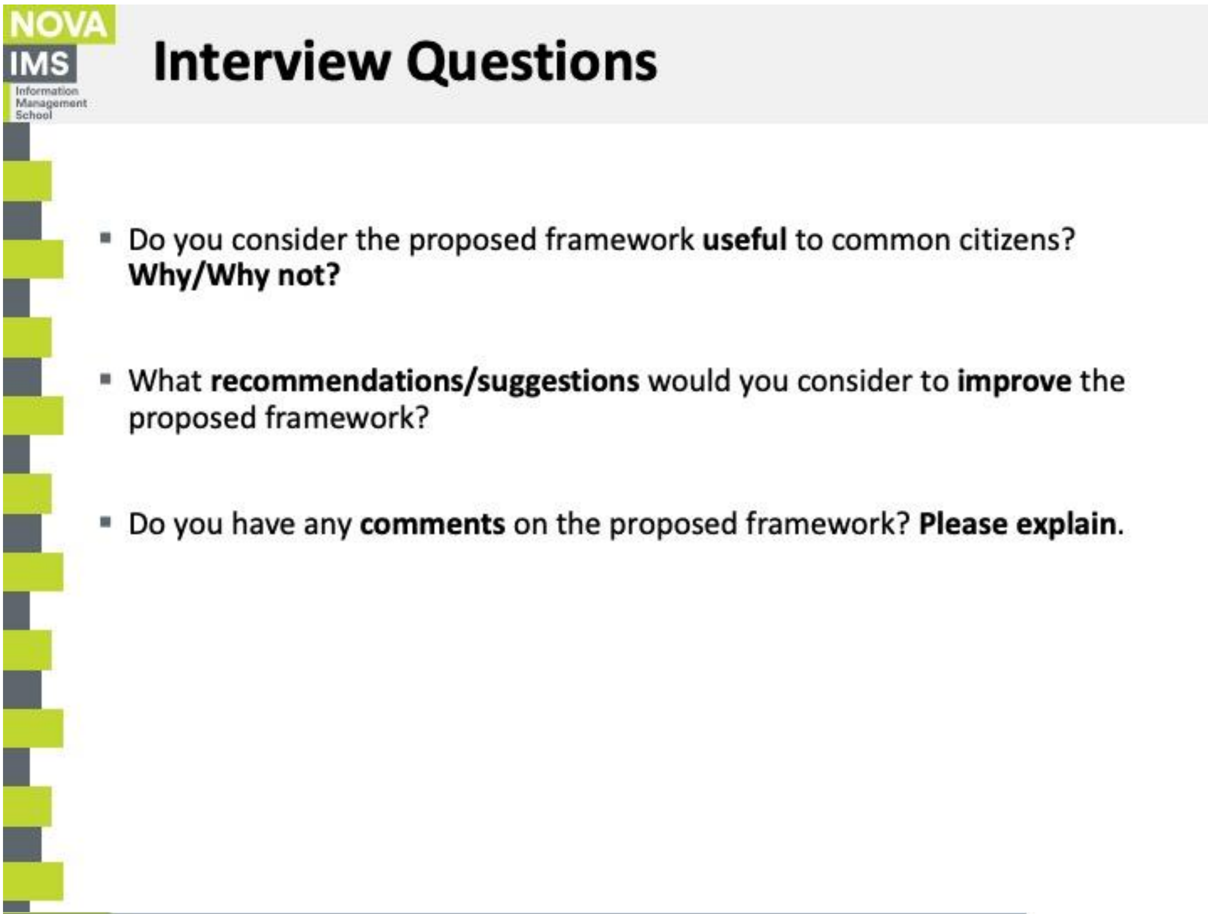
Table 3 – Evaluation Scale used in Complexity's Rate Matrix.

Step 3 – Technology Selection - cont.

Setup Process / Devices	Knowledge Required	Time Required	Training Required	Site Preparation	Budget Required	Complexity Rate (Average)	Complexity Rate (Final Result)
Actuator	Very high (5)	High (4)	High (4)	High (4)	Low (2)	3,9	High (4)
Air Quality Sensor	Low (2)	Low (2)	Low (2)	Low (2)	Medium (3)	2,1	Low (2)
Consumption Meter	High (4)	Medium (3)	Low (2)	Medium (3)	Medium (3)	3,1	Medium (3)
Contact Sensor	Very low (1)	Very low (1)	Very low (1)	Very low (1)	Low (2)	1,3	Very low (1)
Eye-Tracker	High (4)	High (4)	High (4)	Medium (3)	Very high (5)	4,1	High (4)
Fans	Very high (5)	Very high (5)	Medium (3)	Very high (5)	High (4)	4,3	High (4)
Fingerprint Scanner	High (4)	High (4)	Medium (3)	Medium (3)	Medium (3)	3,5	High (4)
Floor-Based Sensor*	a)	a)	a)	a)	a)	a)	N/A
Force-Sensitive Resistor (FSR)	Very hight (5)	Medium (3)	High (4)	Medium (3)	Very low (1)	3,1	Medium (3)

* Articles' prototypes; N/A – Not Applicable; a) Information not available as the device/project to be a prototype yet;

Table 4 – Example of Complexity's Rate Matrix.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Interview Questions
Do you consider the proposed framework useful to common citizens? Why/Why not?
What recommendations/suggestions would you consider to improve the proposed framework?
Do you have any comments on the proposed framework? Please explain.


Thank you for your time and collaboration!
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