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Evaluation of End User Requirements for Smart Home Applications and Services based on a Decision Support System

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Abstract

Smart Home (SH) systems are considered one of the prominent applications in the era of Internet of Things (IoT), where it is possible to control home devices to achieve a better usage in terms of cost and convenience. IoT offers the internet connection and remote management of home automation, integrated with numerous sensors. SHs constitute to be an innovative and popular form of residence in the modern cities, therefore designers need to comply with users preferences and requirements. The current paper defines requirements by chosen features, describing the either non-functional or functional technical, social and financial aspects of a SH. PairWise Comparison (PWC) framework, a fundamental part of many decision making problems, is applied and ranks the users requirements and also presents and prioritizes SHs services, such as e-health and entertainment.

Keywords: Smart Homes, Users Requirements, PairWise Comparison, Internet of Things, Decision Support

1. Introduction

The Internet of Things (IoT) is a new revolution of the Internet that has emerged as a new paradigm of connecting objects through the Internet. The

IoT is not only a network of computers, but it is a network of physical objects. Connected “things” can be devices of all types and sizes, such as cameras, smartphones, vehicles, home systems and devices. All the connected objects communicate and share information based on designated protocols, making themselves recognizable and intelligent by enabling context related decisions [1]. Devices access information that has been aggregated by other devices or they can be components of complex services [2] [3]. IoT enhances connectivity anytime, anyplace with anyone ideally using any path/network and any service. It aims to link devices that self-report in real-time, improving efficiency and bringing important information to the surface more quickly than a system depending on human intervention. IoT tools can be key components of home automation and SHs. SH systems are considered one of the most prominent applications in IoT, where it is possible to control home devices to achieve a better usage in terms of cost and convenience. SH technology is the integration of technology and services through home networking for a better quality of living. More specifically, it is the use of devices in the house that connect via a Internet. [4] [5]. SHs are evolving since home automation integrates an increasing range of appliances. A home automation system comprises a number of subsystems for controlling various aspects of a house, such as a security sub-system, a lighting control sub-system, and an entertainment sub-system [6]. Home automation systems allow ease of access to all devices within a home either locally or remotely via the internet as presented in Figure 1.

SH includes devices such as sensors and other appliances connected to IoT that can be remotely monitored, controlled or accessed and provide services that respond to the perceived needs of the users [7]. In addition, SHs constitute a branch of ubiquitous computing that involves incorporating smartness into dwellings for convenience, healthcare, safety, security, and energy conservation. Remote monitoring systems are common components of smart homes, which use telecommunication and web technologies to provide remote home control [8].

SHs exploit automation technology and modern building techniques and offer to home residents important benefits. Home residents can manage all their home devices through one interface and have remote access to systems including heating, cooling systems and multimedia devices throughout the home. In addition, an increased level of security is offered, since advanced security systems are installed. Motion sensors, cameras and even fingerprint identification appliances are installed in place of conventional locks, enhanc-

Figure 1: Smart Home

ing home security. Furthermore, smart homes boost green technology and provide increased energy-efficiency by using solar, wind and other renewable energy sources. In addition, elderly and disabled people can be monitored with numerous intelligent devices. Sensors can be implanted into their home for continuous mobility assistance and non-obtrusive disease prevention [9] [10].

SH projects that have been conducted over the last decades, integrate different ideas, functions and utilities. A broader spectrum of services is offered to users that targets to user's needs. Users choose installers to deploy and configure home automation systems and tailor them to their individual needs. SH designs and functions are based on users requirements about privacy, security, usability and financial issues. Therefore, a SH system aims to fulfill the various users requirements and provide expected functions and results based on their preferences [11].

Into this context, this paper defines requirements that describe the functional, non-functional, technical, financial and social perspective of a SH. In addition, fundamental SH services that offer a better quality of life are introduced. A decision-making process is proposed that ranks the users requirements and SH services, by adopting the PairWise Comparison framework (PWC). PWC is an integral part of many decision-making frameworks that enables the ranking of the requirements by allowing the users to compare them in pairs, instead of directly assigning their priorities. This reduces the influence of subjective point of views, associated with eliciting weights directly. [12] [13].

The papers' contributions are as follow:

- The proposed requirements defined by the chosen features, describe the non-functional, functional, social and financial aspect of a SH.
- The SHs users' requirements and services are prioritized, therefore the corresponding results can contribute to the optimal design of Smart User Interface (SUI) prototypes. The aim of the prototype is to describe a SH that is low cost, has a user-friendly interface, and is scalable and reliable by using an integrated system of hardware and software [14].
- The ranking of the proposed requirements and the prioritization of popular SH's services can be a useful tool for SH installers to improve their services and be complied with the users preferences, aiming at profitability improvement.
- Users' aspect about the prominent SH services such as, e-health and entertainment is highlighted.

The rest of the paper is organized as follows: Section II presents the related work while Section III introduces the PairWise Comparison framework. Section VI describes the proposed requirements and the most important SH services and Section V discusses the results. Finally, Section IV concludes the paper.

2. Related Work

There are several papers that discuss smart homes. To this end, the body of the relevant literature includes studies that address smart home design and services and studies that discuss the users requirements and acceptation of a smart home environment.

2.1. Smart Home design and services

In [15] different functions and services of a SH were presented. The proposed SH services were related to specific domains.For instance, home-office, multimedia and health applications.T-test was used to were performed to estimate and evaluate the average scores and the online survey was conducted using UniPark, an internet-based computer program.

[16] discussed the design process of a smart home in a twofold approach. Initially, design dimensions that provide design for a heterogeneity of users was presented and then design goals that highlighted directions of SH system design. The current approach was divided in three main phases, each of which combined field-specific, scientific expertise and participants' input. The design fictions were used in a series of four workshops with a total of 34 participants.

In [17] smart home services were categorized and the corresponding sensors were analyzed. In addition the importance of sensors using the sensor tree was estimated. In the paradigm shift of a smart home to smart city, an increased number of sensors and smart objects would be deployed for user-centric services.

In [18] the remote surveillance of domestic animals' health conditions inside the home environment using IoMT Technology, was examined. Pet health was analyzed for vulnerability in home environment and over a fog computing platform of FogBus.

In [19] the latest trends of smart homes and smart cities were presented. Priority directions of smart home development were pointed out. In addition examples of adopting smart systems in different manners were indicated.

2.2. Smart Home users requirements and acceptance

Park [20] examined the motivations for adopting smart home services and related the motivations with the original technology acceptance model (TAM) and the acceptance of the services. An Internet survey was conducted in South Korea. The data ($N = 799$) from the survey were analyzed using Structural Equation Modeling (SEM). Pal [21] developed and tested a theoretical framework empirically for determining the core factors that could affect the elderly users acceptance of SH services for healthcare. It was indicated that the elderly people were rather reluctant to adopt SH environment and preferred to use healthcare services in the conventional approach, without any radical changes.

The research of [22] focused on the security requirements of a SH and sets security goals for the SH environment. Based on historical data, the number of security attacks for the following five year was predicted. Security requirements were defined and several scenarios that evaluated the impact of security threats on smart homes were presented. In addition, [23] analyzed the user requirements of SH for people in dementia, conducting a user-survey and highlighting useful indications about how the smart homes can help their everyday life. Security is one of the most important concerns of this specific group of people, since a secure SH environment can have a positive impact on their quality of life.

Furthermore, [24] introduced end users security and privacy concerns, conducting semi-structured interviews with fifteen people living in smart homes. The paper points out gaps between current system designs and users' security needs and expectations. In addition recommendations for the designs of future smart home platforms and devices were presented.

Finally, Serral [25] introduced a method for the prioritization of users non-functional requirements. The proposed algorithms take inputs values the users requirements and guide a pervasive system in adapting its behavior to user preferences. A web platform was filled by twenty five users and Analytic Hierarchy Process (AHP) was adopted for pointing out users preferences. Although the specific work examines nonfunctional requirements, like the current paper, the number of non-functional requirements is limited, avoiding to overwhelm users with many questions. In addition, the current paper examined and highlighted additional requirements such as functional, social and financial.

Table 1 summarizes the related literature.

The requirements and the expectations towards the SH technology are not expected to be homogeneous across the population. While user-centered requirements have been reported for specific features, a considerable gap persists for design and function based on requirements. The proposed paper defines requirements by chosen features, describing the non-functional, functional, social and financial aspect of a SH. Therefore, the current work targets to explore and highlight users requirements and prioritizes the requirements and the features that define each requirement.

In addition, prominent SH services such as, e-health and entertainment are presented and prioritized, based on users aspect. There are several papers

Table 1: **Summary of the Related work**

Topic	**Ref**	**Method**	**Contribution**
Smart Home design and services	[15]	Online survey	A wide range of potential users evaluated the functions and apps as positive and useful.
	[16]	Workshops	Highlights specific design goals such as design for control, low effort, sociability, and benefits
	[17]	Review	Sensors and smart objects are deployed for user-centric services.
Smart Home-Users' requirements and acceptance	[20]	Online survey (Structural Equation Models)	It creates an useful theoretical framework to explain the usage intention of smart homes among the elderly in a health context
	[20]	Review	The security requirements are highlighted and security attacks are predicted.
	[22]	Online Survey	Security is one of the most important concerns of dementia patients, since a secure SH environment can have a positive impact on their quality of life.
	[24]	Semi-structured interviews	It points out how and why designers implement smart home technologies, mental models, security and privacy concerns.
	[25]	Online survey(AHP)	An algorithm is presented specifying how the pervasive system makes runtime use of the models to exhibit user-adaptive behavior.

that examine the acceptance of SH services but the aspect of users preferences has not been highlighted. The ranking of the proposed requirements and the corresponding features can be a useful tool for SH installers to improve their services and be complied with the users preferences, aiming at profitability improvement.

This work prioritizes SHs requirements and services that have not been thoroughly examined and the results can contribute to the optimal design of Smart User Interface (SUI) prototypes. The aim of the prototype is to describe a SH that is low cost, has a user-friendly interface, and is scalable and reliable by using an integrated system of hardware and software [14].

3. PairWise Comparison Model

A fundamental problem in decision making is to grade the importance of a set of attributes and assign a weight to each of them. Their importance usually depends on several criteria which can be evaluated within the decision-making processes. Pairwise comparisons are widely used in multi-criteria decision analysis (MCDA) and have successfully been applied in many practical decision-making problems either as standalone method or as an essential ingredient of MCDA processes, such as the AHP [26], the Weighted Product Method (WPM) allowing the Preference ranking organization method for enrichment evaluation (PROMETHEE) and the Analytic Network Process (ANP) [27]. PWC provides a structured process for the effective ranking of attributes, aiming at identifying their importance of influence on a general goal [28] [29].

The PWC framework enables the ranking of attributes by allowing a number of end-users, say M, to compare the various attributes A_i, $(1 \leq i \leq N)$ in pairs, instead of assigning their priorities in a single step [12]. This reduces the influence of subjective point of views, associated with eliciting weights directly. According to PWC, each end-user compares all possible combinations of A_i and A_j. The outcome of these judgments for the m^{th} end-user are stored in a square $N \times N$ reciprocal matrix $\mathbf{P}^{(m)}$=$[P_{ij}^{(m)}]$, which will henceforth be referred to as a PWC matrix. The value of the element $P_{ij}^{(m)}$ reflects the importance of attribute A_i over A_j. The end-user needs to complete only the upper triangular elements $(i < j)$ of $\mathbf{P}^{(m)}$ since by definition we have $P_{ij}^{(m)} = 1/P_{ji}^{(m)}$ and $P_{ii}^{(m)} = 1$ for a reciprocal matrix. The weights $w_i^{(m)}$ of attribute A_i according to end-user m can be calculated with various ways. The most widely adopted approach is to solve the eigenvalue problem $P^{(m)}x_q^{(m)} = \lambda_q x_q^{(m)}$, where λ_q are the eigenvalues of $\mathbf{P}^{(m)}$ and $x_q^{(m)} = [x_{pq}^{(m)}]$ are the corresponding eigenvectors. Assuming that the eigenvalues are ordered so that λ_1 is the largest eigenvalue, then the weight of attribute A_i is estimated by normalizing the elements of the principal eigenvector $x_1^{(m)}$ as follows [26]

$$w_i^{(m)} = x_{1i}^{(m)} \sum_{i=1}^{N} (x_{1i}^{(m)}) \tag{1}$$

In order to further simplify the comparisons, introduced the nine-level scale shown in the following table.

Table 2: **The nine-level fundamental comparison scale**

$P_{ij}^{(m)}$	**Explanations**
1	A_i and A_j are equally important
3	A_i is slightly more important than A_j
5	A_i is strongly more important than A_j
7	A_i is very strongly more important than A_j
9	A_i is absolutely more important than A_j
2,4,6,8	intermediate values
Reciprocals of above	used in analogous manner when A_j is more important than A_i

One way of measuring the inconsistency of a pairwise comparison matrix is to calculate the Consistency Ratio (C.R.) defined as $C.R. = C.I./R.I.$, where C.I.=$(\lambda_1 - N)/(N - 1)$ is the Consistency Index and R.I. is an average random consistency index derived from a sample of randomly generated reciprocal matrices with elements scaled according to [26]. If C.R. is smaller or equal than 0.1 is considered acceptable and in this case, the matrix is said to be nearly consistent [26]. After all the comparisons have been completed, the average weight wk for each attribute A_k is calculated by averaging out the weights $w_k^{(m)}$ obtained by the M end-users,

$$w_k = \frac{1}{M} \sum_{i=1}^{M} w_k^{(m)} \tag{2}$$

The weights w_k define the priorities of the attributes and hence the outcome of the PWC process.

In this paper, in order to rate the functional and non-functional requirements of cloud services, one must first evaluate the weights of the requirements and attributes, denoted by w_k and f_{jk}, respectively, affecting pricing of cloud services from end-user perspective. Towards this end, each end-user m performs a series of PWCs according to the aforementioned procedure and the weights are finally estimated.

4. Users Requirements and SH services

Users requirements constitute the active drivers of smart housing technology adoption, which are the underpinning concepts to create user-centered smart homes products as well as services. In addition, various intelligent services, such as home automation services or energy management services, are offered. The types of services that smart homes offer to the users can be grouped based on the users' needs they fulfill or types of technical applications. An overall approach indicate a broader spectrum of services and characteristics, such as security, health, entertainment, energy efficient. The current section presents the proposed users' requirements and the most important smart home services.

4.1. Users Requirements

The proposed users requirements are categorized into three categories, that capture the financial, nonfunctional and functional aspect of a SH. The functional and non-functional aspects of a SH are described by functional and non-functional requirements. In details, functional requirement specifies a function that a SH must be able to perform, whereas non-functional requirements introduce the non-behavioral aspects of a SH, capturing the properties and constraints under which a SH must operate [30]. In addition, financial requirements refer to an actual or estimated sum of cash needed to perform a plan to purchase and maintain a product or service [31].

More specifically:

- **Financial Requirement**: It is mainly related to the cost of installing and maintaining smart technology to a home.
- **Social-technical Requirement**: Describes the social aspect to user-smart home interaction. harmony between human and technology is necessary to be developed in a SH [32].
- **Usability**: It refers to a smart home that offers home automation systems that can effectively be used even by users with limited ICT knowledge.

- **Reliability**: The ability to manage responsiveness of a service, based on real time demand [30].
- **Performance**: It refers to the amount of useful work accomplished by a smart home. For example, it describes the speed of executing smart home's instructions.

The requirements are determined by features that compose and highlight the perspective that each requirement represents.

- Financial Requirements
  - Domestic Energy Consumption: Refers to the total amount of energy used in a house for household work.
  - Maintenance expenses: Refers to any cost incurred by smart home habitats to keep their smart appliances in good working condition.
  - Expenses of installing home automation: The amount that it is paid for smart home automation installation. It includes the cost for buying and installing devices such as smart home appliances, cameras, sensors.
  - Energy saving: Smart services offer energy saving.
- Social technical requirements
  - Privacy: All the smart home appliances are connected to the Internet, and large amounts of information is available on it. Therefore, there is a growing concern about what sensitive data is collected.
  - Physical Security: Physical security describes security measures that are designed to deny unauthorized access to facilities, equipment and resources and to protect personnel and property from damage or harm, such as espionage, theft, or terrorist attacks. [33].
  - Design: Home's design integrates smart technology, avoiding difficult interventions such as digging through the walls.
- Usability
  - User-friendly Interface: A user-friendly interface that provides remote access and control of the home appliances.

  - Automated learning and decision making: A customized environment is provided, based on users' behavior and habits. The devices and sensors along with user interactions in the environment collect data and the smart home make decisions within its environment to suit the users' needs.
  - Configuration: Users can configure smart home functionality based on their familiarity with ICT technology. An end user does not need to have any technical knowledge to run smart home applications. However, with some technical knowledge an end user is able to customize applications [32].
  - Mobility: Users and devices can freely move inside the home, without interrupting the smooth operation of the offered automation services.

- Reliability
  - Automatic recovery: Smart home system can recover from hardware errors.
  - Mean Time Between Failures (MTBF): Measures the reliability of an integrated smart home construction.
  - Mean Time to Repair (MTTR): The average time that a smart home device takes to recover from a system failure.

- Performance
  - Data Transmission Speed: Refers to the connection speed among the appliances of the smart home.
  - Coverage: It is a measure of how wide an area around a wireless smart home transmitter can be. A transmitter needs to have a sufficient signal strength for other smart home wireless devices. Refers to the percentage of smart home devices in the whole home.
  - Outage: Smart home devices interrupt their operation due to unexpected incident, such as power outage.
  - Cloud Backup: The collected data should be stored to the cloud environment.

The categorization into functional and non-functional requirements is presented in Figure 2

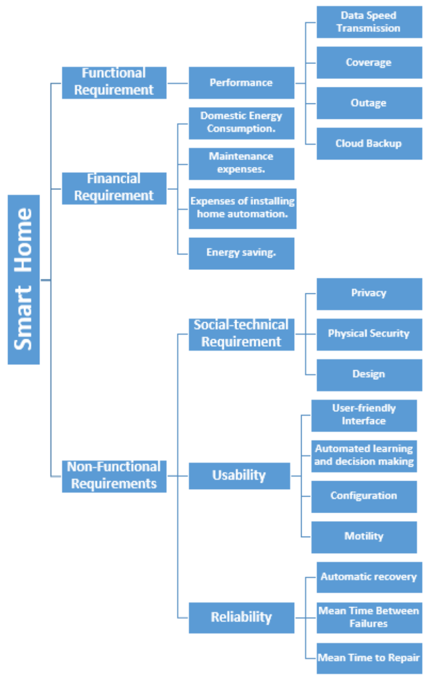

Figure 2: Users requirements

4.2. Smart Home Services

The smart home services are grouped into five (5) categories: [34].

- E-health Services: Use of digital technologies and telecommunications, such as computers, the Internet, and mobile devices, to facilitate health improvement and health care services.
- Security and monitoring Services: A set of internet-connected security gadgets, which typically include a combination of wireless security cameras, sirens, motion detectors, door locks, and sensors that detect when a door or window has been opened.
- Energy Saving Services: Services that monitor and control energy usage, such as power consumption, heating.
- Entertainment and Connectivity Services: Home entertainment devices, such as smart TVs and sound system, can be configured with

a smart home system, making them easy to control via a smartphone.

- Home Appliances Services: Services that include the control and monitor of kitchen, cooking and washing devices. Figure 3 illustrates the fundamental services of smart homes.

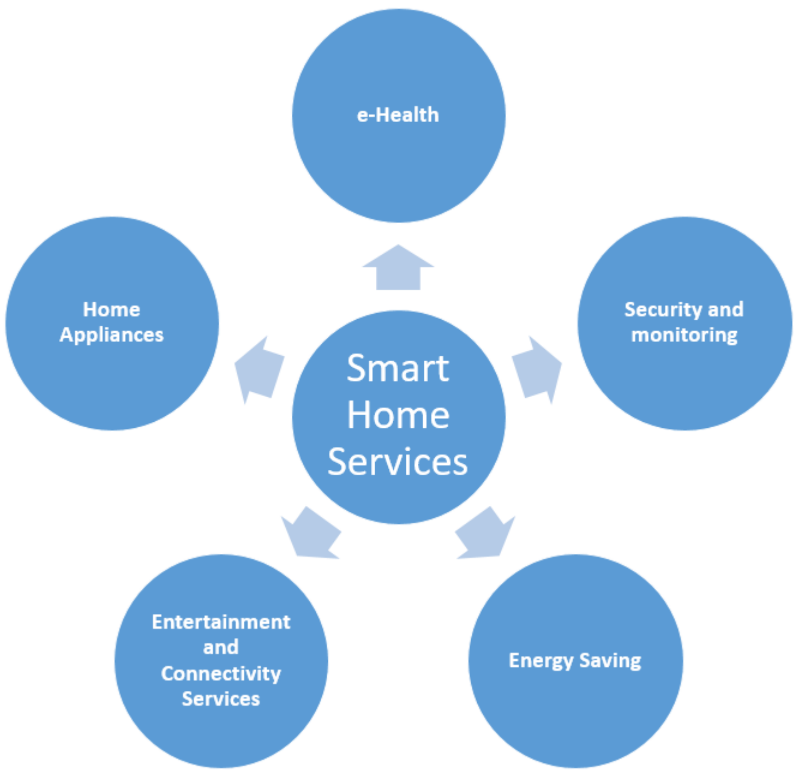

Figure 3: Smart Home Services

5. Results-Discussion

This section presents the results of the PWC surveys, ranking the requirements and the SH services, based on user aspect. For the needs of the present paper a survey platform was developed in order to perform the surveys.

5.1. Surveys Design and Decision Support Platform

The survey-design including the definition of categories and requirements was based on a thorough inspection of previous literature, market needs and was extensively discussed among representatives of several European providers (i.e. OTE, France-telecom, Deutsche-telecom). The feedback from operators was interesting enough and very useful for the final survey-design as they emphasized on the definition of requirements and categories considering the user's perspective in both performance-related issues and socio-economic aspects. After the definition of the requirements and categories a number of M=200 end users with technical skills have filled out the PWCs matrices.The participants were divided into to groups, IT students and IT professionals depicting low and high skilled level, respectively. More specifically, 200 participants (110 males and 90 females), between 22–50 years old, with the average age 30 years,were invited to paricipate in these surveys. The participants had to fill in the PWC matrices according to the AHP framework described above. In more details, each participant fills in the PWC matrix for requirements categories as well as the PWC matrices for the requirements under each category.

The surveys were conducted by a web-based decision support platform incorporating all elements of the PWC framework where experts log on to the platform and fill out the questionnaires, as presented in. The web platform has been developed by the authors and maintained in the Harokopio University of Athens. The data supplied by the users are saved in a database and the survey designer can perform the PWC algorithm in order to estimate the weights and the priorities according to the equations that signify the importance of criteria and factors according to the methodology.

5.2. Requirements for Smart Home

The results of the PWC survey, ranking the requirements and the SH services, based on user point-of-view are shown in Figure 4. According to the results the social-technical requirement is the most important, as its weight reaches 28.18%. It is obvious that users are interested in SHs, equipped with automation devices and simultaneously respect social needs, such as privacy and physical security.

Financial requirement is also of higher concern, rated with 19.60%. Even though SH users acknowledge that a SH is an investment that can provide financial benefits, the results reveal that the SH cost can be an obstacle to smart home implementation. SH technology can be expensive and users worry about are anxious about paying for equipment, which will be proved idle.

Usability and reliability follow with estimated weights equal to 18.93% and 18.32% respectively. One of the challenges of designing SHs is to balance the complexity of the system against the usability of the system [35]. Complex installation procedures and user interfaces, have prevented the adoption of this type of technology. SH residents are not specialists with technical skills, therefore the automation devices should be easy to use for the broad public. In addition, users raise great concern about the vulnerabilities that can be found in a SH environment. SH application are managed by smart devices that integrate various sensors. Serious incidents due to sensors' malfunction, highlight the need for smart devices to operate reliable.

Finally, performance requirement seems to have the lower priority equals to 4.98%, since the corresponding issues have been well-established and offered by the majority of SH solutions.

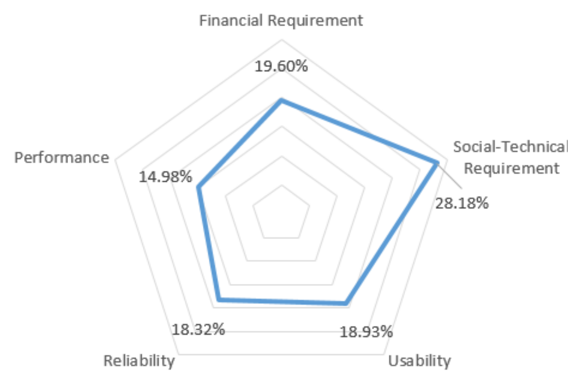

Figure 4: Requirements Ranking

Considering social-technical features, as shown in Figure 5, privacy seems to be the dominant attribute with an estimated weight of 41.01%. The smart home appliances will apparently be working based on the information about user's daily routine, which means that smart home sensors and devices will collect a lot of highly sensitive personal data. Information like user movements and credit card details should be secured.

Even though cybersecurity holds a determinant role in social-technical requirement, physical security is not negligible, since it holds a weight equals to 40.53% . The physical SH security includes the smooth operation of the smart appliances, objects based on users behavior. It deters potential intruders by installing cameras and monitors and records, the appropriate areas. Moreover, fire protection equipment is installed preventing serious accident. Finally, design is an aspect of low concern, reflecting that users are more interested in the technology development related to the intelligent housing rather than avoiding interventions such as digging through the walls.

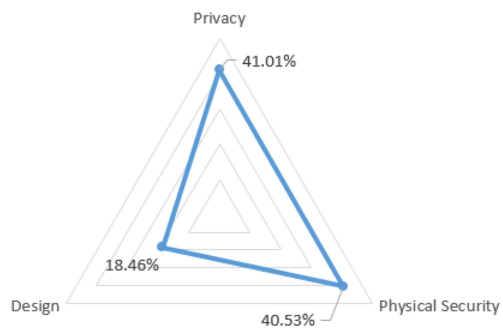

Figure 5: Social-technical's features ranking

Regarding financial features, as shown in Figure 6, users seems to be more concerned about the energy consumption. SH environment includes an extended range of devices and services, resulting in an increased energy consumption. In addition, energy saving and maintenance expenses are also highly prioritized with estimated weights equals to 27.67% and 24.91% respectively.

Energy saving is an increasingly important issue these days. Smart home systems and devices promote energy saving by enabling users to monitor and control usage in new ways. Energy-saving technology is typically managed via smartphone application. Devices are turned on and off even when users are out of the house. Smart home solutions are increasing accuracy and efficiency, affecting the maintenance expenses. However, the installed equipment needs regular maintenance services on a variety of home automation systems, therefore the additional charge is considered by the users.

Finally the expenses of installing home automation are not negligible for users, accumulating importance weight of 17.68%. Market research has indicated that the installation home automation expenses consider to be a significant barrier to smart home adoption [36]. Therefore the high value of the estimated weight is rather justifiable.

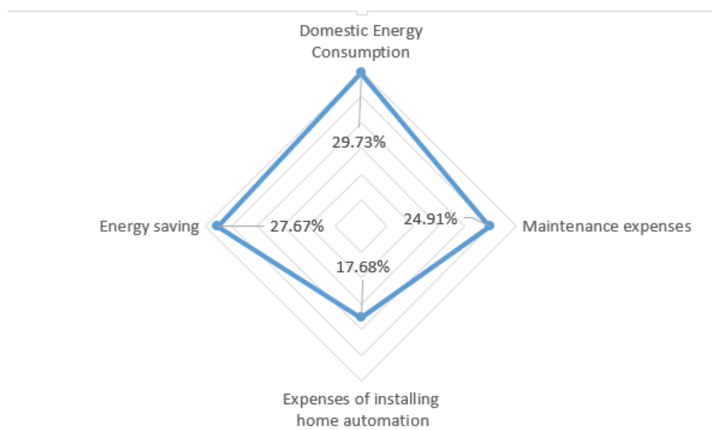

Figure 6: Financial requirement features ranking

Regarding usability features, as shown in Figure 7, user-friendly interface and configuration seem to be the most important features, with estimated weights equal to 28.62% and 27.45% respectively. Users can control house equipment by using smart applications for home automation systems. An effective SH is highly related with a user-friendly interface. A user interface monitors and provides various facilities about home's appliances. A smart phone, laptop, tablet or a standalone device can be used to manage user interface. In addition, it is essential that users are able to configure, monitor, manage smart home devices and applications, without additional expertise in home automation. Smart home automation system addresses to a broad target market with substantial ICT skills.

Mobility and automated learning also hold important weights equal to 22.28% and 21.65%. Mobility is highly ranked, revealing that users prefer to move freely in their home, without interrupting smooth operation of the devices. Finally, the decision-making aspect is a severe priority for users. Devices integrated with the specific strategy and learning algorithms can learn and predict the user's behavior. The ability of a sSH system to recognize and predict the activities of its occupants, increasing the efficiency of a SH.

Examining the features that comprise reliability, as presented in Figure 8 , it is revealed that automatic recovery is the determinant aspect(47.54%). It appears that users are highly concerned about what will happen if smart home fails and how quickly it can recover. In addition, MTTR and MTBF metrics that are also firmly related to the automatic recovery of a smart

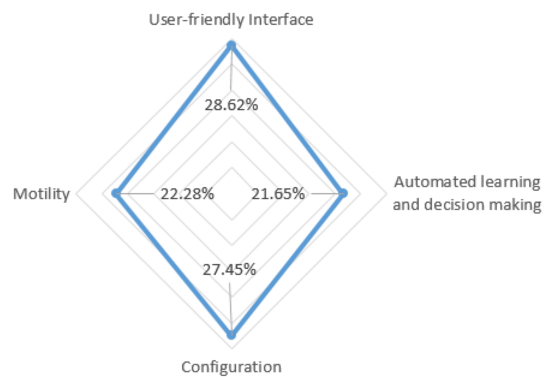

Figure 7: Usability features ranking

home, hold important weights equal to 29.14% and 23.32%.

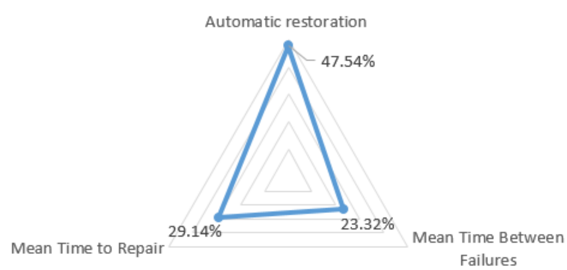

Figure 8: Reliability features ranking

Finally,as shown in Figure 9 outage is the most important aspect pf performance. SSHs are dependent upon electrical power and internet, thus a corresponding outage can cause serious problems to a SH. Depending on the smart devices that are installed in the home, some may still function during a power outage while others may not function at all.

Coverage and data transmission are also highly prioritized with weights 27.44% and 24.67% respectively. An accurate and well-designed SH network is an essential consideration for users. SH coverage is not always simple, since power settings, environmental obstacles and antenna can affect coverage. SH network is interconnected, everything communicates on the network. Most SH devices do not demand the fastest connection. For example thermostats and light bulbs only need to access the network to receive commands from a smartphone or a control panel, therefore the required data transmission speed is limited. However, cameras upload photos and videos, thus increased bandwidth is needed. Finally, cloud backup seems to be an aspect of low concern, revealing that users consider cloud backup a common and already established service.

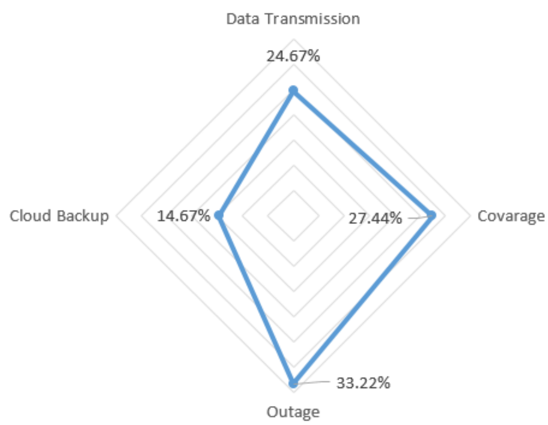

Figure 9: Performance feature ranking

Examining the importance of SH services, as shown in Figure 10. The results indicate that e-health holds the greater weight equals to 29.45%. E-health enhances health care in a more effective way, utilizing the smart home resources. SH is equipped with technology that improves patients assurance and monitor their health conditions. Security-monitoring aspect is also highly ranked. The specific service deter crime, discourage break-ins and increase the possibility of arresting a burglar. Energy saving services follow with the corresponding weight equals to 21.39%. Smart thermostats, lights and water leek offer smart services that contribute to energy saving.Thus, users are beginning to invest to smart home energy solutions to shrink their monthly utility bills. Finally home appliances configuration and entertainment services are ranked lower than the other features.

6. Conclusions

A SH is a strongly technology-driven field, that uses internet-connected devices to enable the monitoring and management of appliances and systems, such as lighting and heating. SH systems achieved great popularity in the

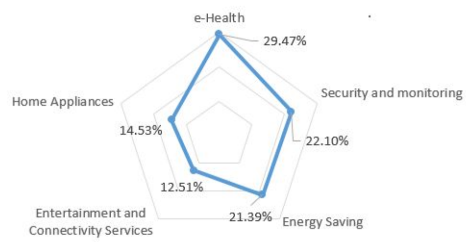

Figure 10: Smart Home Services ranking

last decades as they enhance the convenience and quality of life. Each SH is based on different ideas, functions and equipment. A wide range of services are provided to users, aiming to fulfill their needs and requirements. Users choose installers and designers to deploy and configure home automation features and systems, tailoring them to their individual needs. SHs designs and functions are based on users requirements about privacy, security, usability and financial issues are differentiated. Therefore, SH system needs to fulfill the various users' requirements and provide expected functions and results based on their preferences.

Therefore this paper presents a wide-ranging list of users requirements, focusing on financial, techno-social, usability, reliability and performance requirements of SH. The proposed requirements describe the functional, qualitative and financial approach of a SH and are defined by smart home features. Applying the PWC framework the proposed requirements and features are ranked and prioritized. Based on the results the social-technical requirement of a SH is considered to be the most essential for users. Financial, usability and reliability requirements follow with not negligible weights. Finally performance appears to have a minor priority for users.

Each requirement is described by SH features, thus PWC also ranked the corresponding features of each requirement. Considering social-technical requirement privacy appeared to be the dominant attribute, whereas energy consumption contributes highly to financial requirements. In addition, user-friendly interface is the most essential features of the usability, whereas automatic recovery is the determinant aspect of reliability. Finally, outage is the most important characteristic of performance. In addition the importance of SH services is highlighted.The results indicate that e-health holds the greater weight

The ranking of the proposed requirements and services can be a useful tool for SH installers, designers and manufacturers to improve their services and be complied with the users preferences, aiming at profitability improvement. This approach will help designers, architects, engineers, manufacturers and integrators to explore and develop SHs based on a more expanded aspect. In addition, it can boost researchers examine more thoroughly the role of quality and functionality in SH design can also help them expand or modify the requirements.

As in most cases, there are limitations in this paper. Regarding the survey assessment only skilled assessors have been selected. In addition the chosen requirements and services highlight specific aspects of a smart home. Towards this direction, future research directions may include additional requirements that cover different aspects of a SH. Considering the methodological aspects, it would be interesting to examine the assignment of numerical or categorical values to some features and propose a scale-level survey. Finally, taking into account that users needs are constantly changing and hence provided smart home services are reformed, the proposed model should be further extended to capture the growing requirements.

References

[1] G. Dede, G. Hatzithanasis, T. Kamalakis, C. Michalakelis, Brokering cloud computing: Pricing models and simulation approaches, in: Perspectives, Trends, and Applications in Corporate Finance and Accounting, IGI Global, 2018, pp. 230–251.

[2] K. K. Patel, S. M. Patel, et al., Internet of things-iot: definition, characteristics, architecture, enabling technologies, application & future challenges, International journal of engineering science and computing 6 (5) (2016).

[3] O. Vermesan, P. Friess, Internet of things: converging technologies for smart environments and integrated ecosystems, River publishers, 2013.

[4] R. J. Robles, T.-h. Kim, Applications, systems and methods in smart home technology: A, Int. Journal of Advanced Science And Technology 15 (2010) 37–48.

[5] K. Karimi, S. Krit, Smart home-smartphone systems: Threats, security requirements and open research challenges, in: 2019 International Conference of Computer Science and Renewable Energies (ICCSRE), IEEE, 2019, pp. 1–5.

[6] L. S. Humphries, G. Rasmussen, D. L. Voita, J. D. Pritchett, Home automation system, uS Patent 5,621,662 (Apr. 15 1997).

[7] D. Rocznik, K. Goffart, M. Wiesche, H. Krcmar, Towards identifying user-centered requirements for smart in-house mobility services, KI-Künstliche Intelligenz 31 (3) (2017) 249–256.

[8] K. Gram-Hanssen, S. J. Darby, "home is where the smart is"? evaluating smart home research and approaches against the concept of home, Energy Research & Social Science 37 (2018) 94–101.

[9] R. Harper, Inside the smart home, Springer Science & Business Media, 2006.

[10] J. M. Batalla, A. Vasilakos, M. Gajewski, Secure smart homes: Opportunities and challenges, ACM Computing Surveys (CSUR) 50 (5) (2017) 1–32.

[11] M. Al-Qutayri, Smart Home Systems, BoD–Books on Demand, 2010.

[12] T. L. Saaty, L. G. Vargas, Models, methods, concepts & applications of the analytic hierarchy process, Vol. 175, Springer Science & Business Media, 2012.

[13] T. L. Saaty, A scaling method for priorities in hierarchical structures, Journal of mathematical psychology 15 (3) (1977) 234–281.

[14] P. Weichbroth, M. Sikorski, User interface prototyping. techniques, methods and tools, Studia Ekonomiczne 234 (2015) 184–198.

[15] B. Schiffhauer, J. Bernotat, F. Eyssel, R. Bröhl, J. Adriaans, Let the user decide! user preferences regarding functions, apps, and interfaces of a smart home and a service robot, in: International Conference on Social Robotics, Springer, 2016, pp. 971–981.

[16] P. Fröhlich, User requirements for the design of smart homes: Dimensions and goals, in: Ambient Intelligence: 15th European Conference, AmI 2019, Rome, Italy, November 13–15, 2019, Proceedings, Vol. 11912, Springer Nature, 2019, p. 41.

[17] B. Kang, S. Kim, M.-I. Choi, K. Cho, S. Jang, S. Park, Analysis of types and importance of sensors in smart home services, in: 2016 IEEE 18th International Conference on High Performance Computing and Communications; IEEE 14th International Conference on Smart City; IEEE 2nd International Conference on Data Science and Systems (HPCC/SmartCity/DSS), IEEE, 2016, pp. 1388–1389.

[18] M. Bhatia, Fog computing-inspired smart home framework for predictive veterinary healthcare, Microprocessors and Microsystems 78 (2020) 103227.

[19] E. Deyanov, N. Kharitonova, Trends in the development of the smart home system and its integration into modern society, in: IOP Conference Series: Materials Science and Engineering, Vol. 976, IOP Publishing, 2020, p. 012034.

[20] E. Park, S. Kim, Y. Kim, S. J. Kwon, Smart home services as the next mainstream of the ict industry: determinants of the adoption of smart home services, Universal Access in the Information Society 17 (1) (2018) 175–190.

[21] D. Pal, S. Funilkul, N. Charoenkitkarn, P. Kanthamanon, Internet-of-things and smart homes for elderly healthcare: An end user perspective, IEEE Access 6 (2018) 10483–10496.

[22] W. Ali, G. Dustgeer, M. Awais, M. A. Shah, Iot based smart home: Security challenges, security requirements and solutions, in: 2017 23rd International Conference on Automation and Computing (ICAC), IEEE, 2017, pp. 1–6.

[23] R. Orpwood, C. Gibbs, T. Adlam, R. Faulkner, D. Meegahawatte, The design of smart homes for people with dementia—user-interface aspects, Universal Access in the information society 4 (2) (2005) 156–164.

[24] E. Zeng, S. Mare, F. Roesner, End user security and privacy concerns with smart homes, in: Thirteenth Symposium on Usable Privacy and Security ({SOUPS} 2017), 2017, pp. 65–80.

[25] E. Serral, P. Sernani, F. Dalpiaz, Personalized adaptation in pervasive systems via non-functional requirements, Journal of Ambient Intelligence and Humanized Computing 9 (6) (2018) 1729–1743.

[26] T. L. Saaty, Decision-making with the ahp: Why is the principal eigenvector necessary, European journal of operational research 145 (1) (2003) 85–91.

[27] J.-P. Brans, P. Vincke, B. Mareschal, How to select and how to rank projects: The promethee method, European journal of operational research 24 (2) (1986) 228–238.

[28] E. Triantaphyllou, Multi-criteria decision making methods, in: Multi-criteria decision making methods: A comparative study, Springer, 2000, pp. 5–21.

[29] R. R. Yager, Modeling prioritized multicriteria decision making, IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics) 34 (6) (2004) 2396–2404.

[30] M. Glinz, On non-functional requirements, in: 15th IEEE International Requirements Engineering Conference (RE 2007), IEEE, 2007, pp. 21–26.

[31] K. Pilbeam, Finance & financial markets, Macmillan International Higher Education, 2018.

[32] B. Whitworth, The social requirements of technical systems, in: Virtual Communities: Concepts, Methodologies, Tools and Applications, IGI Global, 2011, pp. 1461–1481.

[33] D. J. Brooks, What is security: Definition through knowledge categorization, Security Journal 23 (3) (2010) 225–239.

[34] N. Balta-Ozkan, O. Amerighi, B. Boteler, A comparison of consumer perceptions towards smart homes in the uk, germany and italy: reflections for policy and future research, Technology Analysis & Strategic Management 26 (10) (2014) 1176–1195.

[35] R. J. Robles, T.-h. Kim, Context aware tools for smart home development, International Journal of Smart Home 4 (1) (2010) 1–12.

[36] C. Wilson, T. Hargreaves, R. Hauxwell-Baldwin, Benefits and risks of smart home technologies, Energy Policy 103 (2017) 72–83.