buildings

Article

Exploring the Sustainable Values of Smart Homes to Strengthen Adoption

Soojung Chang and Kyeongsook Nam *

Department of Interior Architecture Design, Hanyang University, Seoul 04763, Korea
* Correspondence: ksnam@hanyang.ac.kr

Abstract: Despite numerous benefits and developments, smart home technology has not been widely adopted by mainstream users. The purpose of this study is to suggest user-centered smart home design strategies to promote smart home adoption. This study has the following research goals: First, it selects smart home design factors to promote adoption. Second, it examines the importance of how users perceive smart home design factors. To achieve the goals, a user survey was conducted in Korea. As a result, six items, including 38 subfactors, were suggested as smart home design strategies to promote adoption: (1) creating an automated residential environment, (2) guaranteeing service scalability and diversity, (3) increasing service accessibility, (4) improving the lifestyle balance of potential users, (5) securing long-term safety in relation to the use of systems and facilities, and (6) reducing environmental load. The differences in user perception regarding the importance of these factors were investigated. Based on a comprehensive understanding of smart home adoption, this study proposes sustainability values for the factors influencing smart home adoption as they focus on the ability of smart homes to address user burden in terms of physical and spatial changes, and also help to identify adaptations that can be incorporated to meet the diverse needs of users. The results of this study can improve the overall understanding of the process of adopting smart homes and provide reference material regarding user perceptions of the performance conditions, functional characteristics, and service operation and quality of smart homes.

Keywords: smart home; technology adoption; user-centered design; user perception

check for updates

Citation: Chang, S.; Nam, K. Exploring the Sustainable Values of Smart Homes to Strengthen Adoption. *Buildings* **2022**, *12*, 1919. https://doi.org/10.3390/buildings12111919

Academic Editors: Wei Liu, Alan Kabanshi and Yong Cheng

Received: 24 September 2022
Accepted: 1 November 2022
Published: 7 November 2022

1. Introduction

A smart home is an intelligent residential environment in which services are provided to users through a variety of sensors, devices, and electronic appliances connected through a network. The fundamental value of smart homes is in guaranteeing convenient living by actively using information and communication technologies (ICT) that are centered on the residential environment [1,2]. Typical benefits of smart homes that have been reported in previous studies include integrated environmental management, automated residential safety, energy optimization, and health care [1,3,4]. Smart homes can provide integrated management functions by connecting different electronic appliances and devices and can support all activities performed in a residential environment, including household work, official work, rest, and entertainment [5]. In addition, smart homes can optimize energy consumption in residential areas, reducing environmental burdens and economic costs [6]. The automated technology of smart homes can also support the safety and health of vulnerable residents, such as the elderly and the disabled, supporting independent living in the process [7,8]. In other words, smart homes can reduce environmental burdens, reduce maintenance costs, support residents' health and well-being, and further achieve environmental, economic, and social sustainability in residential environments [9]. However, despite these benefits and recent developments, smart home technology has yet to be widely adopted by mainstream users [10,11].

In order to determine the cause of the slow adoption of smart homes, several researchers have suggested that a user-centered approach is necessary. As part of a user-centric approach to studying smart home adoption, measuring the perceptions and needs of potential users is critical. One of the key areas of this research is to identify the benefits and barriers relating to smart homes. Previous studies have focused on the sustainability value of smart homes as one of the major benefits and identified barriers due to which potential users may be hesitant to adopt smart homes [3,7,12–14]. Several studies focusing on the challenges of smart homes that were conducted to address barriers to adoption have noted the effects of performance and technological innovation on adoption, such as interoperability, controllability, and automation [15–17]. However, due to the complex interests surrounding the structure of smart homes, such as technology elements, service content, and spatial requirements, the individual impact of innovative features of smart home technology struggles to fully explain the complexity of smart home adoption. For example, the environmental and cost burden of adopting a smart home is deeply related to changes in the residential environment, such as installation, alteration, removal, and residential movement, not just the purchase price [8,14]. In addition, the intent to adopt smart homes tends to depend on individual characteristics, such as the perception of technology or the effort required to use it [18]. Therefore, the adoption of smart homes should be preceded by consideration of structural and behavioral variability in the context of the residential environment.

Against this backdrop, this study was conducted to identify design factors that can promote smart home adoption. In particular, this study focused on the ability of smart homes to address user burden in relation to physical and spatial changes and identify adaptations that can be made to meet the diverse needs of users in order to spread the adoption of smart homes. The research objectives are as follows: (1) to derive design factors which activate smart home adoption and (2) to structure these factors by identifying differences in user perception for each factor. A literature review was conducted to select smart home design factors and a user perception survey was conducted to identify the factor structure and refine the scattered factors.

This study proposes sustainable values of factors influencing smart home adoption and, by using a quantitative survey as a major research method, a smart home design strategy including 38 subfactors is thus specified. This study can be useful in designing smart home services, devices, and spaces as it suggests effective smart home implementation strategies based on an exploratory approach to smart home adoption. In addition, the findings of this study provide structured data on user perceptions of the performance conditions, functional characteristics, and service operation and quality of smart homes.

2. Smart Home

2.1. Change in the Smart Home Environment

The initial stage of the smart home concept emerged as a product of future home design. A smart home was defined as a residential environment in which inhabitants control the devices connected to the wired home automation system [19]. Earlier smart homes were not very common due to limited wired network technology and high device purchasing costs [20]. However, the increased supply of wireless networks, the reduced cost of sensor technology, and the diffusion of smartphones stimulated interest in smart homes, and currently the smart home market is growing in size based on the B2C model that provides integrated services via individualized and diversified devices [21].

Currently, a platform ecosystem is formed by collaboration between different industries, such as IT, semiconductor manufacturing, and the automobile industry, with a focus on smart homes. The establishment of the collaborative ecosystem raised the need to secure compatibility among different product lines in order to expand the number of devices that are inevitably connected. Smart home technology provides an open interface for suppliers of other companies to develop new additional functional modules, through open architecture, and easily connect the added modules [22]. In particular, smart home use has encouraged a high demand for connectivity and interoperability that can integrate multiple modules and devices [23,24].

2.2. Studies on Smart Home Adoption

Studies have been widely conducted to investigate the factors promoting smart home adoption so as to aid the effective supply of smart home technology. Technology acceptance models (TAMs) were developed based on efforts to increase the usage of innovative technologies among workers in the 1980s [25]. The models are based on the assumption that identifying the factors forming the intention to use a technology and manipulating such factors can accelerate technology acceptance and promote technology usage. Some studies that attempted to expand the research model around TAMs sought to analyze the impact of innovative smart home features on adoption by using the innovative diffusion theory [26]. As a feature influencing innovation diffusion, compatibility has been widely studied across various fields as an important factor affecting the adoption of innovative technology [27]. Similarly, compatibility has shown a significant effect on smart home adoption [16,18,28–30]. Furthermore, compatibility has been expressed in terms of the interconnectivity and interoperability of various devices, i.e., when multiple smart devices and electronic appliances are connected to one another [31,32]. More specifically, the compatibility of a smart home, which can provide integrated management functions by connecting different electronic appliances and devices, offers great convenience to occupants and is expected to have a positive effect on the intention to use [18].

Meanwhile, many attempts have been made to verify the influence of other smart home system characteristics, such as automaticity, controllability, connectivity, mobility, or observability; however, the effectiveness of these factors has provided a degree of controversy in the research field. For example, the automaticity of a smart home is known to have a positive effect on adoption, as it ensures convenience in diverse aspects of life. However, the expected effects of automaticity have not been supported in certain studies. Yang et al. (2018) reported that most people generally desire a controllable smart home system, rather than a completely automated one [31]. At the same time, the effects of automaticity in their study varied depending on the use experience and residential type, implying that automaticity should be used as a strategy for particular user groups, rather than as a generalized strategy. These results were supported in a study by Pal et al. (2018) that was conducted among the elderly population; this population is generally expected to have high demands for an automated management service in residential environments [17]. The trends of prior research indicate the complexity of the smart home adoption process.

To identify the complex smart home adoption process, some studies have observed the adoption impact factors from a broader perspective. Smart homes are complex environments with various types of interactions (e.g., process, performance, management, maintenance) and physical features (e.g., facilities, structure, materials, fabric), and also have an extensive number of technical elements (e.g., devices, sensors, networks) [33–35]. From this perspective, some studies have identified the benefits and problems of smart homes that may arise in the context of residential environments. For example, addressing cost concerns is one of the key challenges of smart home adoption. In this case, the cost is not only related to the purchase cost of the technology, but also to the overall burden of the technology's life cycle, such as installation, maintenance, replacement, and demolition [3,8,10,14,36]. In particular, cost concerns can also be associated with the burden of spatial changes that follows the introduction of smart home technology, as complex interests are intertwined with the residential environment, such as long construction periods, ownership (ownership, sharing, lease, etc.), remodeling, and residential mobility. In fact, it has been reported that the cost burden of advanced information technology is one of the biggest barriers to technology adoption in the construction sector [37], and property ownership has also been reported as one of the barriers to the introduction of smart meters [38]. Against this backdrop, the smart home market, which is growing based on individual devices, suggests that the sweet spot lies somewhere between a traditional residential environment and a home automation-based smart home, thus reducing the expense for consumers [10].

Concerns about the difficulty of using this technology, or about the difficulty of maintenance, were also considered as major barriers to adoption [12–14]. The physical and psychological efforts required to use the same technology can vary by individual. In particular, there are significant differences between those who possess an organizational and technological basis for supporting the usage of new technology and those who do not. As a smart home is centered around ICT and innovative information resources based on data, appropriate support should be provided to ensure that all users of various levels of technology can easily access the service [39]. Given that one of the major barriers to smart home adoption is the concern surrounding complexity of use, it is expected that providing guidance and appropriate support services will facilitate adoption and use [40,41]. Accessibility to technical support services is important, as there have been incidents of people being hesitant to use services because of the financial and psychological costs of requesting technical assistance [42]. In other words, when assistance is guaranteed, technology adoption can be accelerated as the use of the technology becomes easier [43]. Assistance services are also known to affect service quality and user satisfaction [44].

Several studies also found that reliability and security issues had significant effects on the adoption of smart homes [14,15,17,28,31,32]. In order to reduce the impact of these barriers on the adoption of smart homes, Brush et al. (2011) argued that strategic approaches should be accompanied by reduced costs brought about by simplification of installation, the facilitation of easy-to-understand operation, and the promotion of perceived reliability [14].

All previous studies have provided valuable insights into designing better smart homes. Previous studies have commonly argued that strengthening the benefits of smart home adoption and removing barriers are effective in designing well-integrated technologies in residential environments and providing direct benefits to end users [3,10,14]. Overall, the impact factors of smart home adoption are not only related to the innovative nature of the system, but also to the facilitating and supportive characteristics of smart homes as an architectural environment and a sustainable service.

2.3. Design Guidelines for the Diffusion of Smart Homes

Smart homes can meet the expectations of various user groups, such as single-person households, young couples, and dual-income families [6], and are expected to contribute greatly to supporting the independent lives of the elderly and disabled, which is why it is necessary to apply flexible designs that are adjustable, easily used by anyone, and able to meet diverse needs [45]. Accordingly, some countries or states have revised the detailed criteria for housing designs based on universal design principles and sustainable strategies and suggested guidelines that strongly recommend the adoption of a smart home system to allow for Aging in Place among vulnerable groups [46–49]. These guidelines recommend the adoption of various detection devices to help prevent safety incidents.

Meanwhile, Korea has continually been seeking the diffusion of smart homes, which began with the installation of superhigh-speed information and communication networks and the supply of optical network apartments in the 1990s. The Korean government, in 2004, selected home networks as one of the 10 major growth engine industries and promoted their diffusion while also implementing the home network certification system that has focused on wire communications since 2007 [50]. The smart home design certification system, certified by the government, is implemented for the qualitative improvement of smart homes, and the evaluation criteria generally focus on wiring and network performance and whether or not smart home devices are installed [51–53]. Guidelines in Korea recommend realizing smart home compatibility through the application of standard criteria and integrations with various devices.

These guidelines are complementary to one another. For instance, the main purpose of the guidelines in Korea is to guarantee the compatibility of devices and services. For example, they recommend installing wiring on home network facilities, installing user displays such as wall pads, operating an integrated system, and interworking devices using applications. On the other hand, there is relatively little consideration of ease of use [54], which is known to be a factor that is highly influential in technology adoption. Universal design principles suggest ways to promote the accessibility of various control devices in the residential environment and advise that various services (visual notification alarms, etc.) must be easily recognizable by all users.

Moreover, guidelines present criteria that can aid the diffusion of smart home adoption. For example, Korean guidelines emphasize the importance of facility management that provides inhabitant support for technical issues, such as operational difficulty regarding high-quality service maintenance, and strongly recommend adoption of remote technical support services that easily connect users to external service providers.

As previously discussed, bearing the costs related to changing spaces also has a major impact on smart home adoption. To meet the diverse needs of users and different contexts of use, flexible service design that is easy for everyone to use, adjustable, and responsive to various needs is required [45,55]. Flexibility refers to the ability to appropriately predict and respond to changes in situations and environments [56,57]. This flexibility relates to the ability of smart home technology to adapt easily, especially at low cost, to changes in user needs [3]. Against this backdrop, some guidelines have suggested ways to promote the flexibility of residential space in relation to easily adapting to changes in demand. For example, it is recommended to adequately arrange communication and power supply points, such as electricity, phone, and power outlets, switches, and sockets, to allow for changes in furniture layout and potential service expansions in the future; the application of a flexible floor plan that allocates available space is also recommended.

In sum, these guidelines were developed for different purposes, such as for government legislation, market characteristics, and intrinsic design principles, but they all provide criteria that can help to increase utility and secure the sustainability of the components of smart homes (wiring, power supply units, control devices, user displays, wired/wireless networks, integrated systems, building equipment, home appliances, installation space, etc.), thereby suggesting comprehensive spatial design strategies that can lead to more widespread smart home adoption.

3. Methodology

3.1. Factor Generation

A literature review was conducted to determine the design factors affecting smart home adoption. The scope of the literature review included traditional smart home adoption studies and multinational smart home design guidelines as an exploratory approach for the generation of factors. As a result, initial factors were generated, namely connectivity, standardization, ease of use, integration, service scalability, the scalability of the technology, variability, adjustability, polysensory design, diversity, real-time performance, automaticity, contextuality, controllability, and reliability (Table 1). In this process, some factors were revised or merged with others. For example, ‘mobility’ of smart homes was integrated with the ‘real time’ factor, considering that it is the same as providing real-time service anytime and anywhere.

Table 1. Results of the literature review conducted for factor generation.

No.	[46]	[47]	[48]	[49]	[51]	[52]	[31]	[16]	[28]	[32]	[18]	[17]	[15]	[29]	Selection Result	Code
1	○	○	○	○	○			○	○		○	○		○	Selected	CSP
2	○	○			○		○			○					Selected	CM
3	○		○	○	○										Selected	CSE
4	○		○	○	○										Selected	FT
5								○	○			○			Selected	CT
6	○	○		○	○	○	○			○		○	○		Selected	ASP
7	○	○			○		○	○	○						Selected	AU
8	○				○										Selected	FU
9	○			○	○										Selected	FSE
10						○									Selected	FSP
11	○		○	○						○					Integrated with 'real time'	
12						○	○		○	○					Selected	AM
13									○	○	○	○	○		Merged with 'reliability'	
14	○	○			○			○	○		○				Selected	CU
15						○									Selected	FM
16					○										Selected	AT
17		○			○										Selected	ASE

The initial factors were then specified based on the literature review. For example, 'connectivity' is a factor related to technological compatibility and can be achieved by functionally connecting smart devices with software and hardware (e.g., software and applications, smartphones, tablets, PCs) or through integrated control of the residential environment based on external service connections [17,18,58,59]. Through this process, 46 factors were selected. Focus group interviews with researchers and members of academia (professors and doctoral students) were then conducted to evaluate the suitability of the selected factors. As a result, 12 out of the 46 factors were revised and 5 were merged with other factors or deleted, ultimately deriving 41 factors (Table 2).

Table 2. Evaluation tool.

No.	Variables	Item	Description
1	CT1	Apps for smart devices	Apps (applications) for smart devices that can control smart home devices or check the status information of the devices must be provided.
2	CT2	IoT connection scalability	Apps (applications) for smart devices that control at least 5 devices (products) made by different manufacturers or that check status information must be provided.
3	CSP1	Adequate place to install the power supply	All power outlets and power supplies must be located in adequate places so that they are easy to use and the arrangement style, installation location, design, style, and accessories must be consistent throughout the entire residential space.
4	CSP2	Installation of network devices that do not hinder network performance	Hub location, spatial structure, and materials must not hinder WiFi performance (e.g., hub layout considers WiFi range, jammers and interfering substances are removed, etc.).
5	CSP3	Standardized wiring performance	Network facilities must use at least UTP Cat 5e 4P * 1 wiring or power line modems and must consider the universal local network performance (LAN, BAN, PAN, etc.) of general small homes.
6	CSE1	Place to install network facilities	Smart homes must consider the installation of smart home devices that may be added in the future and must thus be designed with empty joints to connect to power and data sources in major locations such as windows and doors.
7	CSE2	Design of accessible storage spaces for network facilities	Storage spaces with a power supply unit that are accessible and have ventilation must be provided to accommodate the hubs for various smart devices.
8	CU1	Proper form and installation method of the switches	All types of switches (such as for lighting, security systems, heating systems, etc.) must be in the form of toggles, lockers, or push button switches and they must be easily recognizable and visually contrast with the surrounding surface.

Table 2. *Cont.*

No.	Variables	Item	Description
9	CU2	Ease of use and manipulability of switches and devices	All switches, power outlets, sockets, and other controlling devices must be easily reached and manipulated with one hand.
10	CU3	Form and installation location of the warning system	The control box and panels for the warning system must be installed in places that are accessible to anyone.
11	CM1	Operation of an integrated system	An integrated management system must be provided to synchronize and optimize operations with various smart devices and systems.
12	FT1	Sufficient number of power outlets	A sufficient number of power outlets must be arranged in major spaces considering the layout of furniture and home appliances that may be added later.
13	FT2	Installation of the power supply unit	Various types of power supply units and data circuits must be installed at the entrance, above or next to the window, or on the baseboard to facilitate the installation of various automatic devices (automatic curtain/blind opening systems, etc.) in the future.
14	FSP1	Use of modular furniture	Modular furniture must be actively used, making it possible to easily remove or modify individual components so as to change the location of the furniture later.
15	FSP2	Preparation for remodeling	Spaces must be planned to facilitate remodeling.
16	FSP3	Response to change in inhabitant lifecycle	The living space must be designed to easily change and expand later.
17	FSE1	Adjustable lighting	The lighting system and brightness can be adjusted to multiple levels through an adjustable system such as a timer.
18	FU1	Polysensory warning systems	All warning systems must be easily recognizable and provide both auditory and visual signals at the same time.
19	FU2	Use of braille signs	Braille signs must be used on remote control switches for various home appliances such as washers, dishwashers, dryers, cookers, microwaves, and boilers.
20	FU3	Voice recognition controller	Devices must be used to directly or indirectly control smart home devices through the reception of audio signals.
21	FM1	Diversity of the integrated system	The integrated system must be interworked with various systems in the residential environment in order to support integrated management.
22	FM2	Diversity of operation and maintenance duties	Operation and maintenance duties must be led by management in various areas of the residential environment in order to efficiently and economically operate and manage the building.
23	FM3	Control and monitoring level	There must be a control and monitoring system for multiple facilities to ensure efficient maintenance and management (e.g., cooling and heating facilities, water supply facilities, firefighting and disaster prevention facilities, etc.).
24	AT1	Interactive monitoring and support service	Real-time interactive monitoring and support services must be provided.
25	AT2	Real-time management of the integrated system server	Real-time measures must be supported on-site by enabling the manager to easily monitor the condition of the server on the web or via an application.
26	ASP1	Cooking equipment anomaly detection and automatic shutoff	A cooking equipment anomaly detector (heat and smoke detection, etc.) and automatic shutoff device must be installed.
27	ASP2	Leakage detection and automatic shutoff	A flood sensor and automatic shutoff valve must be installed.
28	ASP3	Gas detection and automatic shutoff	A gas sensor and automatic shutoff valve must be installed.
29	ASP4	Automatic lighting control	A mobile sensor or bed pressure mat that automatically turns on the light at night must be installed for the safety of elderly and vulnerable individuals.
30	ASP5	Environment detection	At least one type of sensor must be installed (such as a pollutant sensor, temperature and humidity sensor, or CO_2 sensor) to improve the living space, and the environmental information must be provided to the inhabitants.
31	ASP6	Standby power supply system	A system must be installed that protects home network facilities by supplying an emergency power source when the power supply is cut off.

Table 2. *Cont.*

No.	Variables	Item	Description
32	ASP7	Standby power cutoff devices	A standby power cutoff plan must be made for efficient and safe energy use (e.g., installation of standby power automatic shutoff power outlets, standby power cutoff switches).
33	ASP8	Electricity consumption data management	A system to send electricity consumption data to users and manage the data (user displays, etc.) must be installed to prevent electrical safety hazards (such as an overcurrent or leakage current) and support easy power management.
34	ASP9	Electronic security system	In case there is an emergency such as intrusion or fire, there must be a system that automatically detects and sends a signal to the manager.
35	ASE1	Securement of safety in wet areas	Safety incidents that could occur in the bathroom, restroom, and laundry room must be prevented.
36	ASE2	Safety management of bedroom occupants	An infrared fall detection system and emergency alarm must be installed to automatically detect and report safety incidents relating to vulnerable groups.
37	ASE3	Automatic/remote-controlled kitchen appliances	Remote-controlled kitchen appliances (smart ovens, smart microwaves, etc.) must be installed for remote use and monitoring.
38	AU1	Front door open/close detection and camera	A front door open/close sensor and front door camera must be installed to manage the opening and closing of the front door and check visitors.
39	AU2	Home viewer camera	Home viewer cameras must be installed to check real-time videos of the residential space in order to detect intruders and keep an eye on companion animals and children.
40	AM1	Antivirus tool and security for the server	Antivirus and security functions must be inspected for the security of integrated system servers and protection against viruses.
41	AM2	Quality level of facility management organization members	The quality level of the facility management organization and its members must be maintained for efficient maintenance.

3.2. Factor Refinement

A user survey was conducted to refine the generated factors.

3.2.1. Subjects of Investigation

The survey was conducted on 250 adults aged 19 and above through a specialized online survey company in Korea in 2021. In particular, to review the validity of design elements, samples were collected from employees in industries related to smart homes, such as manufacturing, construction and architectural design, information and communications, and science and technical services industries. At least 200 samples are conventionally recommended for factor analysis, and an adequate ratio of sample size and measured variables is 5:1 or above [60,61]. The adequate sample size for 41 factors is N = 205, and thus the total number of samples in this survey was adequate.

3.2.2. Evaluation Tool

This study extracted factors through a literature review and researchers reviewed and included them as part of the evaluation tool for the survey. The extracted design elements were designed to rate importance on a 5-point Likert scale (1 = not at all important, 5 = very important). All respondents were asked to rate the importance of each factor based on the following assumptions: "If my home is a smart home" or "I hope my home changes this way".

Moreover, for analysis of descriptive statistics, the demographic characteristics of users (e.g., gender, age, average income, occupation and work period, education level) and smart home service usage experiences were collected. The demographic characteristics and general matters are measured on a nominal scale.

3.2.3. Data Collection and Analysis Method

The survey was conducted as an anonymous online survey through a specialized survey company. The questionnaire was distributed online and the respondents voluntarily participated and submitted their responses. The survey was approved by the Institutional Review Board, and written consent was obtained from all respondents. The respondents were provided with a detailed explanation of smart homes and each survey item. The survey ended when the total number of responses reached the target, and the collected data were used in statistical analysis. All surveys underwent data cleaning to eliminate incomplete or poor responses. Insincere responses that were completed within a much shorter time frame than average or where the same response to all items was recorded were eliminated. The data collected from the survey were used in statistical analysis using IBM SPSS Statistics ver. 20.0 (IBM, Chicago, IL, USA) and JAMOVI ver. 1.6.23 (The jamovi project, Sydney, Australia).

4. Results

4.1. Demographic Characteristics of Survey Participants

The demographic characteristics of respondents are as shown in Table 3. Among the respondents, 60% were men ($N = 150$) and 40% were women ($N = 100$). Further, 114 respondents were aged 31–40 (45.6%), followed by 25 aged 21–30 (10.0%), 75 aged 41–50 (30.0%), 27 aged 51–60 (10.8%), and 9 aged 61 and above (3.6%); none of the respondents were under 20 years old. The average monthly income of paid workers in Korea as of 2018 was KRW 2.97 million (Statistics Korea 2020), and 143 respondents (57.2%) were earning between KRW 2 million and KRW 4 million a month, followed by 23 (9.2%) earning less than KRW 2 million, 51 (20.4%) earning between KRW 4 million and KRW 6 million, and 33 (13.2%) earning KRW 6 million or more. Regarding occupation, samples were collected from those involved in industries related to smart homes based on the aforementioned purpose, and there were 50 respondents in manufacturing, 50 in construction and architectural design, 50 in information and communications, 50 in science and technical services, and 50 in other types of business. As for work period, 8 respondents had worked for (3.2%) less than 1 year, 47 (18.8%) had worked for between 1 and 4 years, 85 (34.0%) had worked for between 4 and 10 years, 85 (34.0%) had worked for between 10 years and 20 years, 23 (9.2%) had worked for between 20 and 30 years, and 2 (0.8%) had worked for 30 years or more. The college entrance rate in Korea as of 2018 was 69.7% [62], and 83.2% ($N = 208$) of all respondents were college (university) graduates, followed by 26 who were high school graduates (10.4%), and 16 who were graduate students or higher (6.4%). Only 6.8% ($N = 17$) responded that they had used or were currently using related services.

Table 3. Demographic characteristics of the respondents.

Variable		N	%
Gender	Male	150	60.0
	Female	100	40.0
Age	21–30	25	10.0
	31–40	114	45.6
	41–50	75	30.0
	51–60	27	10.8
	61 or above	9	3.6
Income level	Less than KRW 2 million	23	9.2
	Between KRW 2 million and KRW 4 million	143	57.2
	Between KRW 4 million and KRW 6 million	51	20.4
	KRW 6 million or more	33	13.2
Occupation	Manufacturing of electrical equipment and home devices	50	20.0
	General construction, specialized construction (electrical/communications work, building facility installation, etc.), and architectural design	50	20.0
	Information and communications (such as computer programming, system integration and management, information services, etc.)	50	20.0
	Specialized science and technical services (R&D, specialized services, building techniques, engineering, other science and technical services)	50	20.0
	Other types of business not included above	50	20.0

Table 3. *Cont.*

Variable			N	%
Work period		Less than 1 year	8	3.2
		Between 1 and 4 years	47	18.8
		Between 4 and 10 years	85	34.0
		Between 10 and 20 years	85	34.0
		Between 20 and 30 years	23	9.2
		30 years or more	2	0.8
Education level		Up to high school	26	10.4
		College (university) graduate	208	83.2
		Graduate school or higher	16	6.4
Usage experience	Never experienced	Do not know at all	9	3.6
		Know a little	74	29.6
		Know in general	96	38.4
		Know very well	54	21.6
	Have experience	Have used or is currently using	17	6.8

4.2. Factor Refinement and Reliability Testing

Exploratory factor analysis was conducted to reduce dimensionality and extract characteristics by grouping mutually independent factors from the 41 variables extracted. The principal component analysis (PCA) model was used for factor analysis, and varimax rotation was used for rotation. The cumulative explanatory power of the initial model was 42.332%, the KMO (Kaiser–Meyer–Olkin test) measurement was 0.956, and the chi-squared approximation of Bartlett's sphericity test was 5880.339 ($p < 0.001$). However, in some variables, factor loadings and commonality failed to reach the threshold suggested in basic research [63], and thus factors with factor loadings and commonality above 0.4 and 0.5 were selected for reanalysis. Finally, 3 variables (CU2, AT2, AU2) were eliminated and 38 variables were loaded on the 6 factors. The cumulative explanatory power of the revised model was 60.452%, the KMO measurement was 0.957, and the chi-squared approximation of Bartlett's sphericity test was 5431.180 ($p < 0.001$), thereby showing suitability.

Reliability was reviewed based on Cronbach's α which is demonstrated by obtaining similar results when repeatedly measuring the same items. The results show that the reliability measures of all factors exceeded the threshold of 0.6 (range 0.766–0.914) [64].

Confirmatory factor analysis (CFA) was then performed to verify the construct validity of the revised model. The results showed that $\chi 2$/df was 1150/650 = 1.769, which is lower than 3, thus proving the model to be suitable; the goodness-of-fit index was CFI = 0.901, TLI = 0.893, RMSEA = 0.0555, and SRMR = 0.0502, exceeding the general level of fit at CFI $\geq$ 0.9, RMSEA < 0.08, and SRMR < 0.08 [65,66]. The model is comprised of six dimensions, namely, creating an automated residential environment, service scalability and diversity, increasing accessibility, lifestyle balance, securing long-term safety in use, and reducing environmental load, and the explanatory power and eigenvalue of each structure are shown below (Table 4).

Table 4. Factor analysis results.

Constructs	Variables	PCA			CFA			Reliability
		Factor Loading	Eigenvalue	Percentage of Variance Explained	Factor Loading	*p*-Value	CITC	Cronbach's α
Factor 1	ASP1	0.773	16.319	14.848%	0.786	<0.001	0.899	0.914
	ASP3	0.726			0.777	<0.001	0.900	
	ASP9	0.720			0.808	<0.001	0.899	
	ASP2	0.679			0.710	<0.001	0.906	
	AU1	0.638			0.740	<0.001	0.904	
	AM1	0.535			0.709	<0.001	0.906	
	CSP1	0.525			0.690	<0.001	0.907	
	FM3	0.507			0.706	<0.001	0.907	
	FU1	0.492			0.714	<0.001	0.907	

Table 4. *Cont.*

Constructs	Variables	PCA			CFA			Reliability
		Factor Loading	Eigenvalue	Percentage of Variance Explained	Factor Loading	*p*-Value	CITC	Cronbach's α
Factor 2	CSP3	0.664	1.790	12.275%	0.662	<0.001	0.887	0.897
	FM2	0.585			0.664	<0.001	0.888	
	CSE1	0.568			0.670	<0.001	0.887	
	CT2	0.554			0.724	<0.001	0.884	
	FT2	0.542			0.680	<0.001	0.887	
	CT1	0.521			0.707	<0.001	0.886	
	AM2	0.493			0.681	<0.001	0.887	
	CU3	0.482			0.630	<0.001	0.891	
	FM1	0.473			0.729	<0.001	0.886	
	CSP2	0.411			0.684	<0.001	0.889	
Factor 3	FU2	0.731	1.439	10.491%	0.623	<0.001	0.824	0.844
	ASE2	0.658			0.713	<0.001	0.814	
	AT1	0.641			0.608	<0.001	0.826	
	FU3	0.563			0.668	<0.001	0.818	
	ASE3	0.447			0.677	<0.001	0.824	
	ASP5	0.416			0.637	<0.001	0.823	
	ASP4	0.404			0.650	<0.001	0.827	
Factor 4	CU1	0.600	1.247	9.494%	0.666	<0.001	0.723	0.779
	FSE1	0.572			0.685	<0.001	0.711	
	FT1	0.556			0.655	<0.001	0.731	
	CM1	0.450			0.724	<0.001	0.736	
Factor 5	ASP6	0.634	1.141	7.049%	0.673	<0.001	0.711	0.776
	ASE1	0.563			0.741	<0.001	0.697	
	CSE2	0.511			0.644	<0.001	0.749	
	ASP7	0.441			0.673	<0.001	0.731	
Factor 6	FSP2	0.665	1.036	6.294%	0.623	<0.001	0.702	0.766
	FSP1	0.561			0.643	<0.001	0.719	
	ASP8	0.437			0.719	<0.001	0.711	
	FSP3	0.422			0.689	<0.001	0.712	

4.3. Analysis of Perceived Importance

Among the total means of the six dimensions derived from factor analysis, the highest level of importance was given to creating an automated residential environment (4.2178), which was followed by service scalability and diversity, securing long-term safety in use, lifestyle balance, reducing environmental load, and increasing accessibility (Table 5).

Table 5. Comparison of average importance by factor.

Constructs	Min	Max	Mean	SE
Creating an automated residential environment	2.00	5.00	4.2178	0.61424
Service scalability and diversity	1.80	5.00	4.0848	0.56006
Increasing accessibility	2.00	5.00	3.9406	0.58941
Lifestyle balance	2.00	5.00	4.0470	0.60291
Securing long-term safety in use	2.00	5.00	4.0560	0.62243
Reducing environmental load	2.00	5.00	3.9720	0.62593

In terms of the average importance of the subfactors that formed the six dimensions, gas detection and automatic shutoff (Mean = 4.42, SE = 0.778) were highest, followed by leakage detection and automatic shutoff (Mean = 4.34, SE = 0.745), cooking equipment anomaly detection and automatic shutoff (Mean = 4.30, SE = 0.818), electronic security systems (Mean = 4.26, SE = 0.812), and antivirus tool and security for the server (Mean = 4.26, SE = 0.835) (Table 6). On the other hand, safety management of bedroom occupants (Mean = 3.87, SE = 0.878), interactive monitoring and support service (Mean = 3.87, SE = 0.757), and use of braille signs (Mean = 3.82, SE = 0.880) recorded relatively low average importance (Table 6).

Table 6. Ranking of perceived importance by factor.

Constructs	Variable		Mean	SE
Creating an automated residential environment	ASP3	Gas detection and automatic shutoff	4.42	0.778
	ASP2	Leakage detection and automatic shutoff	4.34	0.745
	ASP1	Cooking equipment anomaly detection and automatic shutoff	4.30	0.818
	ASP9	Electronic security system	4.26	0.812
	AM1	Antivirus tool and security for the server	4.26	0.835
	AU1	Front door open/close detection and camera	4.19	0.777
	FM3	Control and monitoring level	4.14	0.766
	CSP1	Adequate place to install the power supply	4.07	0.806
	FU1	Polysensory warning systems	3.99	0.845
Service scalability and diversity	CSP2	Installation of network devices that do not hinder network performance	4.23	0.767
	CT1	Apps for smart devices	4.18	0.756
	CT2	IoT connection scalability	4.13	0.767
	FM1	Diversity of the integrated system	4.10	0.767
	AM2	Quality level of facility management organization members	4.10	0.760
	FM2	Diversity of operation and maintenance duties	4.07	0.818
	FT2	Installation of the power supply unit	4.05	0.795
	CSP3	Standardized wiring performance	4.04	0.757
	CSE1	Place to install network facilities	3.98	0.781
	CU3	Form and installation location of the warning system	3.97	0.799
Increasing accessibility	ASE3	Automatic/remote-controlled kitchen appliances	4.09	0.828
	FU3	Voice recognition controller	4.00	0.821
	ASP4	Automatic lighting control	3.97	0.765
	ASP5	Environment detection	3.96	0.803
	ASE2	Safety management of bedroom occupants	3.87	0.878
	AT1	Interactive monitoring and support service	3.87	0.757
	FU2	Use of braille signs	3.82	0.880
Lifestyle balance	CM1	Operation of an integrated system	4.15	0.723
	FT1	Sufficient number of power outlets	4.06	0.763
	CU1	Proper form and installation method of the switches	4.00	0.809
	FSE1	Adjustable lighting	3.97	0.811
Securing long-term safety in use	ASP6	Standby power supply system	4.13	0.808
	ASP7	Standby power cutoff devices	4.12	0.801
	ASE1	Securement of safety in wet areas	4.04	0.808
	CSE2	Design of accessible storage spaces for network facilities	3.93	0.801
Reducing environmental load	FSP3	Response to change in inhabitant lifecycle	4.04	0.818
	ASP8	Electricity consumption data management	3.99	0.797
	FSP2	Preparation for remodeling	3.97	0.781
	FSP1	Use of modular furniture	3.88	0.868

The means of importance by dimension are as follows. First, in **creating an automated residential environment**, gas detection and automatic shutoff showed the highest mean (4.42), followed by leakage detection and automatic shutoff, cooking equipment anomaly detection and automatic shutoff, electronic security system, antivirus tool and security for the server, front door open/close detection and camera, control and monitoring level, and adequate place to install the power supply. As shown in Figure 1, more than 70% of the respondents said all variables were important or very important, indicating that securing automation and the safety of residents are important aspects of smart homes.

Regarding **service scalability and diversity**, installation of network devices that do not hinder network performance showed the highest mean (4.23), followed by apps for smart devices, IoT connection scalability, diversity of the integrated system, quality level of facility management organization members, diversity of operation and maintenance duties, installation of the power supply unit, standardized wiring performance, place to install network facilities, and form and installation location of the warning system. Most respondents responded that each variable was important or very important (Figure 2).

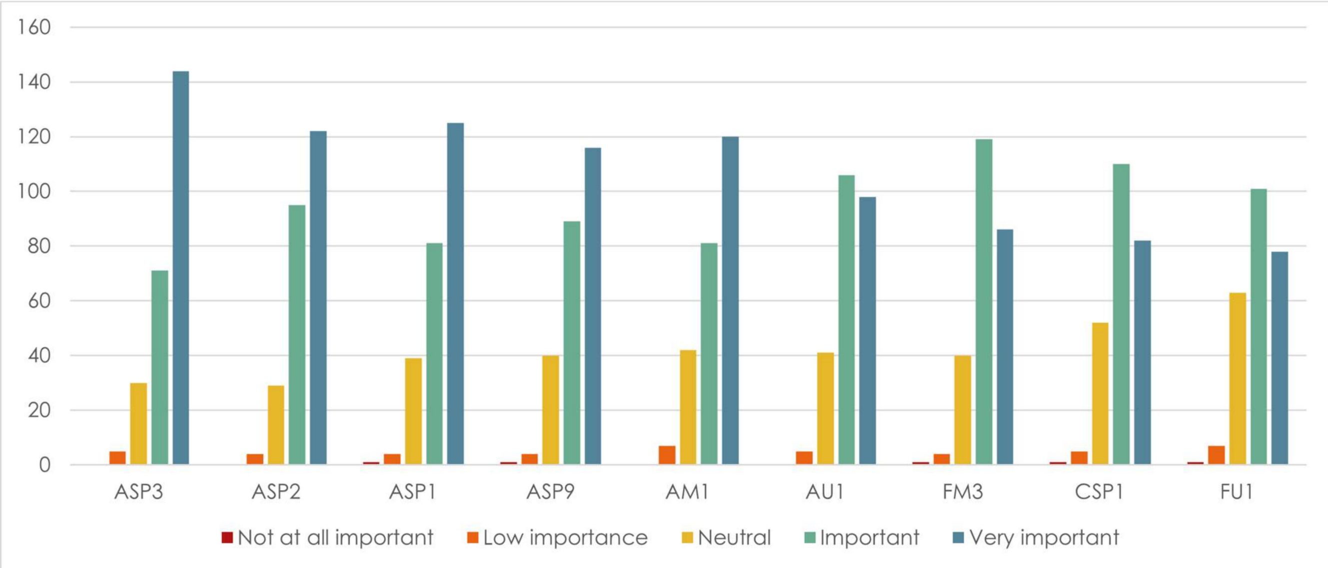

Figure 1. Perceived importance of creating an automated residential environment.

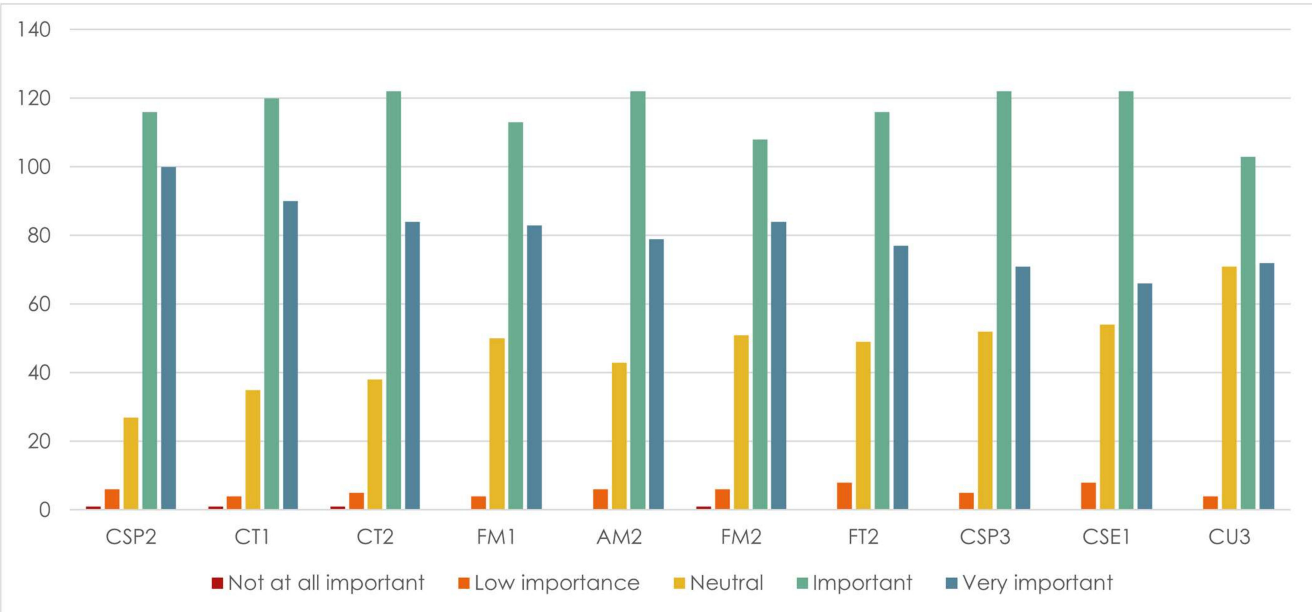

Figure 2. Perceived importance perception of **service scalability and diversity**.

Regarding **increasing accessibility**, automatic/remote-controlled kitchen appliances showed the highest importance (4.09), followed by voice recognition controller, automatic lighting control, environment detection, safety management of bedroom occupants, interactive monitoring and support service, and use of braille signs. For the five variables other than safety management of bedroom occupants and use of braille signs, 70% of the respondents responded that they were important or very important (Figure 3).

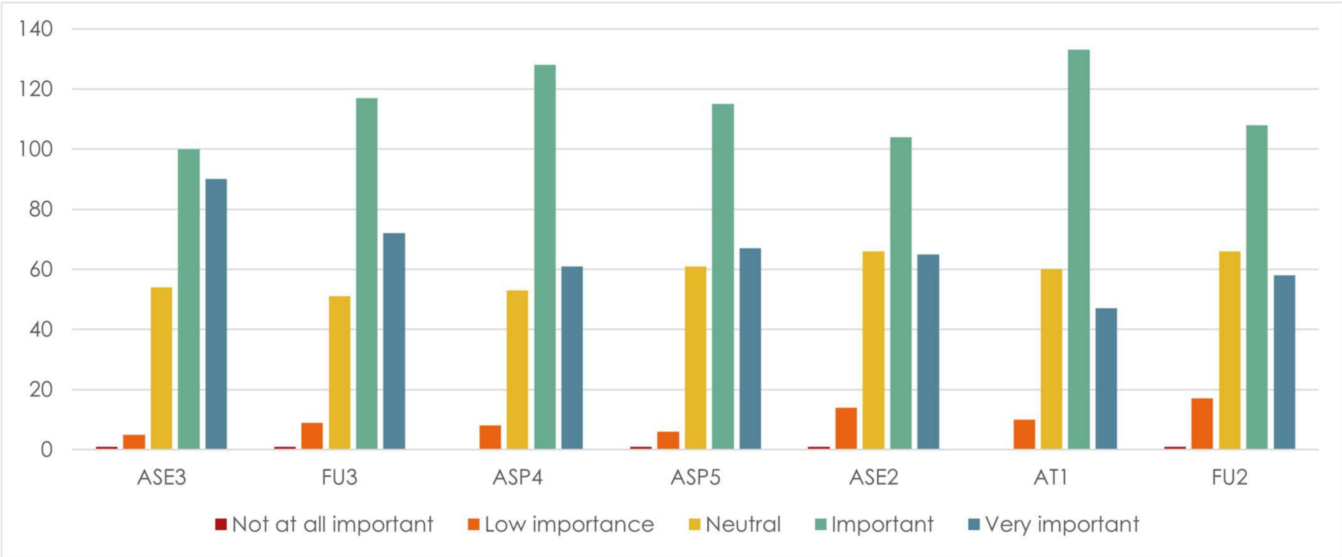

Figure 3. Perceived importance of **increasing accessibility**.

Regarding **lifestyle balance**, operation of an integrated system showed the highest mean (4.155), followed by sufficient number of power outlets, proper form and installation method of the switches, and adjustable lighting. Additionally, 70% of the respondents said all variables were important or very important (Figure 4).

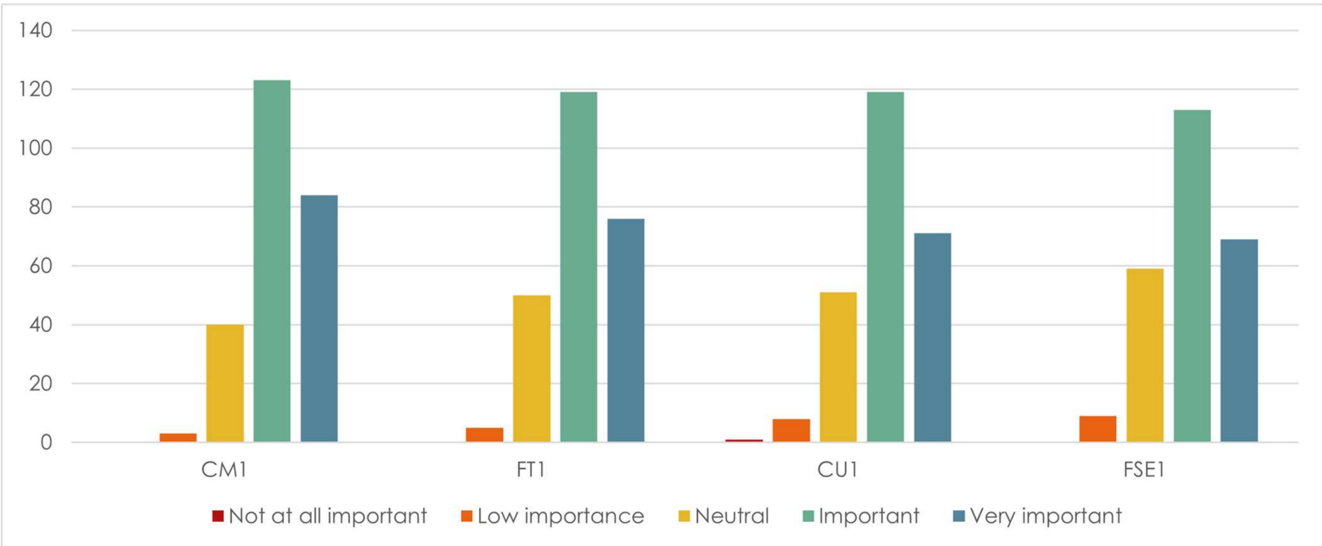

Figure 4. Perceived importance of **lifestyle balance**.

Regarding **securing long-term safety in use**, standby power supply system showed the highest importance (4.13), followed by standby power cutoff devices, securement of safety in wet areas, and design of accessible storage spaces for network facilities. Additionally, 70% of the respondents responded that all variables were important or very important (Figure 5).

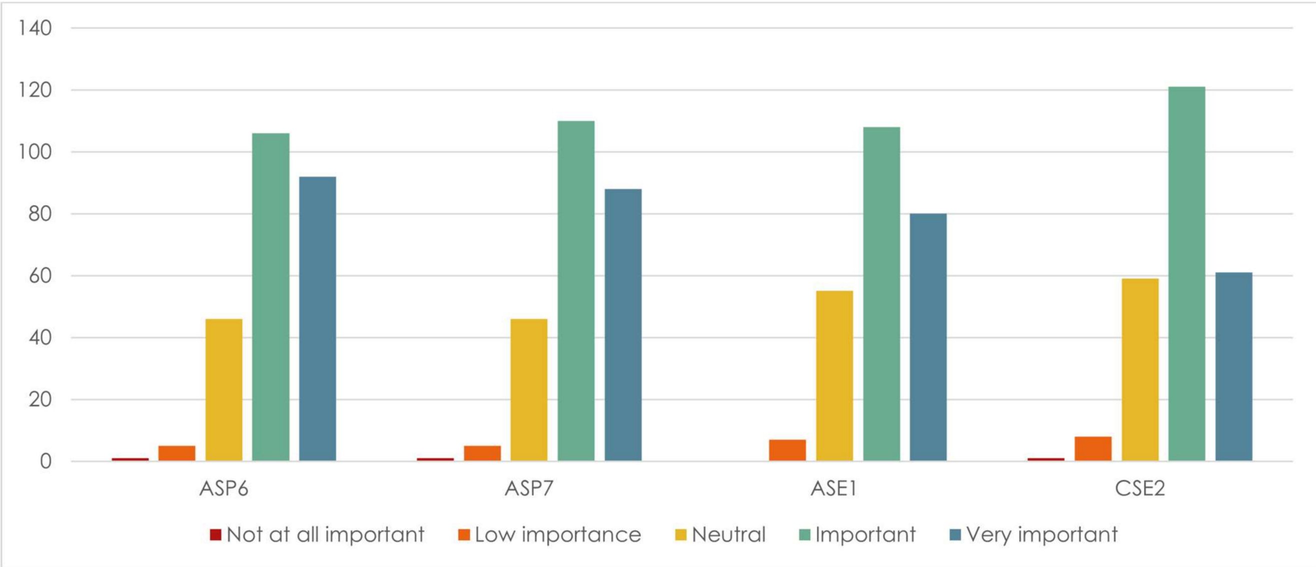

Figure 5. Perceived importance of **securing long-term safety in use**.

Finally, regarding **reducing environmental load**, response to change in inhabitant lifecycle showed the highest mean (4.04), followed by electricity consumption data management, preparation for remodeling, and use of modular furniture. Additionally, 70% to 80% of the respondents responded that each variable was important or very important (Figure 6).

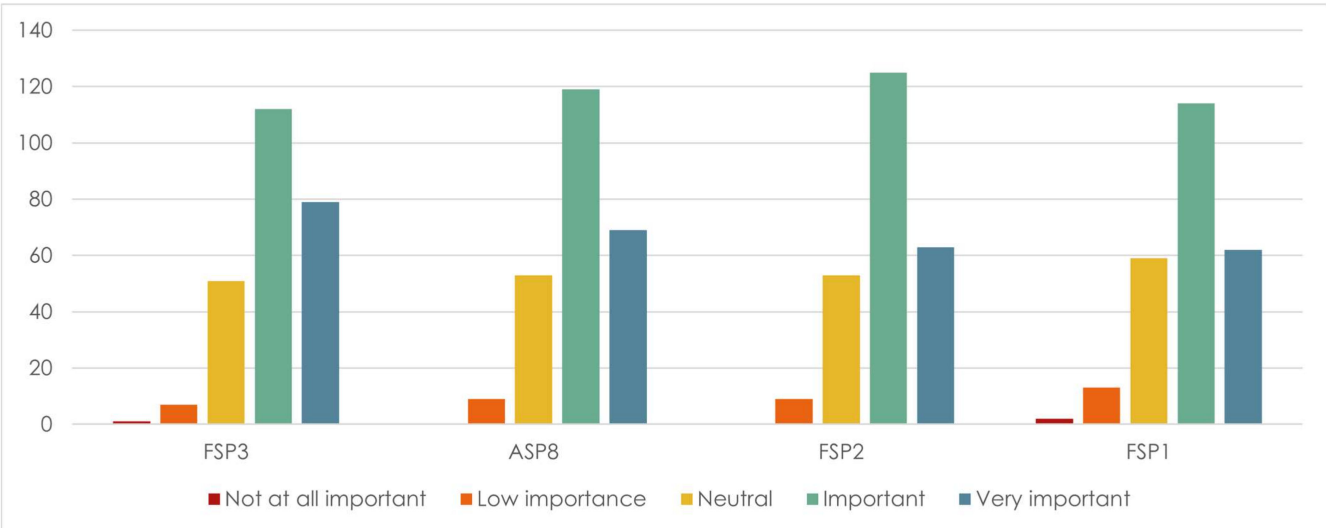

Figure 6. Perceived importance of **reducing environmental load**.

4.4. Effect of Demographic Characteristics on Perceived Importance

An independent samples *t*-test and one-way ANOVA were conducted to review how demographic characteristics of the respondents affected perceived importance. Ex-post analysis was conducted to identify the specific mean difference between groups in the one-way ANOVA, and Dunnett T3 and Scheffe tests were also used according to the assumption of equal variances for each variable.

The results of analysis are as follows (Table 7). For **creating an automated residential environment**, only usage experience had a significant effect on perceived importance. Perceived importance of the group without usage experience was lower than the mean of the group with usage experience to a statistically significant degree ($p < 0.001$).

Table 7. Comparative analysis of means by factor (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Variables	N	Factor 1		Factor 2		Factor 3		Factor 4		Factor 5		Factor 6	
		Mean	Value	Mean	Value	Mean	Value	Mean	Value	Mean	Value	Mean	Value
Gender													
Male	150	4.2126	−0.163	4.1227	1.245	3.9333	0.813	4.0717	0.764	4.0533	−0.083	3.9850	0.402
Female	100	4.2256		4.0280		3.9514		4.0100		4.0300		3.9525	
Age													
21–30	25	4.2133	0.738	4.0360	0.999	4.0457	0.821	4.0300	1.320	4.0800	0.238	3.9900	0.683
31–40	114	4.1959		4.0737		3.9148		3.9803		4.0417		3.9276	
41–50	75	4.2089		4.0613		3.9086		4.0767		4.0300		3.9633	
51–60	27	4.2551		4.1259		3.9471		4.1481		4.1204		4.0926	
61 or above	9	4.4691		4.4333		4.2222		4.3889		4.1944		4.1944	
Income level													
Less than KRW 2 million	23	4.1256	0.983	3.9130	4.156 **	3.7950	1.110	3.7935	3.432 *	3.9348	0.388	3.7717	1.214
Between KRW 2 million and KRW 4 million	143	4.1888		4.0350		3.9261		4.0122		4.0752		3.9895	
Between KRW 4 million and KRW 6 million	51	4.2418		4.1176		3.9580		4.1078		4.0343		3.9412	
KRW 6 million or more	33	4.3704		4.3697		4.0779		4.2803		4.0909		4.0833	
Occupation													
Manufacturing of electrical equipment and home devices	50	4.1711	0.271	4.0760	0.565	3.8743	1.557	3.9950	0.935	3.9600	0.924	3.8850	0.935
General construction, specialized construction, and architectural design	50	4.2111		4.1140		4.0057		4.1100		4.0150		4.0550	
Information and communications (such as computer programming, system integration and management, information services, etc.)	50	4.2000		4.1080		4.0457		4.0750		4.1150		3.9900	
Specialized science and technical services	50	4.2933		4.1400		3.9829		4.1250		4.1700		4.0500	
Other types of business not included above	50	4.2133		3.9860		3.7943		3.9300		4.0200		3.8800	
Work period													
Less than 1 year	8	4.2361	1.082	4.2375	1.612	4.1607	1.568	4.1563	2.643 *	4.2500	1.014	4.0625	0.506
Between 1 and 4 years	47	4.0591		3.9723		3.9726		3.9043		4.0798		3.9628	
Between 4 and 10 years	85	4.2026		4.0435		3.8185		3.9588		3.9500		3.9382	
Between 10 and 20 years	85	4.2837		4.1035		3.9681		4.1176		4.0853		3.9500	
Between 20 and 30 years	23	4.3188		4.3043		4.1242		4.3043		4.2174		4.1522	
30 years or more	2	4.5556		4.5500		4.2143		4.7500		4.1250		4.1250	
Education level													
High school graduate	26	4.3205	0.736	4.0654	0.228	3.9121	0.623	4.0481	1.135	4.1058	0.723	3.9615	0.178
College (university) graduate	208	4.1966		4.0803		3.9320		4.0300		4.0373		3.9663	
Graduate school or higher	16	4.3264		4.1750		4.0982		4.2656		4.2188		4.0625	
Experience													
Never experienced	233	4.1888	6.223 ***	4.0536	8.713 ***	3.9154	2.528 *	4.0161	6.292 ***	4.0365	2.762 *	3.9496	2.112 *
Have experience	17	4.6144		4.5118		4.2857		4.4706		4.3235		4.2794	

For **service scalability and diversity**, only income level and usage experience had a significant effect on perceived importance. The average perceived importance of the group earning less than KRW 2 million a month and the group earning between KRW 2 million and KRW 4 million was lower than the group earning KRW 6 million or more to a statistically significant degree ($p < 0.01$). Moreover, perceived importance for the group without service usage experience was significantly lower than that of the group with usage experience ($p < 0.001$).

For **increasing accessibility**, only usage experience showed a statistically significant correlation. Perceived importance for the group without service usage experience showed a lower mean than the group with service usage experience ($p < 0.05$).

For **lifestyle balance**, income level, work period, and usage experience had a significant effect on perceived importance. Perceived importance for the group earning less than KRW 2 million a month was lower than the group earning KRW 6 million or more ($p < 0.05$), and perceived importance for the group without service usage experience was significantly lower than that of the group with service usage experience ($p < 0.001$). Meanwhile, as a result of the ex-post analysis, the inter-group difference in relation to work period failed to show statistical significance.

For **securing long-term safety in use**, only usage experience showed statistical significance. Perceived importance for the group without service usage experience showed a lower mean than the group with service usage experience ($p < 0.05$).

Likewise, for **reducing environmental load**, only usage experience showed a statistically significant correlation ($p < 0.05$), and perceived importance for the group without service usage experience was lower than the group with service usage experience.

5. Discussion

5.1. Structuralizing Smart Home Design Factors to Promote Adoption

5.1.1. Creating an Automated Residential Environment

Automatically detecting and blocking risks (such as gas leaks, water leaks, fire, intrusion, etc.) is seen as the most typical benefit of a smart home. Therefore, smart homes must provide an automated, convenient, and safe residential environment based on adequate control and monitoring of facilities in a residential space, including systems responsible for cooling, heating, water supply, firefighting, and disaster prevention. The safety of spaces vulnerable to gas leaks, water leaks, and fire, such as the kitchen, must be managed with sensors and automatic shutoff devices. Doors and windows are recommended as locations for the installation of sensors and security cameras that can be used to detect intrusion and provide automatic reporting. The management server of the smart home system must be secure at all times in order to prevent external threats such as hacking, and all warning systems that provide notifications in response to dangers in the residential environment must allow for both audio and visual signals so that anyone can easily recognize them (audio alarms generally must not exceed 120 dB, and visual alarms must use a flasher between 2 Hz and 4 Hz).

As pointed out by a few studies, there must be a good balance between automaticity and controllability [16,31]. Therefore, the control and monitoring of all related services should be able to be changed by the user, and the arrangement style, installation location, and design of all power supply units must be consistent throughout the entire residential space to ensure that they are highly accessible to all users (e.g., all power outlets must be installed between 450 mm and 1200 mm from the floor, and at least 500 mm away from all corners of the indoor space).

5.1.2. Guaranteeing Service Scalability and Diversity

Smart homes need to be able to adequately predict and respond to changes in the surrounding environment and possess the flexibility to make changes, which refers to being able to quickly change to a new state with minimal effort [56,57,67]. Flexibility is also related to not only the current demands of users, but also to long-term demands and potential changes in the future [68]. Moreover, flexibility can be expressed using similar terms, such as customizability, adaptability, and modifiability [56]. From the perspective of service development, a customization based on the flexibility of a technology can generate greater value by providing high-quality solutions to individual users [43]. Thus, flexibility acts as an important factor in reducing errors during use and also promotes adoption [69].

To achieve flexibility in the alteration of smart homes, it is necessary to guarantee diversity and scalability of services. To efficiently and economically manage smart homes, the integrated system must support connections to various functions of the residential space, such as entrances, energy use, safety, and facility management. The manager of the facilities and services must oversee various tasks if possible. Likewise, the practical components used to facilitate the management of smart home services must guarantee strong interoperability so that devices made by different manufacturers can easily be connected and controlled.

Network facilities, wiring, and control systems must be designed based on standardized guidelines, and there must be no hindrance to performance caused by the installation location, spatial structure of the surroundings, or materials (jammers and interfering substances, etc.). Moreover, multi-purpose data cables, power cables, and security power cables must be installed in major living spaces so that additional spurs can be created in all locations. Installing an extra power supply unit at the indoor entrance or above or next to the window will enable the installation of various new smart devices in the future (auxiliary devices for opening and closing doors, automatic curtain/blind opening systems, etc.). The installation of blanked-off connections that are connected to electricity or data sources at major points, such as windows or doors, can be an effective space design strategy for accommodating future user demands that vary depending on life cycle and lifestyle changes.

5.1.3. Increasing Service Accessibility

Smart homes improve convenience in the residential environment through remote-controlled services. In particular, the supply of smart home technology is expected to contribute greatly to enabling vulnerable groups to continue living a safe life at home [8]. Smart homes, which can easily control the components of the residential environment remotely (such as home appliances and lighting) and prevent safety incidents provide great benefits for various vulnerable groups. Thus, smart home designs must have high accessibility for all users. For example, using braille signs on major home appliances and controllers or adopting both voice recognition control and automatic detection via motion sensors can be effective in promoting accessibility for vulnerable groups.

Furthermore, accessibility and the response speed of supporting services must also be carefully considered. Generally, the intention of using a technology increases when the new technology is perceived as being easy to use [25]. In contrast, a lack of knowledge about the technology and a lack of related experience leads to a heightened perception of risk [70]. Thus, technical assistance is important for accelerating technology adoption [40,41]. Providing a technical support service in real time, based on the powerful network connectivity of a smart home, can be effective in increasing smart home adoption [10,71]. In other words, greater adoption of smart homes can be achieved by guiding users to enhance their own use of technology and by having support services that help when users face technical problems, while also ensuring that these services can be accessed quickly and easily.

5.1.4. Lifestyle Balance of Potential Users

It is important to achieve technical compatibility between devices, as the smart home market, which is growing based on individual devices, would thus reduce the associated expenses for consumers [10]. However, harmonization of the lifestyle of potential users is also an essential aspect of achieving compatibility, as the use of smart home applications involves a marked change in the familiar environment of a home [72]. As it is in human nature to maintain existing states and resist changes in behavioral patterns, it is necessary to take an approach where innovations and everyday life coexist while the expected changes in situations caused by the use of this technology are minimized [73]. Some studies have suggested methods for achieving the behavioral and spatial compatibility of smart homes. For example, Li et al. (2019) noted changes in daily life due to the effects of the form, weight, and size of a device when measuring the perceived compatibility of wearable devices [74]. Park et al. (2018) also considered some of the effects of compatibility in terms of the way users want to interact with components in their homes [28]. Therefore, compatibility can also be achieved by familiarizing users with standardized instructions or by matching the device to the lifestyles of users. These are known to have a positive effect on adoption [74,75]. This factor relates to ways of strengthening adoption through the minimization of changes in the familiar environment within the home that are caused by installing smart home technologies, and also relates to the challenge of preventing the physical form of the device and the way it interacts from being separated from the user's lifestyle [28,59,72,74]. A typical example of achieving this goal is the installation of switches and control panels at convenient locations and heights that thus facilitates the use of services in everyday life.

All types of control devices, such as lighting systems, security systems, and heating systems, must be easy to reach and use with little force (e.g., with toggles, lockers, or push button switches). Moreover, a sufficient number of power outlets must be installed in the living space (e.g., at least four dual power outlets should be installed in major living spaces [living room]) so that users can easily install and use home appliances.

This factor is also related to providing optimized services for the everyday lives and habits of users. For example, lighting must be adjustable depending on time and space (considering user lifestyle). In addition, an integrated management system that can easily synchronize and optimize installation of a new smart device or motion change must be provided to users in advance. This system must be operated without disconnection from auxiliary devices, and a backup server should be included so that user data can be constantly collected.

5.1.5. Securing Long-Term Safety in Use of Systems and Facilities

Basic facilities preventing various accidents must be established for safe and continuous use of smart home services. Many smart home devices run on battery power, and thus depletion of built-in batteries or external power supplies being shut off may cause sensor malfunction or network failure [76]. Since there is limited energy availability in smart home devices, it is important to make standby power cutoff plans to actively reduce standby power used by devices [77,78].

Smart home hubs provide intelligent control functions by connecting various devices. When the power supply and Internet are disconnected, some services cannot be provided, which puts a halt to server security, safety management, and the accident detection system, possibly causing severe problems [79].

Therefore, hubs must be located where there is good ventilation, smooth network connection, and consistent power supply. It must be possible to disguise or lock the storage space for hubs in response to various safety issues. Moreover, in case the power supply is shut off, the devices and network facilities must be protected using an uninterruptible power supply, generator, or energy storage system (ESS).

Furthermore, wet areas, such as the bathroom, restroom, and laundry room, must be designed to prevent hindrances to service quality and accuracy. For example, all walls and ceilings in the bathroom and restroom must be built with strong materials so that various devices and accessories can be installed. Moreover, bathroom floors must be designed to facilitate quick drainage in order to prevent puddles. All sensors and devices must secure long-term safety in use through tolerance toward humidity, chemicals, and physical pollutants, as well as through recovery from condensation.

5.1.6. Reducing Environmental Load

As is widely known, smart homes can reduce environmental load through efficient use of energy that is based on increased user participation and environmental friendliness [80,81]. Smart homes effectively optimize the cycle of cooling and heating and provide adequate information and control functions for users to efficiently use energy. In particular, providing detailed feedback on individual energy use is effective in reducing energy consumption [82].

5.2. Smart Home Design Strategies Considering User Perception

Previous studies have reported positive perceptions of smart home devices that can support the independence of inhabitants while guaranteeing safety and convenience [9,83]. Likewise, respondents showed relatively high interest in automated technology that prevents risk factors in the residential environment, such as gas leaks, water leaks, fire, and intrusion (Figure 7). Promoting the benefits of smart homes is an effective way of inducing user adoption, and the adoption of automation technology can therefore be considered. On the other hand, automation technology connotes perceived threats such as security threats, operation errors and suspension, privacy invasion, increased technological dependence, and the burden of expenses, which is why application of automation technology must be safe, user-friendly, and sustainable. For example, servers must ensure security at all times, and control devices must be located in a storage space that can be locked and left unaffected by the external environment without allowing for physical intrusion from the outside. Service functions must provide sufficient controllability and modifiability to users, and spaces must be flexibly designed to allow for alterations and the adoption of new automation technologies.

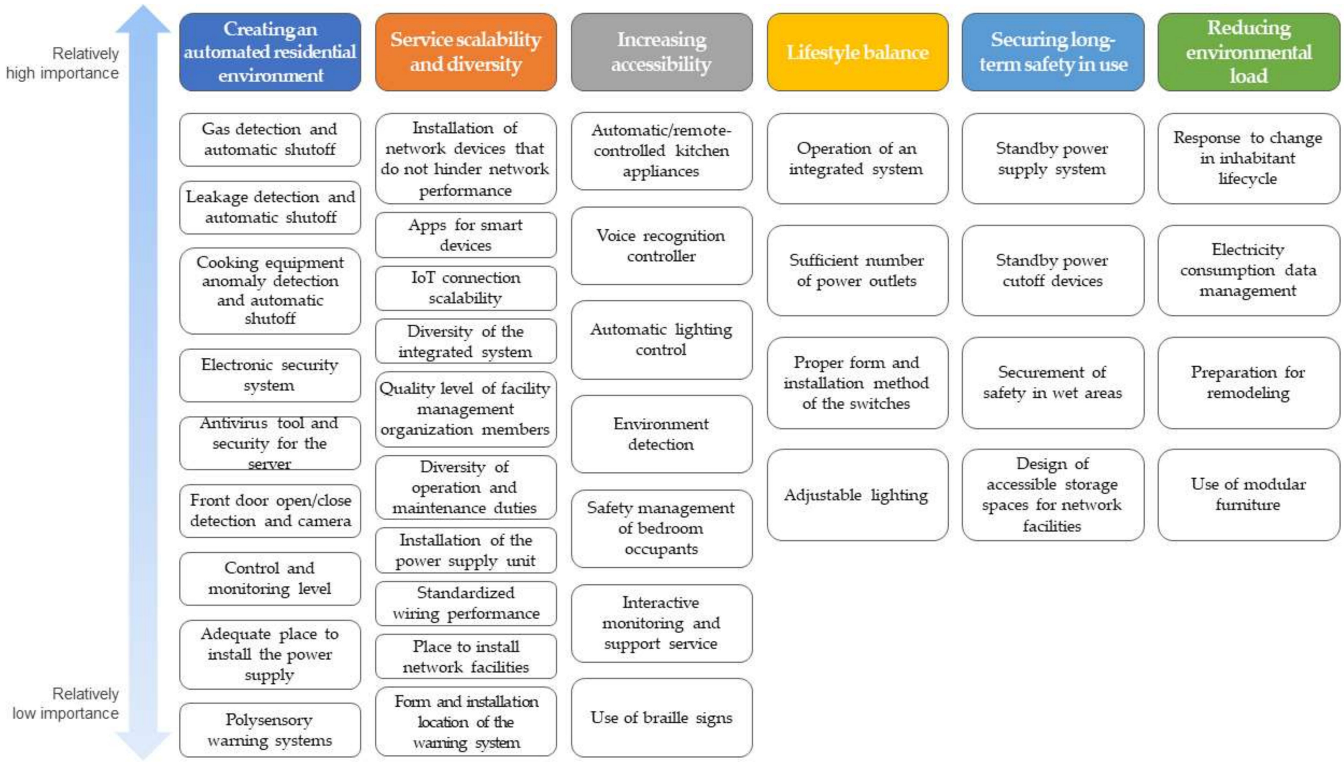

Figure 7. Relative importance of smart home design factors considering user perception.

Among the demographic characteristics of the respondents, usage experience had a significant effect on all factors. Those with usage experience or a high level of awareness about smart homes also showed higher perceived importance. Moreover, those with relatively higher income considered it important to guarantee **service scalability and diver-**

sity and maintain **lifestyle balance**. Usage experience is known to determine the attitude and perception of smart homes [29,31], and income level has a significant effect on adoption [83]. In other words, high-income early adopters that are likely to adopt smart homes want to be guaranteed flexibility, in terms of alterations, so that they can easily install and connect various devices wherever they want based on their needs. They also want the directions and services provided for all devices to be optimized for their lifestyles.

6. Conclusions and Limitations

The technology within smart homes is closely connected to the residential environment, which has a complex layer consisting of various functions, behaviors, and spatial properties. Smart homes can be widely used only when people show interest in adopting these technologies in everyday life. Thus, it is necessary to first understand user expectations and identify factors affecting smart home adoption. The major contributions of this study are as follows. First, this study structuralized smart home design factors from the perspective of promoting smart home adoption. It also integrated complementary materials, such as discourses on traditional technology adoption and smart home design guidelines, as a result of exploratory research. This study also suggested an empirical tool that contributes to the diffusion of smart home adoption by structuralizing factors based on user perception, thereby providing insight on the demands of smart home users.

Second, this study suggested sustainable values of factors affecting smart home adoption. The results of this study suggest ways of reducing environmental and economic burdens in smart homes, such as the exploration of designs that can be easily altered at low cost and with high efficiency. Moreover, based on ease of use, application of universal standards, and technical service accessibility, this study encourages various potential users (especially vulnerable groups that may face difficulty using technology) to become active users of smart homes. Diffusion of smart homes can contribute toward achieving social sustainability by supporting the ability of vulnerable groups to lead an independent life, and can also contribute to resolving their loneliness and guaranteeing their safety.

Despite these contributions, there are some limitations of this study. This study structuralized factors affecting smart home adoption based on a literature review of adoption and design guidelines and reviewed user perceptions regarding the importance of those factors; however, the effect of structuralized factors on actual usage intention has not yet been verified. Therefore, further research must perform actual verification of the selected factors. Moreover, the survey was conducted only among those living in the Republic of Korea, which has a relatively high prevalence of Internet infrastructure; therefore, the research model should be tested in a geographical context with different cultural surroundings or information and communication infrastructures in order to generalize the results. Lastly, since there was limited participation from elderly members, representation of this group is insufficient. Since smart home technology is deeply related to improving the quality of life of the elderly, it is necessary to examine differences in perception according to age groups. Differences in perception within this group between those who are relatively tech-savvy and those who are not should also be examined.

Future research should overcome these limitations and expand the findings of this study to provide a more comprehensive understanding of smart home adoption and the sustainability values of smart homes.

Author Contributions: Conceptualization, S.C.; methodology, S.C.; software, S.C.; validation, S.C.; formal analysis, S.C.; investigation, S.C.; resources, S.C.; data curation, S.C.; writing—original draft preparation, S.C.; writing—review and editing, K.N.; visualization, S.C.; supervision, K.N.; project administration, K.N.; funding acquisition, S.C. and K.N. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2021S1A5A2A01064769).

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the Institutional Review Board of Hanyang University (HYUIRB-202109-002).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: We wish to thank all the respondents who participated in the survey.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Alam, M.R.; Reaz, M.B.I.; Ali, M.A.M. A Review of Smart Homes—Past, Present, and Future. *IEEE Trans. Syst. Man Cybern. Part C (Appl. Rev.)* **2012**, *42*, 1190–1203. [CrossRef]
2. Mennicken, S.; Vermeulen, J.; Huang, E.M. From today's augmented houses to tomorrow's smart homes: New directions for home automation research. In Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing, Seattle, WA, USA, 13–17 September 2014; pp. 105–115. [CrossRef]
3. Balta-Ozkan, N.; Davidson, R.; Bicket, M.; Whitmarsh, L. Social barriers to the adoption of smart homes. *Energy Policy* **2013**, *63*, 363–374. [CrossRef]
4. Baudier, P.; Ammi, C.; Deboeuf-Rouchon, M. Smart home: Highly-educated students' acceptance. *Technol. Forecast. Soc. Chang.* **2020**, *153*, 119355. [CrossRef]
5. Friedewald, M.; Da Costa, O.; Punie, Y.; Alahuhta, P.; Heinonen, S. Perspectives of ambient intelligence in the home environment. *Telemat. Inform.* **2005**, *22*, 221–238. [CrossRef]
6. Paetz, A.-G.; Dütschke, E.; Fichtner, W. Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions. *J. Consum. Policy* **2012**, *35*, 23–41. [CrossRef]
7. Marikyan, D.; Papagiannidis, S.; Alamanos, E. A systematic review of the smart home literature: A user perspective. *Technol. Forecast. Soc. Chang.* **2019**, *138*, 139–154. [CrossRef]
8. Tetteh, N.; Amponsah, O. Sustainable adoption of smart homes from the Sub-Saharan African perspective. *Sustain. Cities Soc.* **2020**, *63*, 102434. [CrossRef]
9. Wilson, C.; Hargreaves, T.; Hauxwell-Baldwin, R. Benefits and risks of smart home technologies. *Energy Policy* **2017**, *103*, 72–83. [CrossRef]
10. Coskun, A.; Kaner, G.; Bostan, İ. Is smart home a necessity or a fantasy for the mainstream user? A study on users' expectations of smart household appliances. *Int. J. Des.* **2018**, *12*, 7–20.
11. Sanguinetti, A.; Karlin, B.; Ford, R. Understanding the path to smart home adoption: Segmenting and describing consumers across the innovation-decision process. *Energy Res. Soc. Sci.* **2018**, *46*, 274–283. [CrossRef]
12. Demiris, G.; Rantz, M.J.; Aud, M.A.; Marek, K.D.; Tyrer, H.W.; Skubic, M.; Hussam, A.A. Older adults' attitudes towards and perceptions of 'smart home' technologies: A pilot study. *Med. Inform. Internet Med.* **2004**, *29*, 87–94. [CrossRef] [PubMed]
13. Demiris, G.; Hensel, B.K. Technologies for an aging society: A systematic review of "smart home" applications. *Yearb. Med. Inform.* **2008**, *17*, 33–40.
14. Brush, A.B.; Lee, B.; Mahajan, R.; Agarwal, S.; Saroiu, S.; Dixon, C. Home automation in the wild: Challenges and opportunities. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Vancouver, BC, Canada, 7–12 May 2011; pp. 2115–2124. [CrossRef]
15. Luor, T.; Lu, H.-P.; Yu, H.; Lu, Y. Exploring the critical quality attributes and models of smart homes. *Maturitas* **2015**, *82*, 377–386. [CrossRef] [PubMed]
16. Park, E.; Cho, Y.; Han, J.; Kwon, S.J. Comprehensive Approaches to User Acceptance of Internet of Things in a Smart Home Environment. *IEEE Internet Things J.* **2017**, *4*, 2342–2350. [CrossRef]
17. Pal, D.; Funilkul, S.; Vanijja, V.; Papasratorn, B. Analyzing the elderly users' adoption of smart-home services. *IEEE Access* **2018**, *6*, 51238–51252. [CrossRef]
18. Shin, J.; Park, Y.; Lee, D. Who will be smart home users? An analysis of adoption and diffusion of smart homes. *Technol. Forecast. Soc. Chang.* **2018**, *134*, 246–253. [CrossRef]
19. Lutolf, R. Smart home concept and the integration of energy meters into a home based system. In Proceedings of the Seventh International Conference on Metering Apparatus and Tariffs for Electricity Supply 1992, Glasgow, UK, 17–19 November 1992; pp. 277–278.
20. Herrero, S.T.; Nicholls, L.; Strengers, Y. Smart home technologies in everyday life: Do they address key energy challenges in households? *Curr. Opin. Environ. Sustain.* **2018**, *31*, 65–70. [CrossRef]
21. Statista. Smart Home Report 2021. 2021. Available online: https://www.statista.com/study/42112/smart-home-report/ (accessed on 30 November 2021).
22. Zhang, J.; Xue, D.; Gu, P. Adaptable design of open architecture products with robust performance. *J. Eng. Des.* **2015**, *26*, 1–23. [CrossRef]

23. Market Data Forecast. *Global Smart Homes Market Report–Segmentation by Product (Lighting Control, Security & Access Control, HVAC, Entertainment, Smart Speaker, Home Healthcare, Smart Kitchen, Home Appliances, and Smart Furniture), Technology (Wireless Technology and Cellular Network Technology), and Region–Forecast to 2025*; Market Data Forecast: Hyderabad, AP, India, 2020.
24. techUK. *The State of the Connected Home 2020 Report*, 4th ed.; techUK: London, UK, 2020.
25. Davis, F.D. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Q.* **1989**, *13*, 319–340. [CrossRef]
26. Rogers, E.M. *Diffusion of Innovations*, 5th ed.; Free Press: New York, NY, USA, 2003.
27. Chen, J.V.; Yen, D.C.; Chen, K. The acceptance and diffusion of the innovative smart phone use: A case study of a delivery service company in logistics. *Inf. Manag.* **2009**, *46*, 241–248. [CrossRef]
28. Park, E.; Kim, S.; Kim, Y.; Kwon, S.J. Smart home services as the next mainstream of the ICT industry: Determinants of the adoption of smart home services. *Univers. Access Inf. Soc.* **2018**, *17*, 175–190. [CrossRef]
29. Nikou, S. Factors driving the adoption of smart home technology: An empirical assessment. *Telemat. Inform.* **2019**, *45*, 101283. [CrossRef]
30. Shih, T.-Y. Determinates of consumer adoption attitudes: An empirical study of smart home services. *Int. J. E-Adopt. (IJEA)* **2013**, *5*, 40–56. [CrossRef]
31. Yang, H.; Lee, W.; Lee, H. IoT Smart Home Adoption: The Importance of Proper Level Automation. *J. Sens.* **2018**, *2018*, 6464036. [CrossRef]
32. Yang, H.; Lee, H.; Zo, H. User acceptance of smart home services: An extension of the theory of planned behavior. *Ind. Manag. Data Syst.* **2017**, *117*, 68–89. [CrossRef]
33. Kua, H.; Lee, S.E. Demonstration intelligent building—A methodology for the promotion of total sustainability in the built environment. *Build. Environ.* **2002**, *37*, 231–240. [CrossRef]
34. Alwaer, H.; Clements-Croome, D.J. Key performance indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings. *Build. Environ.* **2010**, *45*, 799–807. [CrossRef]
35. GhaffarianHoseini, A.; Dahlan, N.; Berardi, U.; GhaffarianHoseini, A.; Makaremi, N. The essence of future smart houses: From embedding ICT to adapting to sustainability principles. *Renew. Sustain. Energy Rev.* **2013**, *24*, 593–607. [CrossRef]
36. Balta-Ozkan, N.; Amerighi, O.; Boteler, B. A comparison of consumer perceptions towards smart homes in the UK, Germany and Italy: Reflections for policy and future research. *Technol. Anal. Strateg. Manag.* **2014**, *26*, 1176–1195. [CrossRef]
37. Williams, T.; Bernold, L.; Lu, H. Adoption patterns of advanced information technologies in the construction industries of the United States and Korea. *J. Constr. Eng. Manag.* **2007**, *133*, 780–790. [CrossRef]
38. Sovacool, B.K.; Del Rio, D.D.F. Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies. *Renew. Sustain. Energy Rev.* **2020**, *120*, 109663. [CrossRef]
39. Caragliu, A.; Del Bo, C.; Nijkamp, P. Smart cities in Europe. *J. Urban Technol.* **2011**, *18*, 65–82. [CrossRef]
40. San Martín, H.; Herrero, Á. Influence of the user's psychological factors on the online purchase intention in rural tourism: Integrating innovativeness to the UTAUT framework. *Tour. Manag.* **2012**, *33*, 341–350. [CrossRef]
41. Venkatesh, V.; Thong, J.Y.; Xu, X. Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *MIS Q.* **2012**, *36*, 157–178. [CrossRef]
42. Kiesler, S.; Zdaniuk, B.; Lundmark, V.; Kraut, R. Troubles with the Internet: The Dynamics of Help at Home. *Hum.-Comput. Interact.* **2000**, *15*, 323–351. [CrossRef]
43. Chan, F.; Thong, J.; Venkatesh, V.; Brown, S.; Hu, P.; Tam, K. Modeling Citizen Satisfaction with Mandatory Adoption of an E-Government Technology. *J. Assoc. Inf. Syst.* **2010**, *11*, 519–549. [CrossRef]
44. Santouridis, I.; Trivellas, P.; Reklitis, P. Internet service quality and customer satisfaction: Examining internet banking in Greece. *Total Qual. Manag.* **2009**, *20*, 223–239. [CrossRef]
45. Maisel, J.L. (Ed.) *The State of the Science in Universal Design: Emerging Research and Developments*; Bentham Science Publishers: Danvers, MA, USA, 2010.
46. National Disability Authority. Universal Design Guidelines for Homes in Ireland. 2015. Available online: https://universaldesign.ie/built-environment/housing/ (accessed on 19 September 2022).
47. National Disability Authority. Universal Design Approach for Dementia Friendly Dwellings. 2015. Available online: https://universaldesign.ie/built-environment/housing/dementia-friendly-dwellings/ (accessed on 19 September 2022).
48. Queensland Government Department of Public Works. *Smart and Sustainable Homes Design Objectives*; Queensland Government Department of Public Works: Brisbane, Australia, 2008.
49. Palmer, J.; Ward, S. Housing of the Future: The Livable and Adaptable House. In *YourHome*; Australian Government: Canberra, Australia, 2013.
50. Korea Agency for Infrastructure Technology Advancement. *AI-Based Smart Housing Technology Development (Smart Housing Platform and Residential Service Technology Development) Planning Report*; Korea Agency for Infrastructure Technology Advancement: Anyang, Korea, 2019.
51. Korea Association for ICT Promotion. Home Network Building Certificate Authority. 2019. Available online: https://www.bica.or.kr/standard/building.do (accessed on 12 September 2021).

52. Ministry of Land, Infrastructure and Transport. Certification of Intelligent Buildings. 2020. Available online: https://www.law.go.kr/%ED%96%89%EC%A0%95%EA%B7%9C%EC%B9%99/%EC%A7%80%EB%8A%A5%ED%98%95%EA%B1%B4%EC%B6%95%EB%AC%BC%EC%9D%B8%EC%A6%9D%EA%B8%B0%EC%A4%80 (accessed on 12 September 2021).
53. Korea Association for ICT Promotion. Broadband Building Certificate Authority. 2021. Available online: https://www.bica.or.kr/standard/house.do (accessed on 19 September 2022).
54. King, W.R.; He, J. A meta-analysis of the technology acceptance model. *Inf. Manag.* **2006**, *43*, 740–755. [CrossRef]
55. Kincaid, D. Adaptability potentials for buildings and infrastructure in sustainable cities. *Facilities* **2000**, *18*, 155–161. [CrossRef]
56. Patten, K.; Whitworth, B.; Fjermestad, J.; Mahindra, E. Leading IT flexibility: Anticipation, agility and adaptability. In Proceedings of the AMCIS 2005 Proceedings, Omaha, NE, USA, 11–14 August 2005; p. 361.
57. Whitworth, B.; Bañuls, V.; Sylla, C.; Mahinda, E. Expanding the Criteria for Evaluating Socio-Technical Software. *IEEE Trans. Syst. Man Cybern.-Part A Syst. Hum.* **2008**, *38*, 777–790. [CrossRef]
58. Yang, H.; Yu, J.; Zo, H.; Choi, M. User acceptance of wearable devices: An extended perspective of perceived value. *Telemat. Inform.* **2016**, *33*, 256–269. [CrossRef]
59. Edwards, W.K.; Grinter, R.E. At home with ubiquitous computing: Seven challenges. In Proceedings of the International Conference on Ubiquitous Computing, Atlanta, GA, USA, 30 September–2 October 2001; Springer: Berlin/Heidelberg, Germany, 2001; pp. 256–272.
60. Tak, J. *Psychological Testing: An Understanding of Development and Evaluation Method*; Hakjisa: Seoul, Korea, 2007.
61. Tabachnick, B.G.; Fidell, L.S. *Using Multivariate Statistics*; Pearson Allyn & Bacon: Upper Saddle River, NJ, USA, 2007.
62. Statistics Korea. Income Statistics of Wage Workers in 2018. 2020. Available online: http://kostat.go.kr/portal/eng/pressReleases/1/index.board?bmode=read&bSeq=&aSeq=380950&pageNo=1&rowNum=10&navCount=10&currPg=&searchInfo=srch&sTarget=title&sTxt=2018 (accessed on 25 August 2020).
63. Field, A. *Discovering Statistics Using SPSS for Windows*; SAGE: Thousand Oaks, CA, USA, 2000.
64. Hair, J.F.J.; Bush, R.P.; Ortinau, D.J. *Marketing Research: A Practical Approach for the New Millennium*; Irwin McGraw-Hill: Sydney, Australia, 2000.
65. Carlback, J.; Wong, A. A Study on Factors Influencing Acceptance of Using Mobile Electronic Identification Applications. Master's Thesis, Jönköping University, Jönköping International Business School, Jönköping, Sweden, 2018.
66. Sharma, S.; Mukherjee, S.; Kumar, A.; Dillon, W.R. A simulation study to investigate the use of cutoff values for assessing model fit in covariance structure models. *J. Bus. Res.* **2005**, *58*, 935–943. [CrossRef]
67. Knoll, K.; Jarvenpaa, S.L. Information technology alignment or "fit" in highly turbulent environments: The concept of flexibility. In Proceedings of the 1994 Computer Personnel Research Conference on Reinventing IS: Managing Information Technology in Changing Organizations: Managing Information Technology in Changing Organizations, Alexandria, VA, USA, 24–26 March 1994; pp. 1–14.
68. Fitzgerald, G.; Siddiqui, F.A. Business Process Reengineering and Flexibility: A Case for Unification. *Int. J. Flex. Manuf. Syst.* **2002**, *14*, 73–86. [CrossRef]
69. Chau, P.Y.K.; Lai, V.S.K. An Empirical Investigation of the Determinants of User Acceptance of Internet Banking. *J. Organ. Comput. Electron. Commer.* **2003**, *13*, 123–145. [CrossRef]
70. Black, N.J.; Lockett, A.; Ennew, C.; Winklhofer, H.; McKechnie, S. Modelling consumer choice of distribution channels: An illustration from financial services. *Int. J. Bank Mark.* **2002**, *20*, 161–173. [CrossRef]
71. Kim, Y.; Park, Y.; Choi, J. A study on the adoption of IoT smart home service: Using Value-based Adoption Model. *Total Qual. Manag. Bus. Excel.* **2017**, *28*, 1149–1165. [CrossRef]
72. Hubert, M.; Blut, M.; Brock, C.; Zhang, R.W.; Koch, V.; Riedl, R. The influence of acceptance and adoption drivers on smart home usage. *Eur. J. Mark.* **2019**, *53*, 1073–1098. [CrossRef]
73. Talke, K.; Heidenreich, S. How to Overcome Pro-Change Bias: Incorporating Passive and Active Innovation Resistance in Innovation Decision Models. *J. Prod. Innov. Manag.* **2014**, *31*, 894–907. [CrossRef]
74. Li, J.; Ma, Q.; Chan, A.H.; Man, S. Health monitoring through wearable technologies for older adults: Smart wearables acceptance model. *Appl. Ergon.* **2019**, *75*, 162–169. [CrossRef]
75. Carter, L.; Bélanger, F. The utilization of e-government services: Citizen trust, innovation and acceptance factors. *Inf. Syst. J.* **2005**, *15*, 5–25. [CrossRef]
76. Saeed, F.; Paul, A.; Rehman, A.; Hong, W.H.; Seo, H. IoT-based intelligent modeling of smart home environment for fire prevention and safety. *J. Sens. Actuator Netw.* **2018**, *7*, 11. [CrossRef]
77. Han, J.; Choi, C.-S.; Lee, I. More efficient home energy management system based on ZigBee communication and infrared remote controls. *IEEE Trans. Consum. Electron.* **2011**, *57*, 85–89. [CrossRef]
78. Maghsoodi, N.H.; Haghnegahdar, M.; Jahangir, A.H.; Sanaei, E. Performance evaluation of energy management system in smart home using wireless sensor network. In Proceedings of the Iranian Conference on Smart Grids, Tehran, Iran, 24–25 May 2012; pp. 1–8.
79. Doan, T.T.; Safavi-Naini, R.; Li, S.; Avizheh, S.; Muni, V.K.; Fong, P.W. Towards a resilient smart home. In Proceedings of the 2018 Workshop on IoT Security and Privacy, Budapest, Hungary, 20 August 2018; pp. 15–21.
80. Longe, O.M.; Ouahada, K.; Rimer, S.; Harutyunyan, A.N.; Ferreira, H.C. Distributed Demand Side Management with Battery Storage for Smart Home Energy Scheduling. *Sustainability* **2017**, *9*, 120. [CrossRef]

81. Sovacool, B.K.; Martiskainen, M.; Del Rio, D.D.F. Knowledge, energy sustainability, and vulnerability in the demographics of smart home technology diffusion. *Energy Policy* **2021**, *153*, 112196. [CrossRef]
82. Chen, C.; Cook, D.J.; Crandall, A.S. The user side of sustainability: Modeling behavior and energy usage in the home. *Pervasive Mob. Comput.* **2013**, *9*, 161–175. [CrossRef]
83. Chang, S.; Nam, K. Smart Home Adoption: The Impact of User Characteristics and Differences in Perception of Benefits. *Buildings* **2021**, *11*, 393. [CrossRef]