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LONG PAPER

Smart home services as the next mainstream of the ICT industry: determinants of the adoption of smart home services

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Abstract This study investigated the core motivations for adopting smart home services and explored the approaches and processes through which the motivations were incorporated with the original technology acceptance model (TAM) and the acceptance of the services. To achieve this purpose, an Internet survey was conducted in South Korea. The data ($N = 799$) from the survey were analyzed using structural equation modeling and confirmatory factor analysis. The results suggested that the perceived compatibility, connectedness, control, system reliability, and enjoyment of smart home services were positively related to the users' intention to use the services, whereas there was a negative association between the perceived cost and usage intention. The structural results also provided evidence of the validity of the original TAM. Although smart home services have attracted users' interest in the housing context, only a few studies have examined how the users' intention to use the services is motivated. The present study represents an initial step to explore the process of adopting smart home services with potential future research areas.

Keywords Smart home services · Technology acceptance model · Compatibility · Perceived connectedness

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1 Introduction

Mobile carriers and cable TV business providers strive to search for and develop new business profit models to expand their congested business environments. As the mainstream of mobile telecommunications markets has moved from voice communication and text messaging services to using mobile data and accessing media contents [1], the majority of participants in the markets have sought to develop products for a range of media content via mobile devices [2]. Moreover, because the traditional markets of TV business providers also meet the plateau of the profit models of the markets that focus on the Internet, cable TV, wireless, and wired telephone services and their supplemental products, providers have attempted to develop strategies for maintaining their customers and developing new profit models to extend their markets [3].

Smart home services are considered one of the most promising potential markets [4]. Based on the rapidly diffused infrastructure of mobile network environments, the demand for smart home services and home security products has increased exponentially [5]. For example, compared to mobile telecommunications, the Internet and cable TV services are considered to have reached saturation in South Korea, and the diffusion rate of smart home services is considerably lower than that of other services [6].

Smart home services are all-in-one remote control services that can handle all equipment and devices installed in the house, which include home applications, facilities, and utilities such as electricity, water supply, air conditioning, boilers, refrigerators, and TVs [7]. This means that smart home services are a set of technologies that provide human-oriented networking environments for connecting equipment and applications in the house. Figure 1 shows the transitions of the access methods, infrastructure, and technologies required for smart home services.

Because the background infrastructure of smart home services is mainly an integrated environment between wired and wireless networks, mobile carriers and cable TV business providers do not expect any barriers to their entry into the smart home services market.

Since 2000, when the use of the Internet and 4G mobile telecommunication services became widespread [8], the majority of mobile carriers and cable TV business providers have developed a network infrastructure, which is essential for smart home services [9]. Moreover, because mobile devices, including smartphones and tablet personal computers, which have diffused rapidly in society, can use mobile applications for controlling smart home services, there is no need to distribute additional devices for the services.

Therefore, considering that mobile devices can provide the required functions for connecting to the services, mobile carriers and cable TV business providers can easily organize and provide smart home services without a huge investment. That is, smart home services can be considered the integration between all housing facilities and the technologies of the Internet of things (IoT) [9, 10].

Despite the significant impact of smart home services in the information and communication technology (ICT) industry and society, few studies have been conducted to explore users' motivations for employing smart home services and how service providers can easily diffuse the acceptance of these services and improve their quality [11, 12]. Therefore, this study examined the core determinants of using smart home services for users' housing environments and explored how the determinants contribute to the acceptance of smart home services by utilizing the technology acceptance model (TAM).

The reminder of this paper is organized as follows. Section 2 provides an overview of the markets for smart home services. The concept of smart home services and the research hypotheses and model are presented in Sect. 3. Section 4 shows the results from the structural equation modeling method (SEM). Finally, the discussion and limitations are presented in Sect. 5.

2 Smart home services and markets

In 2015, the worldwide market for smart home services was estimated at $25.38 billion [13]. With the rapidly increasing size of the market, the global market is predicted to expand to $56.18 billion in 2020 with a 17.2% compound annual growth rate from 2015 to 2020 [13].

With a predicted market expansion in the USA and Europe to $24.3 billion and $10.2 billion by 2017, respectively [14], many studies forecast that smart home services will become an essential installation for housing environments [15, 16].

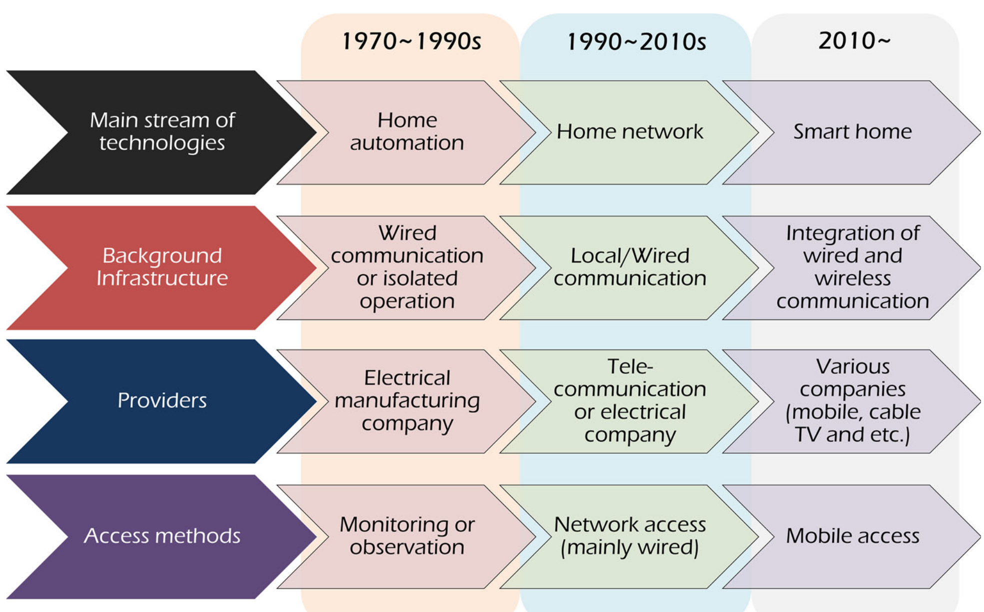

Fig. 1 Transitions of smart home services

Consistent with the global trend of smart home services, the 2015 market size of smart home services in South Korea was estimated to be approximately $8.59 billion, i.e., 21% higher than in 2014 (approximately $7.08 billion) [17]. Moreover, based on the rapidly increased demand for smart home services with the diffusion of mobile networks and the popularization of smart devices, the market size in South Korea is predicted to worth approximately $19 billion in 2019.

Although smart home services have diffused rapidly in our society, there are several challenges that need to be addressed for the future success of these markets. Technically, the services should eliminate several risks, such as system hacking or security threats caused mainly by the use of network connection facilities. In addition, providing a well-designed user interface that allows users to control and access smart home services via multiple network connections is also important. For example, previous studies suggested that the overall customer satisfaction for smart home and house security services is relatively lower than other advanced technologies due to several issues, including the difficulty of controlling smart home services and the lack of real-time information on the home [18].

Table 1 lists the categorizations and products of smart home services, and users' perceived values of the services [19, 20]. Smart home services are categorized into six industrial fields, and users' beneficial values of the services are categorized into four parts: economic, hedonic, security, and comfortable aspects.

To accelerate the acceptance of popularization of smart home services, a deeper understanding of service consumers is required. By presenting the current users' perceptions of these services, the improvement plans and suggestions for the success of the services could also be presented.

Moreover, most studies on smart home services examined the effects of one of the particular characteristics of the services on the users' perceptions [21, 22]. Therefore, the present study proposes a research model that includes various factors extracted by in-depth interviews with experts in multiple aspects of smart home services.

2.1 Extracting potential determinants

To extract the potential determinants of adopting smart home services, ten professors who majored in smart home services and mobile applications participated in in-depth interviews based on four suggested values of the services. Then, a query analysis, associated with users' economic, security, comfortable, and hedonic value perceptions, was conducted. Based on the results and analysis of the interviews, seven factors were used to organize the research model (Table 2).

3 Literature review and research hypotheses

Following the introduction of the term of "Smart Home" in the 1980s [23], the term has been used in various industries with multiple meanings. For example, the concept of smart home in the healthcare industry is used as a residential area that enhances the function of preventing disease by monitoring residents' health, habits and life patterns [24]. In the energy industry, the technological developments and research in smart home focus on the efficiency of energy facilities, including the demand-oriented production and usage of energy. The majority of smart grid and meter technologies focus on this concept of the smart home [25]. In the ICT industry, presenting innovative technologies and solutions through IoT has been the mainstream of smart home environments. In this context, household products with various Internet and mobile applications are connected with wireless network connections [26].

This means that smart home services have different definitions and explanations when applied to different industries. Therefore, the present study uses a comprehensive definition introduced and explained by a previous study: "a residential location equipped with processing, computing, sensing and information technology which provides the functions for responding to the needs of the respondents and improving their safety, comfort, security and life-quality, based on the connection between the inside and outside of the home" [27].

In general, smart home services are organized into several components. There are six main components for the services: four infrastructure and two platform components. Table 3 presents the technological components, roles, and trends of smart home services.

3.1 Technology acceptance model

Exploring the adoption patterns of newly introduced systems or services is one of the most effective ways to estimate the success of such systems or services in the market [28]. Among the many theoretical models for explaining the adoption of particular systems or services, the TAM proposed by Davis is one of the most widely used frameworks [29]. The original TAM was organized into four constructs: the intention to use, attitude, usefulness, and ease of use. In the original TAM, the intention to use is determined by the attitude and perceived usefulness, while the attitude is affected by the perceived ease of use and usefulness. Moreover, there is a significant connection between perceived ease of use and usefulness [29].

TAM has been validated as a useful theoretical model for exploring information-oriented or smart services. For example, Chen et al. [30] used TAM to elucidate the

Table 1 Categorizations of smart home services and markets [19, 20]

Classification: level 1 (industry)	Classification: level 2 (service)	Classification: level 3 (group of products)	Products	Users' perceived values
Smart greenhouse	Energy solution	Solutions for energy conservation of home appliances	Small-sized energy storage systems (ESS), smart plug devices, blocking devices for standby electricity, smart meter devices	Economic value
		Solutions for utilizing renewable energy resources	Small-sized photovoltaic arrays, wind turbines, geothermal pump systems	
	Energy conservation services	Energy conservation and management for house	House management services based on smart home systems	
Smart TV and home entertainment	Device solution	Smart TV	TV applications, smart controller applications	Hedonic value
		Hardware of games	Game platforms and devices	
		Other devices	Smart audio	
	Entertainment services	Media services	IPTV, digital cable TV	
		TV game services	Console game, game applications via smart TV	
		Two-way interaction services	Two-way shopping service, 3D interaction service	
		Other services	Other home entertainment services	
Smart health care	Device solution	Healthcare applications	Smart bio-signal sensors, activity-tracking applications, smart fitness devices in house	Security value
	Healthcare services	Health management services	Emergency correspondence, exercise monitoring, disease prevention	
Smart security	Device solution	Security storage devices	IP media devices, monitoring robots, CCTV systems	
		Other devices	Digital door-locking systems, devices for recognizing bio-signal	
	Security services	Home security services	Security control services with security business enterprises	
Smart convergence home appliances	Device solution	White goods	Smart refrigerators, smart vacuum cleaners	Comfortable value
		Kitchen equipment	Smart water purifiers, smart dishwashers	
		Lighting equipment	Functional lamps (LED, environmental friendly lighting lamps)	
		Cooling and heating equipment	System air-conditioners, smart heaters, house ventilation systems	
	Home convergence appliances	Other services	Convergence appliances based on cloud systems	
Home automation	Device solution	Shared equipment for apartments and multi-family houses	Smart house management systems, parking control systems, ESS facilities, remote and automatic meter reading systems, devices for shared healthcare facilities	
		In-house devices	Home gateway, in-house communication devices, in-house automatic sensing devices	
	Automation services	Management services for apartments and multi-family houses	Community information services, management systems for smart home services	
		Other services	Smart city services for providing the connection between houses and other systems	

intention to employ smart phone devices and confirmed the validation of the original TAM with self-efficacy as a notable determinant. Lai [31] introduced a revised TAM with the concept of reliability (trust) for examining the users' intention to use smart sharing systems and examined how developers and manufacturers improve their systems. Taherdoost et al. [32] included the constructs of security-oriented (privacy, verification), satisfaction-oriented (awareness, support), and external-oriented (compatibility, demographic, trailability) factors with TAM and examined

Table 2 Results of the in-depth interview sessions

Factors	*N*	Categorization of values
Security	25 (19%)	Security value
Cost (maintenance, repair)	18 (14%)	Economic value
Perceived control	15 (11%)	Comfortable value
Enjoyment	14 (11%)	Hedonic value
System reliability	14 (11%)	Security value
Connectedness	12 (9%)	Comfortable and hedonic values
Compatibility	9 (7%)	Economic and security values
Others	24 (19%)	–
Total	131 queries (100%)	–

Table 3 Technological components of smart home services [19, 20]

Technological component	Role
Infrastructure	
Smart home infrastructure	Controlling external access and promoting internal network environments in house
Wired and wireless transmission technology	Supporting mobility for devices and providing the connection between the devices and home network
Contents sharing technology	Sharing contents through various devices and models by improving compatibility functions
Machine to machine sensing technology	Sensing and controlling the status and circumstance of devices in house and information management
Platform	
Cross-functional platform	Using identical services in various device-types through the platform
Service–server platform	Supporting the management, control, verifications, and service functions for smart home services

how these constructs contribute significantly to the users' attitude and intention to use smart card technologies. In accordance with the confirmations of the original TAM in previous studies [29, 33], the following hypotheses to estimate the acceptance of smart home services based on the original TAM are proposed:

H1 Attitude toward smart home services has a positive effect on the intention to use the services.

H2 Perceived usefulness of smart home services has a positive effect on the intention to use the services.

H3 Perceived usefulness of smart home services has a positive effect on the attitude toward the services.

H4 Perceived ease of use of smart home services has a positive effect on the attitude toward the services.

H5 Perceived ease of use of smart home services has a positive effect on the perceived usefulness of the services.

3.2 Hedonic value

3.2.1 Perceived enjoyment

To explore the motivational factors of TAM, Davis et al. [34] considered perceived enjoyment as a potential determinant of TAM. Considering the definition of perceived enjoyment introduced by Davis et al. [34], the present study defined perceived enjoyment as "the extent of which the use of smart home services is perceived to be playful and enjoyable" [34, 35]. Moreover, several empirical studies have investigated the connection between the perceived enjoyment and the users' perceptions. Rese et al. [36] reported that the users' perceived enjoyment of advanced information technologies is a notable determinant of the perceived usability of the technologies. Yi and Hwang [37] and Cheung and Vogel [38] also indicated that the perceived ease of using information-delivering systems is affected significantly by the perceived enjoyment of the systems. Park and del Pobil [39] provided evidence of the relationship between perceived enjoyment and the ease of using advanced service technologies. Therefore, the following hypothesis is proposed:

H6 The perceived enjoyment of smart home services has a positive effect on the perceived ease of use of the services.

3.2.2 Perceived connectedness

In smart environments, users want to use and interact easily with the available components in the environment. For example, users wish to interact with the services for the components at their convenience rather than their physical inconvenience [40]. In the case of smart home services, there can be more positive connectedness perceptions in virtual environments in using the services.

Similar to online communication services [41], smart home services provide a range of functions, including maintaining, operating, and controlling the components of the services. Therefore, users can feel that they are easily connected to smart home services and use the components in the services easily [42]. Hence, the present study proposes the following hypothesis:

H7 Perceived connectedness of smart home services has a positive effect on the perceived ease of use of the services.

3.3 Comfortable value

3.3.1 *Perceived control*

Perceived control is defined as the "users' perceptions on their capability, resources, and skills for naturally performing the behavior and usage of a particular service or system" [43]. Although manufacturers and developers of information modeling technologies have tried to provide well-designed interfaces for users, users need the basic control skills to employ these technologies. Considering Csikszentmihalyi's flow state and the previously defined explanation on perceived control [44], perceived control in the context of the present study is defined as "the users' feeling of how proficient it is to achieve a selected activity" [45]. In the field of communication and information services, Lee and Chang [46] provided evidence supporting the relationship between the users' perceived control and their attitudes toward the services. Park et al. [45] also found that the users' perceived usability of mobile services is affected significantly by the users' perceived control and skill on the services. The following hypothesis is therefore proposed:

H8 The perceived control of smart home services has a positive effect on the perceived usefulness of the services.

3.4 Security value

3.4.1 *Perceived system reliability*

Based on the definition introduced previously [47, 48], the perceived system reliability used in this study is referred to as the "users' perceived level that smart home systems can present reliable services that make the users meet their expectations toward the systems" [48, 49]. As validated in several studies on information systems and services, the users' perceived usability in utilizing the systems and services is affected significantly by their perceived system reliability [50–52]. Lu et al. [53] indicated that the users' perceived system reliability is a notable determinant of TAM when using wireless mobile services. Gefen and Straub [54] also provided evidence of a significant relationship between the users' perceived usefulness and their perceived trust formed by the users' perceived system reliability in using online services. Therefore, the present study proposes the following hypothesis:

H9 The perceived system reliability of smart home services has a positive effect on the perceived usefulness of the services.

3.4.2 *Perceived security*

Security is an important issue in diffusing information-oriented services [55]. Based on the definition of perceived security introduced by several prior studies on information systems and services [56], the present study defined perceived security as the "users' perspectives toward the protection level against the potential threats when using smart home services." Cheng et al. [57] reported that the users' evaluations of the security degree of online services determine their overall usability perceptions on those services. Shin [58] conducted a survey on the users of IPTV, which is one of the most widely used services in homes, and found that the users' perceived security is one of the notable determinants of their overall perceptions of IPTV services. Therefore, based on the evidence from previous studies on the perceived security [40], this study proposes the following hypothesis:

H10 Perceived security of smart home services has a positive effect on the perceived usefulness of the services.

3.4.3 *Compatibility*

Since Rogers [59] introduced the definition of compatibility as "the extent to which a unique innovation is consistent with the current and traditional values and needs," it has become one of the most essential characteristics when diffusing new technology or services. Crespo et al. [60] reported that perceived compatibility is one of the most important factors contributing to online-oriented services. Holahan et al. [61] also reported that developers should consider perceived compatibility for effective technology usage. Islam [62] indicated that the perceived compatibility of information management systems contributed significantly to the users' perspectives toward the systems.

The connection between the perceived compatibility of and the users' attitude toward a particular wireless technology is also supported [63]. Therefore, regarding the

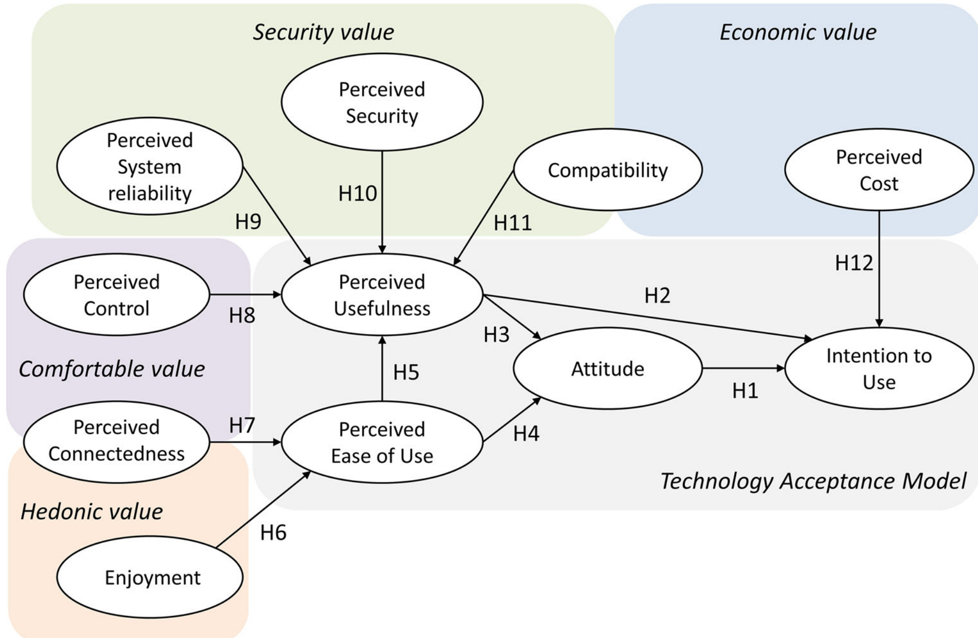

Fig. 2 Research model used in this study

following relationship between perceived compatibility and attitude, the present study proposes the following hypothesis:

H11 The perceived compatibility of smart home services has a positive effect on the perceived usefulness of the services.

3.5 Economic value

3.5.1 Perceived cost

Although the motivations and determinants of the acceptance of newly developed services have been widely explored, the cost aspect is one of the largest barriers to diffusing the services [64, 65]. In estimating the users' intention to employ a particular service, users attempt to weigh up the benefits and costs of that service. The perceived cost in information services and systems is generally defined as "the concerns related to the costs used in purchasing, maintaining, and repairing the essential components in the services and systems" [66]. Following the definition introduced by previous studies, the present study defined the perceived cost as "the concerns on the estimated costs in purchasing, operating, using, and repairing the components employed in smart home services."

A large number of prior studies on information services and systems suggested a negative association between the perceived cost and intention to use [67]. Williams et al. [68] reported that the perceived cost of using advanced information technologies in the construction field is one of the largest barriers to using the technologies in South Korea and the USA. Ansolabehere and Konisky [69] also indicated that the public attitudes toward building new power plants are notably affected by the perceived construction cost. Therefore, this study proposes the following hypothesis based on the previously supported negative relationship between the cost concept and intention to use.

H12 The perceived cost of smart home services has a negative effect on the intention to use the services.

3.6 Research model

This study extended the original TAM to an integrated model, including the suggested motivations and hypotheses. Figure 2 shows the research model with the predicted relationships.

4 Method

Based on the extracted factors and the original TAM, 42 items were collected by prior studies. All questionnaire items were translated from English into Korean by two professional translators. Following the translation, the items were back-translated to ensure the validity of the translation results. Four professors who majored in information services, systems, and communication reviewed and revised the collected items. After the review session, two rounds of a pilot survey were conducted with 20 researchers with more than six-month experience with smart home services. Based on the results of two rounds of

Table 4 Questionnaire items used in the current study

Factors	Items	Explanations	References
Enjoyment	E1	Using smart home services is fun	[70–72]
	E2	It is so interesting to use smart home services	
	E3	Using smart home services is exciting and pleasant	
Perceived connectedness	PC1	I feel good because I can access smart home services anytime	[40, 73, 74]
	PC2	I feel like being connected to the smart home services because I can take any information on the services' components that I want	
	PC3	I feel comforted because I can interact with the components in my house via smart home services	
Perceived control	CON1	In my life, using smart home services in entirely my control	[75, 76]
	CON2	I have enough knowledge and ability to use smart home services	
	CON3	I can skillfully use smart home services	
Perceived system reliability	SR1	Smart home services perform their functions rapidly	[48, 77]
	SR2	Smart home services are reliable without errors	
	SR3	Smart home services are being immediately responsive to my request	
Perceived security	PS1	Smart home services are safe for my personal information	[40, 78]
	PS2	I think my information in smart home services will not be manipulated	
	PS3	I think that nobody can see and use my information stored in smart home services	
Compatibility	COM1	Using smart home services in compatible with my life	[75, 79, 80]
	COM2	Using smart home services fits well with the way I like to manage my house	
	COM3	Using smart home services fits well with the way I want to interact with the components in my house	
Perceived cost	COS1	Smart home services are expensive	[81]
	COS2	I am not able to easily afford smart home services	
	COS3	Buying and operating smart home services are a burden to me	
Perceived ease of use	EU1	Using smart home services is not difficult for me	[82–84]
	EU2	My interaction with smart home services is understandable and clear	
	EU3	Interacting with smart home services does not require my mental effort	
Perceived usefulness	PU1	Using smart home services improves my job effectiveness	[24, 42, 77, 79]
	PU2	Using smart home services makes me accomplish my tasks more rapidly	
	PU3	I think that smart home services are beneficial in my job	
	PU4	Smart home services are a useful service for houses	
Attitude	AT1	Using smart home services in a good idea	[29, 40, 85, 86]
	AT2	I have positive feelings toward smart home services in general	
	AT3	It is a wise idea to use smart home services	
Intention to use	IU1	I recommend others to use smart home services for their houses	[29, 48, 74, 84]
	IU2	I am likely to continually use smart home services in my life	
	IU3	I intend to use smart home services as much as possible	

a pilot survey, 8 items were excluded. Therefore, 34 items remained in the main survey. In order to check the reliability of the constructs, Cronbach's alpha values were calculated. The values of the final round presented acceptable levels (0.841–0.944). Table 4 lists the questionnaire items used in the main survey. All questionnaire items were evaluated on a 7-point Likert scale (1 = "strongly disagree"—7 = "strongly agree").

Two professional survey companies in South Korea conducted an Internet survey for two months by sending out 3500 emails to users of smart home services. Of the 841 responses, 799 validated responses after data filtering were used in the analysis. Table 5 lists the respondents' demographic information.

5 Results

Table 6 presents descriptive information of the constructs in the research model.

Table 5 Respondents' demographic information used in the current study ($N = 799$)

Age	N (%)	Usage period	N (%)
20–29	327 (40.9%)	3–6 months	109 (13.6%)
30–39	264 (33.0%)	6–12 months	247 (30.9%)
40–49	151 (18.9%)	12–24 months	371 (46.4%)
50–59	41 (5.1%)	More than 24 months	72 (9.0%)
Above 59	16 (2.0%)		

Living area	N (%)	Education	N (%)
Metropolis	510 (63.8%)	High school or below	207 (25.9%)
Small and medium-sized cities	182 (22.8%)	College	503 (63.0%)
Rural area	107 (13.4%)	Graduate or above	89 (11.1%)

Residential type	N (%)	Gender	N (%)
Apartment	495 (62.0%)	Male	487 (61.0%)
Multi-household house	195 (24.4%)	Female	312 (39.0%)
Detached house	86 (10.8%)		
Others	23 (2.9%)		

5.1 Tests of validity

AMOS 18 and SPSS 18.0 were used to conduct SEM and confirmatory factor analysis (CFA) for hypothesis testing and to examine the validity of the research model. As presented in previous studies on SEM and CFA [87], the sample size should be greater than 200, and all factor loadings, composite reliability and Cronbach's alpha values should be higher than 0.7. Moreover, the degrees of average variance extracted (AVE) were greater than 0.5, and the square root of AVE was higher than the correlation levels between the two specific factors. Tables 7 and 8 present the validity tests and the recommendations.

5.2 The measurement and structural models

As shown in Table 9, the fit indices of the measurement and structural models confirmed the validity of the employed constructs.

5.3 Hypothesis testing

Figure 3 and Table 10 present the results of the research model. All hypotheses except H10 were supported. The users' intention to use smart home services was determined significantly by the perceived usefulness (H2, $\beta = 0.658$, CR $= 17.363$, $p < 0.001$), attitude (H1, $\beta = 0.249$, CR $= 6.918$, $p < 0.001$), and perceived cost (H12, $\beta = -0.091$, CR $= -4.566$, $p < 0.001$).

Two factors, perceived usefulness (H3, $\beta = 0.736$, CR $= 23.942$, $p < 0.001$) and ease of use (H2, $\beta = 0.140$, CR $= 5.154$, $p < 0.001$), had positive effects on attitude. The perceived usefulness was determined significantly by compatibility (H11, $\beta = 0.501$, CR $= 11.662$, $p < 0.001$), perceived control (H8, $\beta = 0.322$, CR $= 7.607$, $p < 0.001$), system reliability (H9, $\beta = 0.117$, CR $= 4.820$, $p < 0.001$), and ease of use (H5, $\beta = 0.107$, CR $= 3.991$, $p < 0.001$). On the other hand, the perceived security had no effect on the perceived usefulness (H10, $\beta = 0.024$, CR $= 0.620$, $p > 0.05$). Finally, enjoyment (H6, $\beta = 0.188$, CR $= 2.493$, $p < 0.05$) and perceived connectedness (H7, $\beta = 0.376$, CR $= 4.821$, $p < 0.001$) were positively associated with the perceived ease of use.

The perceived cost, usefulness, and attitude contributed 76.9% of the variance in the intention to use. The perceived usefulness and ease of use contributed 66.0% of the variance in attitude, whereas 68.1% of the variance in the perceived usefulness accounted for the perceived ease of use, system reliability, control, and compatibility. Figures 4 and 5 show the standardized total effects of selected factors on attitude and intention to use. The perceived usefulness had the greatest impact on both attitude and intention. Among the external motivations of intention to use and attitude, perceived compatibility had the greatest effects, 0.368 and 0.421, respectively. This indicated that the sequential association of compatibility-usefulness-intention was validated to explain user adoption of smart home services.

5.4 Supplemental analysis

To determine the values with the most influential effects on the users' intention to use smart home services, the sum of

Table 6 Descriptive information

Construct	Mean (SD)	Construct	Mean (SD)
Enjoyment	5.79 (0.94)	Perceived cost	3.36 (1.07)
Perceived connectedness	5.31 (1.12)	Perceived ease of use	5.13 (1.12)
Perceived control	5.23 (1.06)	Perceived usefulness	5.44 (1.04)
Perceived system reliability	4.57 (0.83)	Attitude	5.07 (1.09)
Perceived security	5.32 (1.10)	Intention to use	5.31 (1.20)
Compatibility	5.50 (1.04)		

Table 7 Internal and convergent validity tests

Factor	Item	Internal reliability		Convergent reliability		
		Cronbach's alpha	Item-total correlation	Factor loading	Composite reliability	Average variance extracted
Enjoyment	E1	0.874	0.837	0.927	0.923	0.800
	E2		0.822	0.923		
	E3		0.833	0.830		
Perceived connectedness	PC1	0.849	0.811	0.811	0.870	0.691
	PC2		0.823	0.851		
	PC3		0.844	0.831		
Perceived control	CON1	0.909	0.829	0.920	0.943	0.847
	CON2		0.773	0.945		
	CON3		0.707	0.896		
Perceived system reliability	SR1	0.921	0.807	0.926	0.950	0.863
	SR2		0.777	0.937		
	SR3		0.803	0.925		
Perceived security	SEC1	0.734	0.770	0.753	0.804	0.577
	SEC2		0.776	0.769		
	SEC3		0.753	0.757		
Compatibility	COM1	0.898	0.874	0.857	0.938	0.834
	COM2		0.895	0.936		
	COM3		0.877	0.944		
Perceived cost	COS1	0.816	0.748	0.858	0.896	0.742
	COS2		0.703	0.864		
	COS3		0.757	0.862		
Perceived ease of use	EOU1	0.890	0.782	0.885	0.932	0.820
	EOU2		0.719	0.946		
	EOU3		0.781	0.885		
Perceived usefulness	USE1	0.944	0.852	0.931	0.960	0.856
	USE2		0.855	0.951		
	USE3		0.803	0.918		
	USE4		0.810	0.901		
Attitude	AT1	0.952	0.869	0.948	0.969	0.911
	AT2		0.885	0.962		
	AT3		0.848	0.954		
Intention to use	IU1	0.961	0.911	0.965	0.975	0.928
	IU2		0.887	0.969		
	IU3		0.876	0.956		

the effects of the employed factors in the research model on the intention was calculated (without the factors in the original TAM). Table 11 lists the results of the total standardized effects of four values of intention.

6 Discussion

An acceptance model was proposed for smart home services integrating enjoyment, compatibility, perceived connectedness, control, system reliability, security, and cost as the core motivations based on TAM. The structural results indicate how the factors employed affect the adoption of smart home services. The results show that perceived usefulness is the most influential predictor of intention and attitude. Moreover, the effects of compatibility were investigated as the greatest motivation, highlighting the significance of providing compatible services between the traditional user devices and components in the service for users.

As explained in the structural results, perceived usefulness, which was enhanced by one strong (compatibility),

Table 8 Discriminant validity test (the square roots of average variance extracted are presented in the diagonal positions)

	1	2	3	4	5	6	7	8	9	10	11
1. Enjoyment	0.894										
2. Perceived connectedness	0.671	0.831									
3. Perceived control	0.297	0.311	0.920								
4. Perceived system reliability	0.233	0.248	0.114	0.929							
5. Perceived security	0.673	0.382	0.408	0.250	0.760						
6. Compatibility	0.560	0.556	0.292	0.225	0.552	0.913					
7. Perceived cost	−0.101	−0.101	−0.154	−0.078	−0.094	−0.100	0.861				
8. Perceived ease of use	0.526	0.229	0.305	0.355	0.252	0.425	−0.171	0.906			
9. Perceived usefulness	0.581	0.510	0.353	0.221	0.228	0.508	−0.146	0.542	0.925		
10. Attitude	0.592	0.318	0.287	0.346	0.371	0.521	−0.220	0.616	0.546	0.954	
11. Intention to use	0.204	0.301	0.300	0.289	0.095	0.104	−0.300	0.224	0.616	0.147	0.963

Table 9 Fit indices of the measurement and research models

Fit index	Measurement model	Research model	Recommended value	References
GFI	0.917	0.912	>0.900	[87–92]
AGFI	0.903	0.901	>0.900	
RMSEA	0.072	0.079	<0.080	
NFI	0.901	0.887	>0.800	
NNFI	0.909	0.904	>0.800	
CFI	0.905	0.903	>0.900	
IFI	0.929	0.919	>0.900	
$\chi^2/d.f.$	4.855	4.895	<5.000	

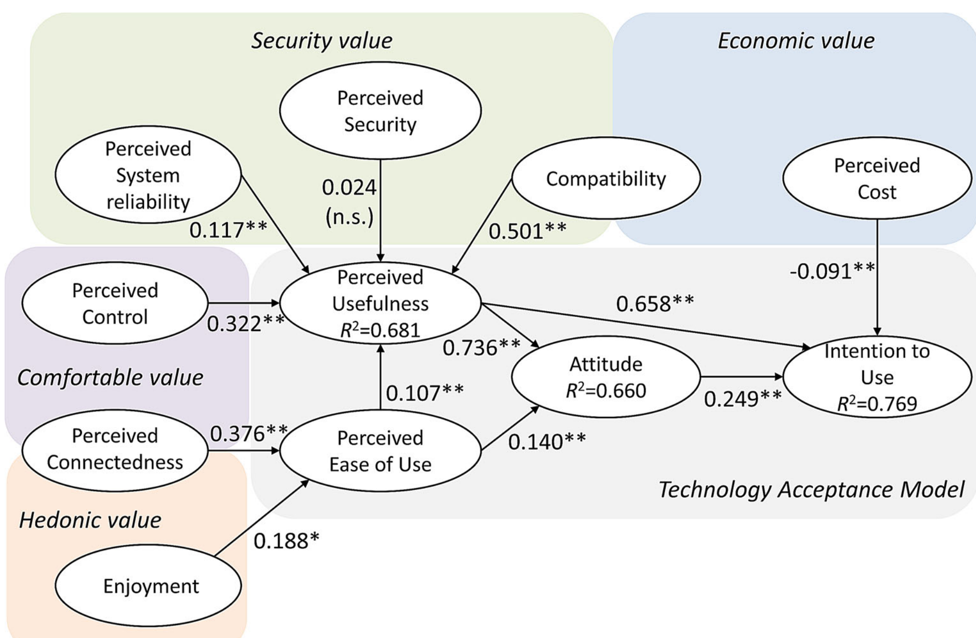

Fig. 3 Summary of the research model (*$p < 0.05$, **$p < 0.001$)

two moderate (perceived connectedness and control), and two weak (perceived system reliability and enjoyment) factors, played a key role in leading to a positive attitude and intention. In particular, the effects of compatibility and perceived control on the usage intention were greater than those of enjoyment, perceived cost, connectedness, and

Table 10 Results of the research model

Hypothesis	Standardized coefficient	SE	CR	Supported
H1. Attitude → Intention to use	0.249**	0.041	6.918	Supported
H2. Perceived usefulness → Intention to use	0.658**	0.045	17.363	Supported
H3. Perceived usefulness → Attitude	0.736**	0.033	23.942	Supported
H4. Perceived ease of use → Attitude	0.140**	0.029	5.154	Supported
H5. Perceived ease of use → Perceived usefulness	0.107**	0.027	3.991	Supported
H6. Enjoyment → Perceived ease of use	0.188*	0.074	2.493	Supported
H7. Perceived connectedness → Perceived ease of use	0.376**	0.099	4.821	Supported
H8. Perceived control → Perceived usefulness	0.322**	0.043	7.607	Supported
H9. Perceived system reliability → Perceived usefulness	0.117**	0.025	4.820	Supported
H10. Personal security → Perceived usefulness	0.024	0.047	0.620	Not supported
H11. Compatibility → Perceived usefulness	0.501**	0.046	11.662	Supported
H12. Perceived cost → Intention to use	−0.091**	0.023	−4.566	Supported

* $p < 0.05$
** $p < 0.001$

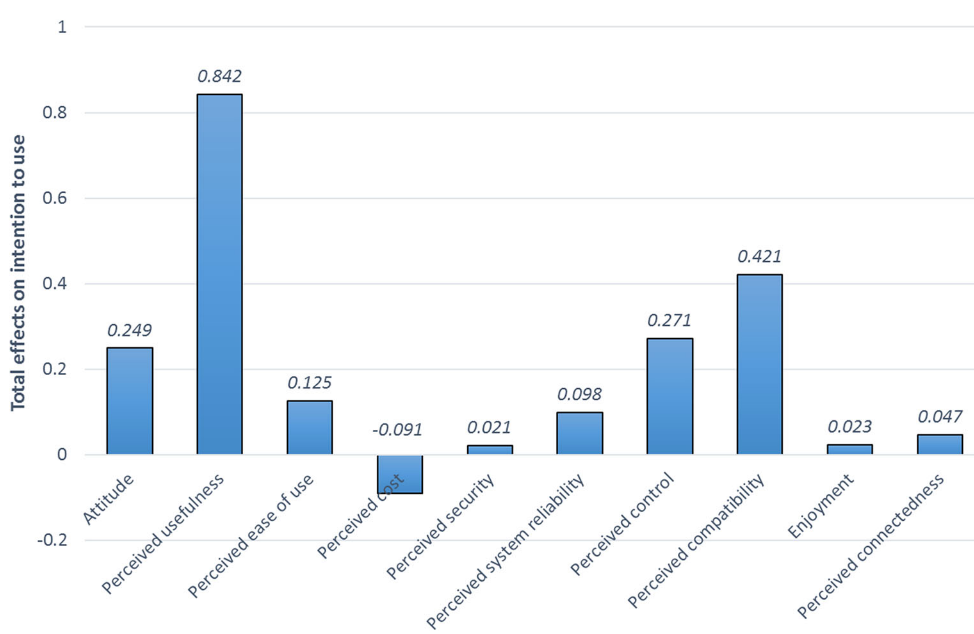

Fig. 4 Total standardized effects on intention to use

system reliability. This shows that an easily controllable and compatible interface is required to improve the users' experience of smart home services.

Another significant finding is that the perceived connectedness and system reliability are the notable motivations of TAM. This means that the users' acceptance is

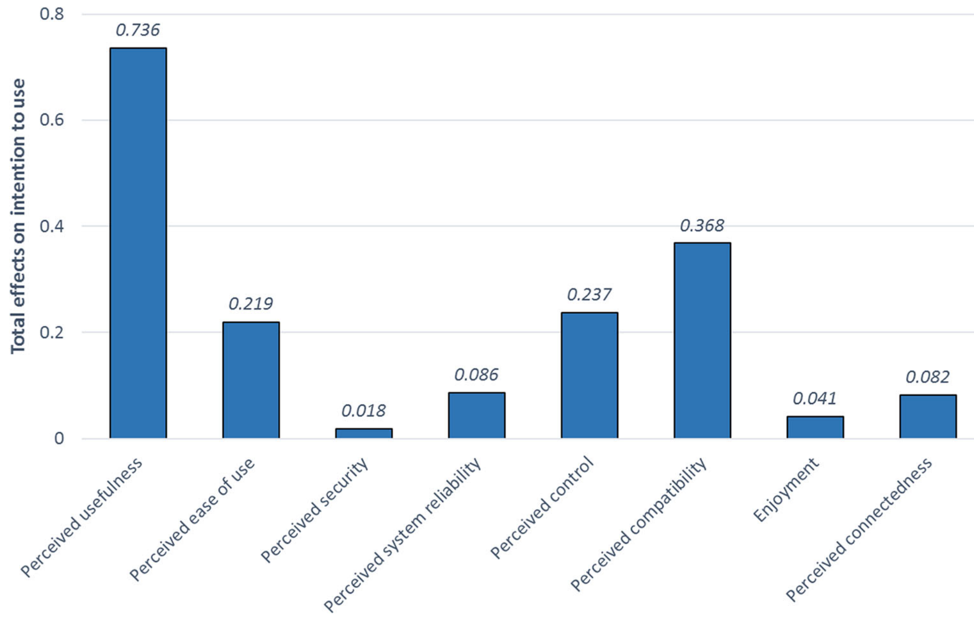

Fig. 5 Total standardized effects on attitude

Table 11 Total standardized effects of four values on the intention

Values	Hedonic	Comfort	Security	Economic
Effects	0.070	0.318	0.540	0.512

Perceived connectedness is included in both comfort and hedonic values; compatibility is included in both economic and security values; the absolute effect of perceived cost on the intention is used

associated with not only providing more reliable connected services but also suggesting the connections among the components in the services. Although the perceived cost and enjoyment had notable impacts on the users' intention, the magnitude of the effects of these factors was smaller than that of other motivations. This suggests that users already take a notable amount of investment into consideration with utilitarian perceptions. Moreover, because the majority of participants in the main survey were older than 30 years of age, lived in apartments in metropolitan areas, and hold college or graduate degrees, they were more likely to have the financial capacity to buy, use, and operate the services without having to consider the cost.

Both theoretical and practical implications can be presented by the findings of the present study. In a theoretical perspective, the research model integrating the original TAM framework and seven external motivations was validated, demonstrating the theoretical validation and capability of TAM for predicting the acceptance of newly introduced services. In particular, the study presents an improved comprehension of the structural connection among the security, comfort, hedonic, and economic values through the original TAM.

In a practical perspective, the research model of the present study provides an awareness of the acceptance pattern of the popularized information-oriented services in a housing context. Moreover, service providers and related industry can take ideas for improving the current services from the research model. The developers of smart home services should aim to provide easily controllable and connected interfaces and the background for the efficiency and usability of the services by considering the user-based (market-oriented) approach, rather than a technology-oriented approach in the manufacturing and designing process.

However, various study limitations raised the following points that need to be addressed in future studies. First, the present study did not consider any individual characteristics that can be associated with the intention to use information-oriented services. Second, the study results may be difficult to generalize in other contexts. The respondents in the main survey were more likely to be more innovative, self-motivated, and interested in their housing contexts. Moreover, consumers' cultural difference is one of the most important and significant antecedents of their intention to use particular services. By demonstrating the suggested limitations, future research will extend the present study findings and provide a more comprehensive understanding of smart home services. For example, future research can utilize the present findings to explore how other emotional and psychological motivations can affect the patterns of the consumers' service usage. Moreover, future research can also investigate the inter-correlations among seven external factors (perceived cost, security, system reliability, control, connectedness, enjoyment, and compatibility) and four value concepts (economic, security, comfortable, and hedonic). The proposed research model can be used as a baseline for explaining and understanding the user adoption of smart home services in future research that includes other potential factors as determinants of consumers' intention to use, in order to enhance the generalization of future research results.

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