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Embracing the Smart-Home Revolution in Asia by the Elderly: An End-User Negative Perception Modeling

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ABSTRACT There has been a rapid growth in the Internet of Things (IoT) enabled smart-homes recently. Although these IoT powered smart-homes offer new opportunities, their household penetration is quite low. The main objective of this paper is to develop a better understanding of the reasons underlying the end-user resistance to the adoption of the IoT enabled smart-homes, with elderly people as the target population. Due to a rapid increase in the worldwide elderly population, various forms of information and communication technology (ICT) services are used for their well-being, and hence the target of this paper. A very few research has focused on the end-user experience of using smart-homes with all of them using an acceptance-based approach. Using different negative-perception modeling, we try to identify the main barriers to smart-home usage by the elderly people. Accordingly, an online survey was conducted with 254 elderly people across four Asian countries. Partial least squares structural equation modeling (PLS-SEM) was used to test our theoretical model having ten constructs. Two constructs (perceived-uselessness and self-efficacy) were found to be non-significant, while the remaining proved to be significant (innovativeness, perceived-reliability, perceived-interoperability, service-cost, privacy-concern, psychological-barrier, home administrative policy, and government-policy). To the best of our knowledge, this is the first research studying the IoT enabled smart-homes using a resistive approach and should provide the groundwork for further research in user-experience studies with IoT technology.

INDEX TERMS Elderly, IoT, negative perception modeling, resistance, smart-home services.

I. INTRODUCTION

The amalgamation of various Internet of Things (IoT) based devices and our traditional homes has resulted in the creation of *'smart-homes'*. For this research, we define smart-homes as "*a residence which is equipped with high-tech network, linking sensors and other IoT based domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants*" [1], [2]. As of 2019, the global smart-home market is valued at $46.25 million US Dollars (USD) and is expected to grow at a rate of 25% from 2019-2022 [3]. However, the household penetration stands at only 7.5% in 2019 (mostly concentrated in the United States), which shows that the rate of adoption is quite low [3]. At the same time, an increase in the elderly population globally has been a cause of serious concern among the research fraternity [4]. With the recent advancements in IoT and other related Information and Communication technologies (ICT), including smart-homes, they can be used by the aged people for various types of healthcare and social support services [5], [6].

Although, a lot of work is being done on the technological aspects of smart-homes, yet their adoption rate is very low mainly due to their disruptive nature and inherent conservativeness of the older people towards any new technology [7], [8]. The main thrust of current research, is on the underlying IoT and smart-home technologies like the devices, sensors, communication protocols used and the services they provide [9]– [11]. However, very little is known

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about the subjective opinion of the people towards using these services [9]. Also, the physical and psychological needs of people change with age [12]. The elderly people tend to possess certain unique characteristics that need to be taken into account when developing and commercializing smart-home solutions for them [13].

Slow penetration of the various smart-home services among the end customers is a cause of concern for the IoT industry. Clearly, there is a strong consumer resistance towards these new smart-home services and technologies. This resistance can manifest itself in three different forms: rejection (consumer does not accept a product/service), post-ponement (current circumstances are not suitable for adopting a product/service) or opposition (consumers perceive a product/service to be a threat and hence resist its adoption) [14], [15]. For this work, we investigate into the factors responsible for its low adoption using a resistive approach in order to reduce the probability of innovation failure. Adoption and resistance are two faces of a coin, which can ''coexist during the life of an innovation'' [16].

There are three aspects in which current research on IoT and smart-homes lack. First, there are extremely few works that focus on the end-user psychology that tries to understand the users' basic needs, their specific requirements, and other motivational factors that can influence the decision making process. Second, all these works (discussed in detail later in the literature review section) take an adoption/diffusion approach in order to gauge the user intention towards the smart-home services. However, this is insufficient because they do not take into account the oppositional reactions of the end users and other resistive factors that are responsible for the low adoption rate of the smart-homes. Adoption will begin only after the initial resistance offered by the end users, and hence understanding the resistive factor(s) in the first stage of any new product/service is a key issue. Third, since the concept of smart- homes is relatively new; hence the engagement of the elderly users' with these systems/services is less probable, as traditionally they are reluctant to accept any new innovative solutions [17]. The older adults' adoption of technology is a complex issue that is affected by many factors and needs special treatment [18].

Clearly, there is a research gap and lack of relevant theoretical framework(s), modeling the smart-home usage by the general people and elderly users' in particular. We aim to bridge this gap by providing a better understanding of the elderly users' resistance to smart-home usage. Specifically, we aim to answer the following two research questions:

R_1: What are the factors that influence the older adults' resistance towards using various smart-home services and what is the underlying theoretical model?

R_2: How does the proposed resistive model perform in an empirical setting?

The novelty of this research can be judged by two aspects. First, instead of looking into the adoption scenario, we try to identify the risk factors and barriers to adoption and propose a resistive theoretical framework. We believe that by implementing this negative-perception modeling, the exact reasons of low smart-home usage among the end users' can be identified and proper theoretical, methodological, and managerial /policy implications can be framed. Second, we give special emphasis to the elderly people and try to explore factors that are specific to this target group.

The remaining paper is divided into six sections. SECTION II provides the background and related research. SECTION III presents the conceptual development, hypotheses, and the theoretical framework. The research methodology used has been detailed in SECTION IV along with the results in SECTION V. Finally, SECTION VI deals with the conclusion, implications obtained from this study along with the current shortcomings of this research and the scope of future work.

II. BACKGROUND AND RELATED RESEARCH

In this Section, we setup the context to this research by using two approaches: 1) a thorough systematic review of the current literature and 2) conducting semi-structured interviews with elderly people in particular (aged 55 and up) who are actually residing in a smart-home. Using this dual approach, we aim to identify the actual usage scenario of the smart-home services by the elderly people along with identifying the potential barriers to the user perception and the current state of theoretical work related to smart-home usage by this group of people.

A. SYSTEMATIC LITERATURE REVIEW

An extensive search on relevant databases (IEEE Xplore, ACM Digital Library, SpringerLink, ScienceDirect, PubMed, and Web of Science) was conducted using certain keywords. Data filtering was done using an inclusion/exclusion criterion that had been setup specifically for this purpose. The systematic review that was conducted is an extension of the work presented by the authors in [19]. The flowchart of the study selection, including the search queries used and the inclusion/exclusion criterion has been shown in Fig. 1. Three independent researchers were assigned with this task. Any ambiguity regarding the inclusion/exclusion of particular literatures were sorted out via mutual discussions, both during the abstract matching as well as the full-text reading phases. Cohen's kappa (κ) score (statistical measure of inter-researcher reliability) of 0.748 and 0.716 was obtained for the abstract matching and full-text reading phases respectively, with both being significant ($p < 0.001$).

Out of the 43 literatures that were included for the final analysis, 31 of them deal with the underlying IoT based smart-home technologies and the varied form of services that they provide. All the end-users that were involved in the experiments were elderly people being exposed to some form of service that belong to any one of the five domains: health monitoring, environment monitoring, social communication, recreation and entertainment, or providing companionship. Health monitoring is an active area of research, where various sensors and other IoT devices are used for gathering data,

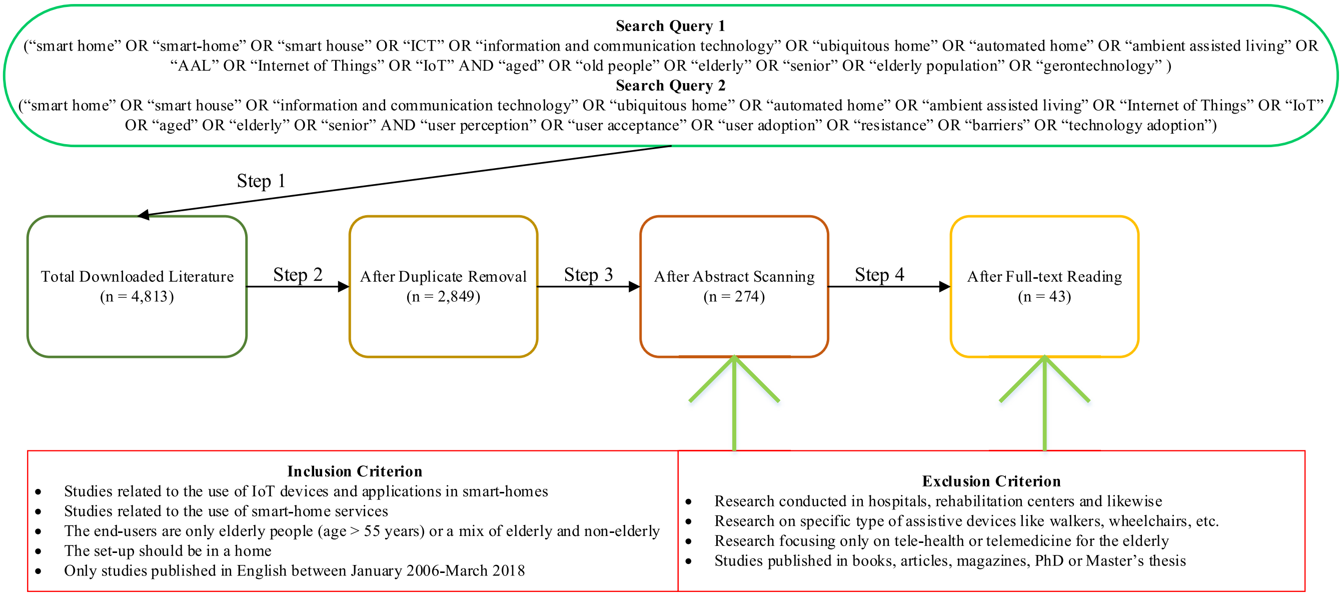

FIGURE 1. Flowchart of study selection showing search queries and inclusion/exclusion criterion used.

TABLE 1. Current state of end user perception modeling for IoT based devices and smart homes.

Ref No	Use-case	Approach	Theoretical Framework	End users	Concerning Factors
[20]	Smart homes	Acceptance modelling	Modified TPB	Varied age group	Privacy and Physical risk
[21]	Smart homes	Acceptance modelling	Modified TAM	Varied age group	Cost, Privacy/Security risk
[22]	Ambient assisted living	Resistive modelling	×	Elderly	Cost, Interoperability, Privacy/Security risk
[9]	Ambient assisted living	Acceptance modelling	×	Elderly	×
[23]	Smart homes	Acceptance modelling	TAM/VAM	Varied age group	Privacy risk, Innovation resistance
[24]	Smart homes	Acceptance modelling	TAM/TRA/TPB	Elderly	Reliability, Privacy/Security risk, Cost
[25]	Smart homes	Acceptance modelling	Modified TAM	Varied age group	Cost
[26]	Smart homes	Acceptance modelling	Modified UTAUT	Varied age group	×
[27]	Smart homes	Acceptance modelling	×	Varied age group	Reliability, Privacy/Security risk, Cost
[28]	Smart products	Resistive modelling	Self-proposed	Young students	Privacy risk, Cost, Innovativeness
[29]	IoT based devices	Acceptance modelling	Modified TAM	Varied age group	×
[32]	Smart homes	Acceptance modelling	Self-proposed	Elderly	Expert advice, Cost, Technology anxiety, Trust

TAM: Technology Acceptance Model
TRA: Theory of Reasoned Action
TPB: Theory of Planned Behavior
UTAUT: Unified Theory of Acceptance and Use of Technology
VAM: Value Based Adoption Model

which are subsequently analyzed for detecting anomalies and taking corrective measures. Details about the relevant literatures explaining all the use-cases can be obtained in [19].

There is one major observation from the systematic literature review. 31, out of 43 literatures (around 72%) deal with providing various innovative smart-home services or improving the underlying technology, with no mention about the subjective opinion of the end-users who are a part of the study. Hence, there is very limited knowledge with respect to the end-user's perception about these services along with the factors that can motivate/demotivate them from using such a system. In TABLE 1., we provide a summary of the work that has been done from an end-user technology adoption point of view in the context of IoT based devices and smart-homes. Most of the research follows a technology acceptance based approach, with only three of them concentrating solely on the elderly users. Clearly, there is a lack of theoretical approach in end user perception modeling. For this work, we follow an innovation resistance approach to identify the barriers that are responsible for the low acceptance rate of the various IoT based smart-home services.

B. SEMI-STRUCTURED INTERVIEW

With respect to the current research presented in [20]– [32], our work differs in the way the factors are identified, which affect the service acceptance. Apart from the systematic literature review, we interview some elderly participants who have been living in a smart-home for months, past the novelty phase and into day-to-day use. Thus, our aim is to build a framework that is based upon real-life use cases of the various smart-home services, rather than providing with a hypothetical and conceptual scenario that is adopted by the current works.

The semi-structured interview was conducted in the smart-city of Lavasa in Pune, India for a period of 1 month (December 2018). 12 participants were interviewed (mean

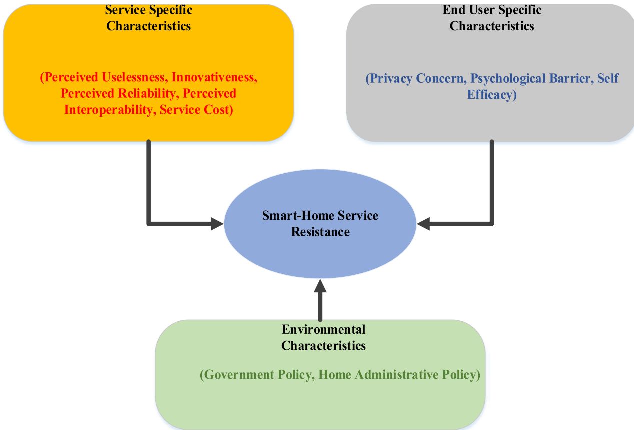

FIGURE 2. **Barriers to smart-home services adoption.**

age of 63.2 years) by two researchers: one in charge of the interview process and the other one taking down relevant notes. The semi-structured interview process has a certain degree of flexibility, due to which this qualitative technique was chosen [30], [31]. On an average, each interview lasted for 45 minutes. All the participants were staying in a smart-home for at least 1 year (min = 1.2 years and max = 3 years). Two of the elderly participants were female with the remaining ones being male.

The participants were asked questions like describing the smart-home devices they own, how they use it, what concerns they have using the various smart-home services (specially related to security and privacy), whether they had any disagreements with other users of the smart-home and their long-term perception after using the service.

While analyzing the data obtained from the semi-structured interview process along with the previously carried out systematic review, we tried categorizing the resistive factors into certain themes. Three broad themes are identified as: a) service-specific characteristics, b) end-user characteristics and c) other environmental characteristics. Fig. 2 shows the details of the broad themes identified and lists down the factors in a thematic basis. 10 prohibitive factors are identified that forms the basis of our research model and discussed in detail in the next section. Using this dual approach of systematic literature review along with semi-structured interviews with elderly people having hands-on experience in using an IoT based smart-home service for factor identification, makes our proposed theoretical framework more robust and realistic in nature.

C. CONCLUSION

From a theoretical perspective, the current literature falls short in a number of aspects. First, majority of the existing research is based on a technology adoption perspective related to the study of smart-homes and related services. An adoption based perspective is advantageous in providing an assessment of the market potential or predicting the success of a new product [33]. However, they are insufficient, as they do not take into account the oppositional reactions from the consumers [16]– [34]. It is essential to include the drivers of consumer resistance when considering the introduction of new products/services because these drivers may present obstacles to the diffusion and acceptance of an innovation [35].

Similarly, from a managerial perspective also, studying innovation through a resistive approach reduces the probability of innovation failure [16]. It provides opportunities for the companies to change the attributes of a new product and boost the rate of adoption [36].

Research investigating the effects of the IoT based smart-homes on the elderly mindset in extremely limited. Moreover, majority of the existing works focus on the health aspects of the elderly people [22]– [32]. In addition, none of them takes into account the resistive factors that can play a role into their acceptance. Hence, the existing research gap is clear, which forms the motivation for the present work. We aim to propose a theoretical framework underlying the elderly mindset in using the smart-home services using a negative perception modelling approach. For creating a more robust model by proposing the most relevant attributes for the present context, a dual approach of literature review combined with a semi-structured interview has been conducted. 10 resistive factors are identified (8 from the literature review, and 2 novel factors from the semi-structured interview). The underlying factors along with the theoretical framework are presented next.

III. CONCEPTUAL DEVELOPMENT, HYPOTHESES AND THEORETICAL FRAMEWORK

In this section, we elaborate on the 10 prohibitive factors that have been identified by giving them a working definition, establish relationships between them by framing suitable hypotheses, and finally presenting our proposed theoretical framework.

A. PERCEIVED USELESSNESS (PU) (SERVICE-SPECIFIC CHARACTERISTICS)

Perceived usefulness is one of the key constructs of TAM, which is a widely used theoretical framework for evaluating adoption patterns [37]. It has a positive effect on the adoption intention, which has been established by many previous researches in a variety of contexts [38]– [41]. For the present work, since we are looking for the prohibitive factors responsible for the low adoption rate of the IoT based smart-home services, hence perceived uselessness is taken as a more relevant factor that lies at the opposite spectrum of perceived usefulness. We define perceived uselessness as *"An individual's negative assessment or perception about the usefulness of a particular technology or service in his/her daily life."* Obviously, if the end user's feel that a product or service is not useful, its adoption rate will be low. Generally, the elderly people are less tech-savvy [42]. Hence, unless they find the new services to be useful, the probability of acceptance is slim. The relevant hypothesis is framed as:

H_1: Perceived uselessness has a positive impact on the elderly users' smart-home services resistance.

B. INNOVATIVENESS (I) (SERVICE-SPECIFIC CHARACTERISTICS)

Innovativeness can be defined as *"the willingness to accept any new technology or service if it is considered to be innovative i.e. novel"* [43]. Novelty can be perceived by the end users' when there is a radical change in a product concept or some attribute of the product [44]. Many prior studies have considered *'innovativeness'* to be a critical factor in technology adoption; particularly with new technologies [45], [46]. If the users perceive that using the various home IoT devices and other smart-home services aid in their daily life or are capable of bringing radical positive lifestyle changes, the probability of technology acceptance will increase. Hence, the services being provided by the smart-homes must be groundbreaking and disruptive enough to have a positive influence on the peoples' mind. The positive association of innovativeness with technology adoption has been considered in a number of previous researches also [47]– [49]. Using any new technology or service has a certain degree of learning curve associated with it, and therefore will be an interesting factor to investigate keeping in mind the special needs and characteristics of the elderly people [13]. Accordingly, we posit:

H_2: Innovativeness has a negative impact on the elderly users' smart-homes services resistance.

C. PERCEIVED RELIABILITY (PR) (SERVICE-SPECIFIC CHARACTERISTICS)

With any new device or service, the users are uncertain about their performances. There can be concerns in the mind of the end users' regarding device malfunction, stability of the services being provided, overall quality of the products/services, etc. In the present context, we define perceived reliability as *"the possibility of the IoT based home devices malfunctioning and not being able to provide the intended/advertised services."* The evolution of smart-homes has just begun, and hence some aspects of the underlying technology may be immature [50]. This can cause concerns among the end users' related to the overall system reliability that negatively affects its adoption. Previous research has shown the association of reliability and the underlying technological uncertainty to the end user acceptance of a product/service [51], [52]. This factor is particularly important for the elderly population that we consider due to their inherent conservative nature and resistance to any new technology [17]. Hence, we propose the following hypothesis:

H_3: Perceived reliability has a positive impact on the elderly users' smart-home services resistance.

D. PERCEIVED INTEROPERABILITY (PI) (SERVICE-SPECIFIC CHARACTERISTICS)

Smart-homes typically contain devices made from different manufacturers. Enabling these different devices, applications and ecosystem to work in tandem is a serious challenge due to a confusing array of technologies and protocols used (Zigbee, Z-Wave, Bluetooth, Wi-Fi, etc.). This is where perceived interoperability comes into play that can adversely affect the user's intention to use the system. In the context of smart-homes, interoperability can be achieved either by adopting universal standards for a communication protocol or by using a specialized device in the home network that acts like an interpreter among the different smart-home devices and protocols [1]. The relationship between interoperability and usage acceptance has been established by previous research in the context of smart wearable devices and big data solutions for organizations [38], [53]. Keeping in mind the conservative nature of the elderly people in general, and their non-willingness to accept newer technologies/services, this can be factor worth investigating for the present context. Perceived interoperability is therefore defined as "*the degree to which the different devices/sensors from the different manufacturers can work and communicate among themselves to provide a uniform and comprehensive service"* The relevant hypothesis is:

H_4: Perceived interoperability has a negative impact on the elderly users' smart-home services resistance.

E. SERVICE COST (SC) (SERVICE-SPECIFIC CHARACTERISTICS)

The high initial cost, which is associated with any new technology, product, or service, is often seen as a major obstacle towards their acceptance [54], [55]. A number of previous studies on innovative and new services ranging from mobile-commerce systems, e-training services, high-speed home-based broadband access to the acceptance of smart-meters have found a close relationship between cost and user perception [56]– [59]. Generally, the elderly people lead a retired life, and therefore have a limited source of income. Therefore, a higher service cost can definitely prove to be a resistive factor for its acceptance. In the present context, we define service cost as "*the cost that has to be incurred by the elderly people to purchase, install, maintain, and repair the various components and devices which are a part of the smart-home system."* The relevant hypothesis is:

H_5: Service cost has a positive impact on the elderly users' smart-home services resistance.

F. PRIVACY CONCERN (PC) (END-USER-SPECIFIC CHARACTERISTICS)

Concern for protecting users' data and its privacy is a challenge today, especially with an increase in the development of various types of IoT based smart-devices and services [60], [61]. The smart-homes are capable of collecting, managing, monitoring, and analyzing the personal data that they gather from its residents. This data contains private and sensitive information such as logs of personal activities, health status and financial information [62]. The general mass along with the elderly people have negative views regarding the privacy aspect, which can affect the adoption of such systems/services [63]– [64]. We define privacy concern as "*the state of mind of the elderly people where they* *fear that their personal data will be lost and privacy will be infringed upon."* The hypothesis is:

H_6: Privacy concern positively influences the elderly users' smart-home services resistance.

G. PSYCHOLOGICAL BARRIER (PB) (END-USER-SPECIFIC CHARACTERISTICS)

The concept of IoT based smart-homes is new and the services that it provides lack widespread commercialization. Using a relatively new technology or complicated service can create a negative impression on the end users' mind, which might lead to psychological frustration, pressure, or anxiety about using such a system [65]. This factor is especially true for the elderly people because their adoption of any new technology is a complex issue that is affected by many factors [18]. Traditionally, they are reluctant to accept any new innovative solutions because they fear that it will reduce their peace of mind, create mental stress, increase their dependence on technology and fear of social isolation [48], [66]– [68]. Thus, overall there is a negative impact of technology on the attitude, behavior, and physiology of the human [69]. In our context, psychological barrier is therefore defined as *"the perception of the elderly people of any possible mental frustration, anxiety, pressure, technology-dependence, or social isolation resulting from the use of the smart-home services."* The hypothesis is:

H_7: Psychological barrier positively influences the elderly users' smart-home services resistance.

H. SELF-EFFICACY (SE) (END-USER-SPECIFIC CHARACTERISTICS)

Self-efficacy refers to an individual's mindset that one can successfully execute a certain behavior required to produce certain outcomes [70]. Several researchers have identified a positive relationship between self-efficacy and the intention to adopt technology [71]– [73]. Also, higher the self-efficacy, lesser was the resistance offered to adopt the technology. With the introduction of the IoT based devices and service, there will be a continuous learning curve associated with it, until the technology matures. Therefore, self-efficacy is defined as *"the elderly individuals' positive perception of his/her ability, skill and knowledge to use the smart-home services naturally without seeking any outside human help."* The corresponding hypothesis is:

H_8: Self-efficacy has a negative impact on the elderly users' smart-home services resistance.

I. HOME ADMINISTRATIVE POLICY (HAP) (ENVIRONMENTAL CHARACTERISTICS)

We introduce this factor for the first time that emerged out from the interview that was conducted. The elderly people are incidental i.e. secondary users of the home IoT based devices and services because generally, they are not primarily involved in selecting the devices, configuring them and related service provisioning. Usually, they have limited access to the various resources, which is provisioned by some smart-home service provider or other members of the family (primary users). For example, in the semi-structured interview that we conducted, particularly one elderly participant was frustrated and disappointed because he did not have access to the Nest thermostat (the primary user did not want anybody to access the thermostat to keep the home at a certain temperature to save electricity). Similarly, another elderly user complained of the low broadband speeds that he was getting, compared to other family members. In this case, the primary user had configured the home network (bandwidth provisioning) in such a way that the elderly user was given very limited bandwidth. Hence, the way a smart-home is configured can create discriminations among its users and hence, be a source of frustration and willingness not to use such a service. We, define home administrative policy as *"the manner/policy in which the various IoT based home devices are configured and provisioned to give services that creates a sense of division and inferiority among certain users of the system."* The relevant hypothesis is:

H_9: Home administrative policy positively influences the elderly users' smart-home services resistance.

J. GOVERNMENT POLICY (GP) (ENVIRONMENTAL CHARACTERISTICS)

There is a lack of trust by the end users' in the government policies towards the concept of smart-homes [50]. A general perception among all the interviewees pointed towards a more active participation and long-term engagement plan from the government in the smart-home use-case. Specifically, in certain aspects, like energy saving (by using smart meters) and environmental protection, the users' suggested that government should lead by example by giving incentives to the users or some other means. Therefore, we define government policy as *"various measures taken on behalf of the government that creates a positive perception among the people to use the IoT based smart-home devices and services."* The hypothesis is:

H_{10}: Government policy negatively influences the elderly users' smart-home services resistance.

The final dependable construct that we measure is smart-home resistance (SHR). The relevant theoretical framework as per the hypotheses just proposed, has been shown in Fig. 3.

IV. RESEARCH METHODOLOGY

A. DATA COLLECTION

An online questionnaire was developed and administered among the elderly people to measure their perception regarding the IoT based smart-home devices and services. Before sending out the questionnaire, 4 experts from the domain of information science, IoT technology and human-computer interaction were consulted for ensuring its validity and relevance. The survey was conducted across 4 Asian countries: India, Thailand, Indonesia, and Malaysia.

A non-probabilistic snowball sampling technique was used to recruit the participants, where our contacted elderly

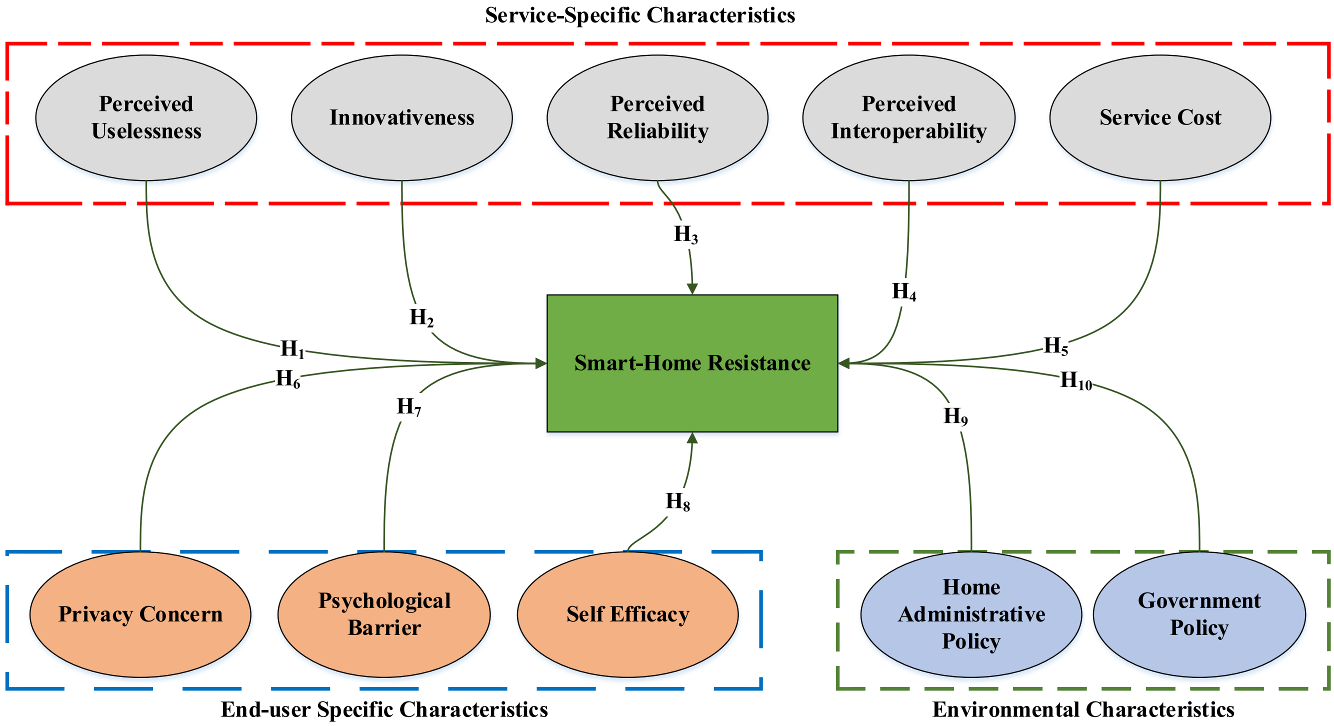

FIGURE 3. **Theoretical framework and hypotheses.**

subjects were further requested to contact their elderly acquaintances.

The survey instrument was structured in two parts. The first part contained certain questions to gather the socio-demographic data of the participants like age, gender, location, and household income, along with a screening question. The screening question was used in order to minimize the hypothetical response biases from those people who absolutely had no idea or prior knowledge about IoT devices and smart-homes in particular. The screening question used was "*Do you know what smart home technologies and services are?*" Response options ranged from "*no idea*", "*vague idea*", "*general idea*", "*and "good idea" to "already using some form of smart home technology*." Respondents who answered "*no idea*" were filtered out from the remaining survey. For all other respondents, they moved on to Part 2. The second part of the survey contained open-ended questions that measure the attitude of the respondents towards the smart-home services. Out of the 254 total responses obtained, 15 did not pass the screening criterion, and hence 239 responses were treated as valid which were used for further analysis. TABLE 2 shows the relevant descriptive statistics of our respondents' socio-demographic background. Fig. 4 shows the respondents percentage distribution for the screening question.

B. CONSTRUCT OPERATIONALIZATION

The second part of the survey contained open-ended questions used for measuring the elderly peoples' resistance to use the smart-home services. A 5-point Likert scale was used to evaluate the questionnaire items (1 = "strongly agree" to 5 = "strongly disagree"). TABLE 3 gives the details of the administered questionnaire along with the relevant descriptive statistics of every construct. For each construct, the changes that were incorporated in the measurement scale have been shown under the references column in TABLE 3. HAP and GP did not have any previously used measurement

TABLE 2. **Characteristics of the elderly used in the study (N = 254).**

Characteristics	Number (N)	N %
Age		
55-64	112	44.1
65-74	90	35.4
75 and above	52	20.5
Gender		
Male	167	65.7
Female	87	34.3
Location		
India	104	40.9
Thailand	85	33.5
Indonesia	29	11.4
Malaysia	36	14.2
Household income		
Less than 15,000	7	2.8
15,001 – 30,000	40	15.7
30,001 – 40,000	139	54.7
More than 40,000	68	26.8
Education		
High school or below	21	8.3
Bachelor degree	164	64.5
Master degree or above	69	27.2
Home ownership status		
Owned	217	85.4
Rented	37	14.6

TABLE 3. Construct operationalization along with descriptive statistics.

Construct	Description	References	Mean	Std. Dev
Perceived uselessness	PU1: The functionality provided by the IoT based smart-homes offer little advantages PU2: Using the IoT devices and services in a smart-home provide little added value PU3: Generally the IoT technologies used in the smart-homes do not help in my daily living	[32, 74]	4.13	0.75
Innovativeness	I1: Living experience in an IoT based smart-home is different from a traditional home I2: The concept of IoT based smart-homes is unique I3: The services offered by IoT based smart-homes are new and rewarding	[75,76]	2.68	1.06
Perceived reliability	PR1:It is uncertain if the service provided by the IoT devices in home will be satisfactory PR2: The IoT devices may malfunction and not provide service as expected PR3: I fear loss of control over my smart-home due to improper functioning of the IoT devices/sensors PR4: IoT based smart-home services are unreliable and with errors	[65]	2.14	0.92
Perceived interoperability	PI1: Purchasing the IoT devices/sensors from different vendors for my smart-home creates operational problems PI2: It is difficult to control the IoT devices present in smart-home with my smartphone PI3: The IoT devices in a smart-home are difficult to be integrated with each other	[38, 77]	2.71	1.03
Service cost	SC1:It is difficult for me to afford the IoT devices and sensors needed for my smart-home SC2: Purchasing and maintaining a smart-home is a burden for me SC3: The subscription charge of my smart-home service provider is very expensive	[78, 79]	3.08	0.94
Privacy concern	PC1: The smart-homes collecting my personal data without my permission concerns me PC2: The information gathered by smart-homes can be tracked, analyzed and misused PC3: I fear to use a IoT based smart-home service due to loss of my data and privacy	[80]	3.36	1.07
Psychological barrier	PB1: Using the services provided by an IoT based smart-home is frustrating and irritating PB2: The complexity in using IoT based smart-homes gives me stress and mental anxiety PB3: I fear that my dependence on IoT based smart-homes will isolate me from my family	[50, 65]	2.84	0.57
Self-efficacy	SE1: I have sufficient knowledge and ability to use the IoT based smart-homes by myself SE2: I will be able to operate the various IoT based devices inside a smart-home although I've never used them before SE3: Adopting IoT based smart-home services is entirely within my control	[81]	3.11	0.86
Home administrative policy	HAP1: I am concerned about the lesser privileges that I am given while using the various smart-home services by the home administrator HAP2: All the users of a smart-home system must be given equal rights with respect to all the services it offers HAP3: Discriminating between the different home users of a smart-home service creates a negative impact on its usage	[×]	3.35	1.12
Government policy	GP1: The government should play a more active role in framing policies encouraging smart-home usage GP2: Limited campaigning and publicity about IoT technology and smart-homes result in overall ignorance among the public	[×]	3.29	0.71
Smart-home resistance	SHR1: I am likely to oppose the use of the services provided by the IoT based smart-homes SHR2: Smart-homes are not for me SHR3: I do not intend to use the IoT technology based smart-homes anytime soon	[15]	2.95	0.83

scale, and hence were framed by us. The next section gives the result analysis in detail.

V. RESULTS

SPSS 17.0 has been used to conduct the Confirmatory Factor Analysis (CFA), while Smart PLS 3.0 is used for carrying out the Partial Least Square Structural Equation Modeling (PLS-SEM) for testing the proposed model and the corresponding hypotheses.

A. PSYCHOMETRIC QUALITY OF CONSTRUCTS

The internal consistency for reliability of the used questionnaire has been measured by the Cronbach's alpha values. These are shown in TABLE 4. For all the constructs, the value of Cronbach's alpha is greater than the threshold level of 0.7, which suggests a high degree of internal reliability [82].

Results for the test of convergent validity have been reported in TABLE 4. Regarding the convergent validity, we verified two conditions:

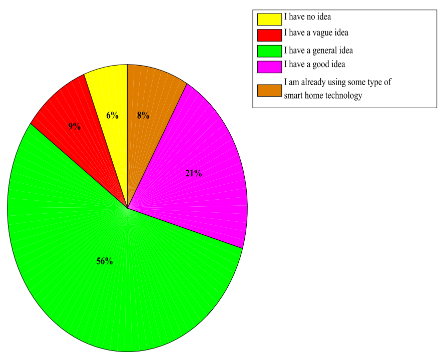

FIGURE 4. Distribution pattern of the screening question.

- The factor loading of every item measuring a particular construct was calculated and found to be greater than 0.6. This is the first minimum requirement for the convergent validity test to pass [83].
- The average variance extracted (AVE) value was also calculated for every construct and found to be greater

TABLE 4. Internal and convergent validity.

Construct	Items	Cronbach's Alpha	Factor Loading	Composite Reliability	Average Variance Extracted
Perceived uselessness	PU1	0.871	0.904	0.932	0.820
	PU2		0.932		
	PU3		0.880		
Innovativeness	I1	0.913	0.916	0.939	0.838
	I2		0.927		
	I3		0.904		
Perceived reliability	PR1	0.920	0.892	0.944	0.807
	PR2		0.910		
	PR3		0.877		
	PR4		0.915		
Perceived interoperability	PI1	0.814	0.864	0.915	0.782
	PI2		0.914		
	PI3		0.875		
Service cost	SC1	0.792	0.851	0.867	0.684
	SC2		0.832		
	SC3		0.798		
Privacy concern	PC1	0.883	0.860	0.863	0.677
	PC2		0.832		
	PC3		0.775		
Psychological barrier	PB1	0.861	0.748	0.810	0.588
	PB2		0.760		
	PB3		0.792		
Self-efficacy	SE1	0.802	0.895	0.953	0.872
	SE2		0.966		
	SE3		0.939		
Home administrative policy	HAP1	0.775	0.925	0.954	0.874
	HAP2		0.947		
	HAP3		0.933		
Government policy	GP1	0.754	0.836	0.832	0.712
	GP2		0.852		
Smart home resistance	SHR1	0.931	0.850	0.852	0.658
	SHR2		0.803		
	SHR3		0.779		

TABLE 5. Discriminant validity.

Construct	PU	I	PR	PI	SC	PC	PB	SE	HAP	GP	SHR
PU	**0.905**										
I	-0.679	**0.915**									
PR	0.608	-0.526	**0.898**								
PI	-0.505	0.425	-0.366	**0.884**							
SC	0.392	-0.568	0.468	-0.523	**0.827**						
PC	0.414	-0.285	0.223	-0.247	0.176	**0.823**					
PB	0.428	-0.598	0.372	-0.416	0.341	0.552	**0.767**				
SE	-0.511	0.561	-0.451	0.472	-0.224	-0.266	-0.674	**0.934**			
HAP	0.359	-0.324	0.322	-0.363	0.265	0.292	0.418	-0.331	**0.935**		
GP	-0.250	0.411	-0.213	0.452	-0.428	-0.454	-0.691	0.226	-0.132	**0.844**	
SHR	0.163	-0.632	0.574	-0.426	0.653	0.617	0.414	-0.254	0.497	-0.398	**0.811**

than 0.5, which is the second test for convergent validity [84]. Therefore, the mean variance shared between the latent variable (construct) and its indicators (items) is greater than 50%. When AVE is greater than this threshold, the variance explained by the items is greater than the variance arising from the measurement error.

The discriminant validity of the constructs was also tested, in order to ensure that two measures, which are not supposed to be related, are in fact, unrelated. The result of the discriminant validity test has been reported in TABLE 5. While examining the discriminant validity, the square root of the AVE for every construct should be greater than the correlational values that it shares with the other constructs. This is exactly what happens in our case (the diagonal elements in TABLE 5 represent the square root of AVE). Thus, the discriminant validity is also confirmed.

B. HYPOTHESES TESTING

The hypotheses testing was done in Smart PLS 3.0. In order to test for the significance level and obtaining the path coefficients, the bootstrapping procedure was followed [85]. In the bootstrapping method, subsamples are created with randomly drawn observations from the original set of data (with replacement). The sub-sample is then used to estimate the PLS path model. The process is repeated until a large number of random sub-samples have been created. For our

TABLE 6. Results of hypotheses testing.

Hypothesis No	Path	Standardized Coefficient (β)	t-statistics	p-value	Status
H_1	PU -> SHR	0.027	0.529	0.324	**Not supported**
H_2	I -> SHR	-0.478	5.863	< 0.001	Supported
H_3	PR -> SHR	0.336	3.129	< 0.001	Supported
H_4	PI -> SHR	-0.314	3.071	0.032	Supported
H_5	SC -> SHR	0.826	16.792	< 0.001	Supported
H_6	PC -> SHR	0.621	12.346	< 0.001	Supported
H_7	PB -> SHR	0.282	2.347	< 0.001	Supported
H_8	SE -> SHR	-0.046	0.773	0.510	**Not supported**
H_9	HAP -> SHR	0.208	2.168	< 0.001	Supported
H_{10}	GP -> SHR	-0.195	1.943	< 0.001	Supported

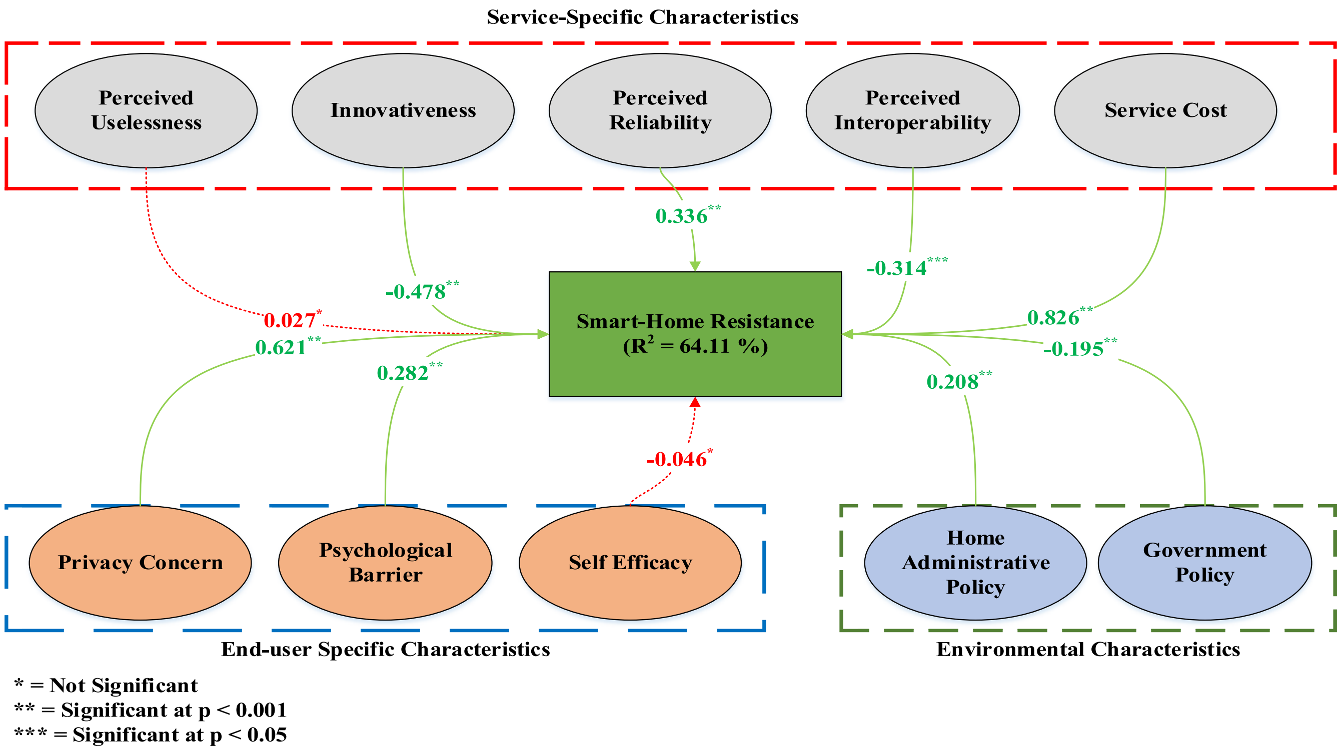

FIGURE 5. Final theoretical framework.

case, we used a maximum iteration value of 300 that gives an optimal performance [85]. TABLE 6 gives the results of the hypotheses testing, while the final theoretical framework has been shown in Fig. 5.

For PLS-SEM, the goodness-of-fit index (GoF) is calculated in an alternative way as outlined in [86]. The AVE and R^2 values obtained from the structural model are used for calculating the GoF index. The recommended GoF value should be greater than 0.36 [86], [87]. We obtain a GoF value of 0.73, thereby proving the model validity.

Results show that the relationships between perceived uselessness ($\mathbf{H_1}$) and self-efficacy ($\mathbf{H_8}$) to the smart-home resistance are not supported (in both cases the p-value is greater than 0.05), while the remaining ones are valid. Service cost is the greatest predictor of smart-home resistance with a β value (path coefficient) of 0.826 ($\mathbf{H_5}$, $\beta = 0.826$, t-statistics $= 16.792$, $p < 0.001$). This is followed by privacy concern, which also has a significant positive impact on the smart-home resistance ($\mathbf{H_6}$, $\beta = 0.621$, t-statistics $= 12.346$, $p < 0.001$). The three constructs, innovativeness, perceived interoperability and government policy are significant and all have negative impacts on the smart-home resistance ($\mathbf{H_2}$, $\beta = -0.478$, t-statistics $= 5.863$, $p < 0.001$; $\mathbf{H_4}$, $\beta = -0.314$, t-statistics $= 3.071$, $p = 0.032$ and $\mathbf{H_{10}}$, $\beta = -0.195$, t-statistics $= 1.943$, $p < 0.001$). This proves hypotheses $\mathbf{H_2}$, $\mathbf{H_4}$ and $\mathbf{H_{10}}$. The remaining three constructs: perceived reliability, psychological barrier, and home administrative policy are also supported and have positive impacts on smart-home resistance ($\mathbf{H_3}$, $\beta = 0.336$, t-statistics $= 3.129$, $p < 0.001$; $\mathbf{H_7}$, $\beta = 0.282$, t-statistics $= 2.347$, $p < 0.001$ and $\mathbf{H_9}$,

$\beta = 0.208$, t-statistics = 2.168, $p < 0.001$). All the factors taken together can explain 64.11% of the variance in the dependable construct i.e. smart-home resistance.

VI. CONCLUSION, RESEARCH IMPLICATION, AND LIMITATIONS

A negative perception modeling has been used for this work to identify the factors that resist the IoT based smart-home adoption among the elderly people in an Asian context. In order to propose a relevant and more realistic theoretical framework, apart from conducting a systematic literature review, we also carried out a semi-structured interview with elderly people who were actually using a smart-home. A number of useful insights are obtained from this research, which are discussed next.

A. THEORETICAL IMPLICATIONS

Our results show that the positive influence of perceived uselessness on smart-home services resistance (as proposed in the hypothesis) is not valid. This is a very encouraging fact, because it implies a positive mindset of the elderly people to use the IoT based smart-home services for fulfilling their needs. The effect of perceived usefulness on the behavioral intention has been established by many previous researches and is proved in our case too [38]– [41]. The participants in our survey have overall positive perceptions about the IoT technologies being used for providing the smart-services in a home and they consider them to add significant values to their life. This is in line with the general opinion that we obtained from the conducted interview, where all the elderly people agreed to the fact that using IoT devices installed in their homes enrich their life in some meaningful way.

There is a considerable negative effect of innovativeness on the smart-home services resistance as evident from a moderate β value of -0.478. This implies that the elderly people perceive the IoT technology and the varied devices/sensors used to be different from their normal perception and the services they provide to be unique. To them, the entire changes brought forward by the IoT era in the form of smart-homes, are too radical, disruptive and new. These elderly people have an inherent characteristic to resist changes and rely less on technology [17], [18]. Therefore, to them a technology being novel will alleviate their perceived risk associated with the technology innovation.

Furthermore, perceived reliability has a positive association with the smart-home services resistance. The elderly people perceive the underlying IoT technology that powers the smart-homes to be still immature and the various devices/sensors used to be unreliable. Often, this group of people have limited physical mobility due to their age. Therefore, they expect a robust performance from whatever device they own and use. Due to the very little commercialization and availability of the smart-homes and related services, the users are concerned about the after-sales service and other maintenance issues that might crop up from using such a system.

Perceived interoperability is another factor that affects the smart-home usage in a negative way. The users' find it difficult to purchase IoT products from different vendors and make them work together seamlessly. Therefore, the capability of cross-device communication from different manufacturers is extremely limited, which points towards a lack in technical standardization. The elderly people have limited enthusiasm in learning new technology [13], [17]. They expect plug-and-play type of devices that can easily integrate with their existing infrastructure.

We also examine the effect of service cost on the smart-home services resistance. Technological innovations are generally expensive and majority of the people (apart from the early adopters) are reluctant to spend substantial amounts of money [88], [89]. This is particularly true for the elderly people as they live a retired life having limited source of income and hence, differ from the early adopters [90]. Our research provides empirical evidence of the positive effect of price on end-user resistance. In-fact, the highest β value is obtained in this case, which signifies the importance of this factor.

Another contribution of the present research is to show that privacy concern influences the elderly resistance in using smart-homes. Previous findings assert the concerns of data privacy and leakage of sensitive personal information as one of the primary end-user concerns [63]– [64]. This is proved valid for our use-case too. The elderly users are extremely worried about their data anonymity and reluctant to share their personal information with the smart-home service providers or any other third party. This is evident from the second highest β value that is obtained for this case. The IoT based devices and sensors having the capability to collect automatically the user data increase the risk for this scenario.

A significant positive association between psychological barrier and smart-home services resistance is also observed. With aging, the learning interest decreases [91]. However, with any new technology there is a continuous learning curve involved. This is a conflicting requirement that creates a negative perception in the minds of the elderly people. They also fear about their increased dependence on technology by using the smart-homes. Widespread depression due to loneliness and staying alone is already a problem that they face [92], [93]. Hence, they fear that depending too much on technology might result in addiction that will separate them more from their real world of friends and family. Therefore, they perceive the IoT based smart-homes to be a source of potential threat.

The effect of self-efficacy on smart-home services resistance is found to be non-significant. This is a strange observation, because previous results report a strong relationship between self-efficacy and technology adoption [71]– [73]. We attribute this finding to the unique characteristics of the elderly people who are the primary users of our study. Due to age, they are less innovative by nature and tend to rely less on their technical capabilities [94], [95]. The IoT paradigm is relatively new, and the varied devices along with the services they provide can be a complex issue from an elderly perspective. Hence, they have a negative perception regarding these services and tend to resist their usage.

Home administrative policy has a positive effect on the resistance to smart-home usage. This is an example of a case where technology can lead to discrimination between people with respect to their usage rights and access privileges. The elderly people are treated as secondary users (having less or absolutely no privilege in smart-home service provisioning) by the smart-home system administrators or other users responsible for service configuration that creates an inferiority complex and negative perception in their minds. Although, the weight associated with this factor is considerably less ($\beta = 0.208$), it should not be overlooked in order to create a positive perception among the peoples' minds.

Finally, the effect of government policy on smart-home resistance is found to be significant. The participants in our survey feel that the government plays a dormant role in the context of the IoT based smart-homes. Previous research points towards an increased role on behalf of the government in terms of policymaking and other issues that can create a favorable environment for accepting new technologies and services like IoT, which has the potential to change the way people live [96], [97].

The factors discussed above form the core essence of this research where we try to create a meaningful theoretical framework to measure the resistance of IoT based smart-home services among the elderly people.

B. MANAGERIAL AND POLICY IMPLICATIONS

The negative perception modeling approach enabled us to definitively identify the resistive factors opposing the use of IoT based smart-homes and hence, provide with proper managerial/policy insights. The elderly people have specific requirements that must be fulfilled if this technology is to succeed.

The elderly people have no doubts regarding the usefulness that IoT technology can bring in the form of smart-homes. However, they worry about the variety of IoT devices and sensors that are available in the market, which provide a diverse range of services. Indeed, the IoT market as of today is flooded by a plethora of similar products providing near-identical functionalities from different vendors. Additionally, to make the situation even worse devices from different vendors are not interoperable. This results in the creation of a highly monolithic environment, where the users are forced to choose a specific vendor or service provider in order to set-up a smart-home environment. Thus, the message from the users of smart-homes to the different vendors and service providers is clear. They must be willing to co-operate among themselves and try creating a seamless environment where the users can choose which devices to use. This will be made possible by creating open standards and protocols that must be adhered by all the manufacturers to allow seamless interaction between devices.

Secondly, the smart-homes are capable of providing a variety of services. However, the elderly users are often not technologically innovative. Hence, they expect the manufacturers or the service providers to conduct proper training sessions in order to give a hands-on experience about how these systems work. In addition, the devices must be simple to operate. This is possible if the manufacturers focus on creating plug-and-play sort of devices that are capable of auto-configuring themselves once connected to the home network. The user-interface design should also be kept in mind and made as simple as possible. Moreover, proper advertising and marketing strategies must be formulated by the vendors that try to promote the use of the IoT based smart-homes.

Thirdly, there is a serious concern regarding the price of availing a smart-home service and the huge upfront investment that needs to be done for creating a smart-home. Historically, any new technology or service has been associated with a high initial cost. However, the IoT technology has already passed that novelty phase and hence should now focus on reducing costs that will enable the end users to reap its benefits and allow mass adoption. The government should also play a prominent role in this aspect by creating a favorable environment (promoting the use and benefits of smart-homes, giving tax evasions to companies for encouragement or other policies) that will lead to the growth of the IoT industry in general.

Fourthly, the companies must address the security/privacy concerns. This can be done by rethinking the way a smart-home is designed. For example, the companies can adopt a *'privacy by design'* approach that commits to selectively and sustainably minimize any information systems' privacy risk through technical and governance controls [97]. This can be done, for example, by allowing the users' to easily erase any data, which is captured by the IoT devices or sensors. Additionally, efforts should be made to improve the transparency about how data are collected from the different devices and how they are controlled. Timely awareness campaigns can be conducted by the service-providers to address the consumers concerns.

Lastly, whenever designing a smart-home, the end users should be taken into confidence. Their exact requirements should be identified and prior approval must be sought regarding the services each user can use or the resources that are allocated to each one of them. Creating a more transparent environment while service provisioning and configuring will reduce misunderstands and the negative feeling among certain users.

C. STUDY LIMITATIONS AND FUTURE WORK

The present work has a number of limitations, which further open up new areas of research. This study was conducted in an Asian context. Further research must be done in order to verify whether the results can be generalized to other parts of the world. A comparative study can be done with elderly people residing in other continents in order to enhance the understanding of the differences in consumer resistance to the IoT based smart-homes. In addition, opinion from more elderly people who are actually using the smart-homes should be taken into account, as it will represent a more realistic scenario. In this research, we did not take into account the different types of resistance. However, it will be interesting to examine the role of the identified factors in determining passive, active, and very active resistance as a part of our future work.

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