Received December 2, 2017, accepted January 22, 2018, date of publication January 26, 2018, date of current version March 12, 2018.

Digital Object Identifier 10.1109/ACCESS.2018.2798614

Smart Homes and Quality of Life for the Elderly: Perspective of Competing Models

DEBAJYOTI PAL[1], TUUL TRIYASON[1], SUREE FUNILKUL[2], AND WICHIAN CHUTIMASKUL[2]

[1]IP Communications Laboratory, School of Information Technology, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand

[2]Requirements Engineering Laboratory, School of Information Technology, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand

Corresponding author: Debajyoti Pal (debajyoti.pal@sit.kmutt.ac.th)

This work was supported by the National Research Council of Thailand.

ABSTRACT The percentage of the elderly population has been on rise steadily over the past few years across the globe, which is a cause of serious concern among the research fraternity. A lot of research is going on that tries to harness the benefits of the various information and communication technologies to enable these elderly people to live independently and promote a sense of overall well-being. Although in the evolutionary phase, yet smart homes can help these elderly people in their daily life. However, for the success of such smart systems, the intention of the users towards using those systems must be understood. But, there is a serious lack of relevant exploratory research that tries to measure and explain the adoption of such smart homes by the elderly population from a multiple theory perspective: namely, the technology acceptance model, the theory of reasoned action and the theory of planned behavior. The main aim of this paper is to fill up this void of a lack of theoretical approach by testing the three models in the context of the adoption of smart homes by the elderly population. In order to do so, we conducted a survey with $N = 239$ (after screening) and analyzed the results using the structural equation modeling and confirmatory factor analysis techniques. Results suggest that all the three models are valid although they do not take into account certain factors that are unique to this context. This paper paper provides the initial groundwork to explore the process of adopting smart home services by the elderly with potential future research areas.

INDEX TERMS Elderly, smart homes, multimodel approach, quality of life.

I. INTRODUCTION

The tremendous growth in the percentage of an elderly population is a serious problem being faced by many countries of the world [1]. According to a report by the United Nations, the ratio of people having an age of 50 or above will double by 2050 with respect to the total world population [2]. Thus, recently a lot of focus is being given on research dedicated towards the well-being of the elderly population. With the recent advancements in various information and communication technologies (ICT) including smart-homes, they are being widely used by the aged people for various types of healthcare and social support services [3]. All these smart-solutions have the same common objective of improving the quality of life (QoL) of the user. As per the World Health Organization (WHO), QoL is defined as "individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" [4]. Considering the health status and various vulnerability issues that the elderly people have to face, investigating into their QoL is an area of prime concern.

Primarily smart homes and related technologies consist of various kinds of sensors, appliances, and monitoring systems that are connected together and act like an automated system enabling both localized and remote control of the environment [5]. The type of sensors, control appliances, and devices that are installed depend upon the application type and nature of support provided. They range from hot water systems, lighting for homes, fridges, TVs to sensors and equipment that are used for the purpose of health monitoring [6]. Smart home services are considered one of the most promising potential markets as the demand for related products has increased exponentially over the past few years [7], [8]. Although there are a number of advantages of a smart home system, they also bring forth certain challenges [9], [10]. Thus, it is important to explore the aged users' motivations for adopting such smart systems by employing the popular and widely accepted theoretical models like Technology

Acceptance Model (TAM), Theory of Reasoned Action (TRA), and the Theory of Planned Behavior (TPB).

TAM is a widely used theoretical framework that studies the impact of perceived usefulness (PU) and perceived ease of use (PEOU) on the adoption of technology [11]. TRA is another classical model of persuasion that predicts how individuals will behave based on their pre-existing attitudes and behavioral intentions [12]. Finally, the TPB framework extends the TRA by adding a perceived behavioral control (PBC) construct [13]. All these three models have been used interchangeably in a variety of scenarios depending upon the usage context in order to gauge the user intention towards a particular thing.

The various smart home technologies are gradually maturing. Majority of the existing research focuses on the technological aspects and implementation details of the smart homes. This has been elaborated in detail in the literature review section of the paper. However, for the success of any new technology or service and its subsequent commercialization, it is very important to gauge the intention of the users. The psychology of the end users needs to be clearly understood in order to determine the prime motivating factors that will enable the success of a new service/technology. This is the exact area where current research lacks since the primary focus is given on the core technological functionalities rather than the user intention. Since, the entire idea behind smart homes is to increase the user convenience, hence for this research, we target a specific group of people who are above the age of 50 (elderly population). Lack of a relevant theoretical framework in the context of smart homes motivated us to explore this issue from a multiple theory perspective. The exact research question that we try to answer in this paper is: "To what extent are the existing models i.e. TAM, TRA and TPB able to explain the older adults' smart home services acceptance behavior and how do these models perform in an empirical setting?". The motivation behind selecting these three models as reference ones in this work is due to their widespread popularity in various ICT adoption scenarios that has been discussed in depth in Section III of the paper.

Rest of the work is organized as follows. Section II provides a background of the smart home technologies and services being used by the elderly people. Section III presents a brief introduction to the three models being tested in this paper along with the research hypothesis. The methodology has been discussed in Section IV, while Section V presents the result analysis. Section VI provides the discussion while the conclusion and the scope of future work have been given in Section VII.

II. SMART HOME TECHNOLOGIES AND SERVICES

In this section, we present an elaborate review of the smart homes meant specifically for the elderly people. Depending on the usage scenario, we have tried classifying the existing smart-home systems into five dimensions as shown in Fig. 1.

A brief description has been given below.

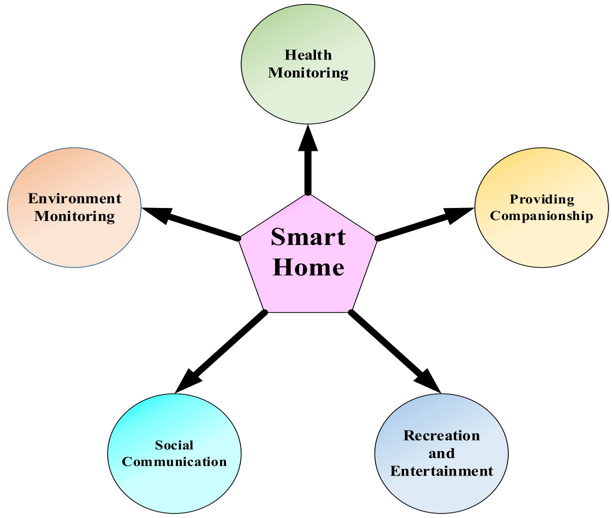

FIGURE 1. Five dimensions of smart home used by the elderly.

A. SMART HOMES FOR HEALTH MONITORING (HM)

A lot of work has been done to monitor the health of the elderly who are suffering from some type of disease; especially chronic ones like dementia. In fact, use of these smart technologies has resulted in an enhanced feeling of safety, less fear, and anxiety. Home automation also enables these elderly people to remember their daily tasks (which often they tend to forget) like taking medicine, drinking water, brushing teeth, etc. and enables them to act more independently, which improves their overall QoL [14]. Thus, smart-homes are able to address the support needs, reduce the social isolation, and increase the self-esteem of these elderly people.

B. SMART HOMES FOR ENVIRONMENTAL MONITORING (EM)

Smart-homes often provide an environmental monitoring system by deploying several sensors at appropriate locations in a residential home. These sensors are targeted towards not only the elderly population but also the entire household in general. They aim to fulfill the physiological needs of the elderly and provide them with a sense of safety. These monitoring systems generally come in handy during medical emergencies. Environmental control systems like smoke detectors, electronic door openers, etc. have been designed, but the effect that these can have on the elderly is not clear [15]. Overall, smart-homes designed for this type of application tries to facilitate the sense of functional independence among the elderly.

C. SMART-HOMES FOR PROVIDING COMPANIONSHIP (PC)

Depression due to social isolation is very common among the elderly people. A range of robotic services in the homes has been tried by different researchers that act as social companions for these old people. In-fact these robots are used when a person is ill or recovering from an illness (where pets are not allowed) and it aids in the recovery process. Smart robotic environments are also very useful for people suffering from dementia where they can serve as companions thereby inflicting a positive mood, and decreasing loneliness [16].

D. SMART-HOMES AS A MEANS OF SOCIAL COMMUNICATION (SC)

Decreased mobility and other physical problems that increase with old age often lead to a sense of loneliness. Smart-homes that enhance the communication capability by providing some means of visual communication with friends and relatives have positive effects on the mental state and improve the QoL [17]. Video-based solutions have proven to be very effective in improving the mental satisfaction of these people. Smart-homes have been often used to reduce the feelings of loneliness, boredom, and social isolation among the elderly [18].

E. SMART-HOMES FOR RECREATION AND ENTERTAINMENT (RE)

Smart homes can provide various types of recreational facilities and entertainment to the old users. Installation of smart home lighting systems that can change color and intensity as per mood conditions and use of other smart appliances like television, microwave ovens, washing machines, robots, etc. tends to improve the QoL of the elderly. Smart-homes providing interactive gaming facilities have also proven to be beneficial that has a positive effect on the elderly health.

TABLE 1 presents the characteristics, that emerged out from the literature review process and separated into the five domains as presented above. We have tried to group the results according to Schulz's fundamental questions, namely "*who, what and how*" [19].

It is evident from the literature review that a lot of work has been done towards the elderly well-being and smart homes. The entire focus of existing research is on the technological perspective and service implementation. However, the perception of these people towards such systems is not known. This is in line with the findings in [20], where the authors concluded that for aging research there is a lack of theoretical approach. This is the exact research gap that we try to address in this paper by introducing the multi-model perspective.

III. THE MULTI-MODEL PERSPECTIVE

A. TECHNOLOGY ACCEPTANCE MODEL

TAM proposed by Davis is one of the most popular theoretical models for explaining the adoption of a particular technology. The original version of TAM has four constructs: Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Attitude (ATT), and Behavioral Intention (INT). PU is the extent to which an individual perceives a positive impact of using a particular information technology in a specific context [11]. PEOU is the extent to which an individual perceives that using a particular type of technology would be free from efforts [11]. ATT is an individual's attitude towards using a particular technology in a positive way. INT represents an individual's intention towards using a particular technology [11]. The overall original TAM version has been shown in Fig. 2 and the corresponding hypotheses can be framed as:

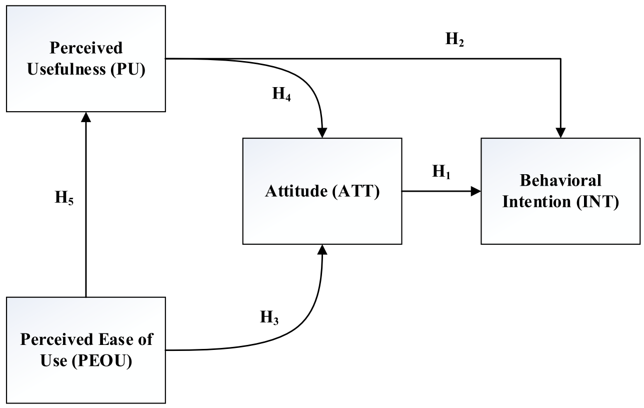

FIGURE 2. Technology acceptance model.

H_1: Attitude has a positive effect on the intention of the elderly adults to use the smart home services.

H_2: Perceived usefulness of the smart homes has a positive effect on the intention to use these services.

H_3: Perceived ease of use of the smart homes has a positive effect on the attitude towards these services.

H_4: Perceived usefulness of the smart homes has a positive effect on the attitude towards these services.

H_5: Perceived ease of use of smart homes has a positive effect on the perceived usefulness of the services.

Depending, on the usage scenario researchers, has extended the TAM model by introducing new factors and moderator/mediating variables to the original theoretical framework [45]. For example, Venkatesh et al. used TAM in an official context to explore the user intention towards using personal computers, while Pikkarainen used it in the context of Internet Banking and Pinho used it in the context of social networks [46]–[48]. In all these research in order to explain the underlying theory, new variables were added to the original TAM model. However, due to the use of so many different variables depending on the usage scenario, the original TAM theory is no longer parsimonious, which poses a serious challenge for theory development. Thus, presently the main challenge is to understand to what degree the original theory can explain the user intention. Due to this reason for this paper, we chose to use the original unaltered TAM/TRA/TPB versions.

B. THEORY OF REASONED ACTION

The TRA model that has its roots in the domain of social psychology defines the relationships between attitude (ATT), subjective norm (SN), and behavioral intention (INT) as shown in Fig. 3. Subjective norm is a new concept that has been added to this model and defined as a person's perception that most people who are important to him think he should or should not perform the behavior in question [12].

TABLE 1. Overview of literature review that illustrates the core findings.

Reference No/ Application Area	Who	What	How
[14]/HM	Elderly people with dementia Sample size: Not mentioned	Provide assistance in remembering daily activities and promote self-independence	Use of multiple ICT technologies and help from care-givers
[15]/EM	Elderly having age > 50 and mentally impaired Sample size: Not mentioned	Provide mechanisms to increase the participatory behavior and activity	Heterogeneous methods mainly by using a variety of sensors like door-openers, smoke-detectors, motion detectors, etc.
[16]/PC	Normal elderly people with no specific disabilities or requirements Sample size: Not mentioned	Mechanisms to decrease the overall stress level and loneliness and create a positive mood	Use of home robots that are used to provide companionship
[17]/RE	Elderly people with limited mobility and physical functioning Sample size: Not mentioned	Provide mechanisms to improve communication with friends and relatives and reduce depression	Use of mobile phones and other home audio-visual systems for purpose of video communication
[18]/SC	Elderly people with dementia Sample size: Not mentioned	Provide assistance with health monitoring, security measures and increased social contact	Use of mobile phones, videophones, and robots in home
[21]/SC	Elderly living alone Sample size: 20	Monitoring the daily activities of the elderly and predicting the level of social engagement from number of daily visitors	Gathering information from various types of home sensors and using Markov Modulated Poisson Process (MMPP) to analyze the data
[22]/PC	Normal elderly people with no specific disabilities or requirements Sample size: 70	Provide healthcare facilities for the elderly and trying to improve both mental and physical health	Design and implementation of field-trial of a robot "Matilda" that provides human-like assistive service and companionship
[23]/HM	Normal elderly people with no specific disabilities or requirements Sample size: Not mentioned	Discovering and monitoring patterns of daily activity among the elderly	Gathering information from various kinds of sensors installed in the homes and subsequent data analysis using a variant of hidden Markov model
[24]/HM	Elderly people Sample size: 15 (10 people suffering from Parkinson's disease and 5 healthy ones)	Designing of a fall prevention system for the elderly	Gathering vital signal information from smartwatch and other home-based motion sensors and doing the risk estimation by using a fuzzy-logic based decision making
[25]/HM	Stunt actors who mimic the elderly Sample size: 3	Designing of an acoustic fall detection system that is capable of automatic detection and report it to a caregiver	Use of a circular microphone array that captures sound signals (with a beamforming technique) and classify them into fall or non-fall category by applying Mel-frequency Cepstral Coefficients (MFCCs) features with the nearest neighbor (NN) approach
[26]/HM	Normal elderly people with no specific disabilities or requirements Sample size: 28	Exploration of the issues of QoL being faced by the elderly people in relation to their experiences of and attitudes towards using ICT for healthcare needs	Using focus groups and supplementary questionnaires to collect qualitative data from older people and measure their attitudes
[27]/HM	Normal elderly people with no specific disabilities or requirements Sample size: Not mentioned	Exploring the use of smart-home technologies by the elderly in a residential setup to improve their QoL and their perceptions of privacy that can inhibit their acceptance	Use of a qualitative study to gauge the user perception
[28]/HM	Normal elderly people with no specific disabilities or requirements Sample size: 14	Assessing the older adult's perception towards using a smart-home (bed sensor, gait monitor, stove and motion sensors, etc.) that enhances their sense of security and monitors health condition	Conducting focus group sessions that are audio-taped and later used for content analysis
[29]/HM	Normal elderly people with no specific disabilities or requirements divided into 3 groups depending upon age (mean age = 50, 68 and 75) Sample size: 22	Determination of the ergonomic and functional requirements of optical and wearable fall sensors for fall detection	Conducting a semi-structured interview across 3 focus groups and getting back the feedback from the users to judge if such systems can improve the elderly QoL
[30]/HM	Normal elderly people with no specific disabilities or requirements Sample size: 15	A computer vision based fall detection system for the elderly that is used in a home environment	Vision (digital video camera) based method by transforming the video frame into certain features by using image processing techniques and then creating a classification model by using a Support Vector Machine (SVM) classifier

TABLE 1. *(Continued.)* **Overview of literature review that illustrates the core findings.**

Reference No/ Application Area	Who	What	How
[31]/HM	Elderly people suffering from dementia Sample size: 11	Provision for a continuous monitoring scheme both inside and outside the residence for conducting a stray prevention system for the elderly	Using radio frequency identification, GPS sensors and GIS for elderly monitoring and subsequent feedback about the system
[32]/HM	Elderly people suffering from depression Sample size: 20	Implementation and testing of algorithms on sensor data collected from elderly homes that helps to detect depression	Use of neural network, C4.5 decision tree, Bayesian network and SVM classifiers to detect the severity of depressions
[33]/HM	Normal elderly people with no specific disabilities or requirements Sample size: 19	Investigating different factors and attributes that can help in the design process of a smart home healthcare system	Conducting interviews across different households and identifying 15 empirically derived attributes that can help in the design process
[34]/HM	Normal elderly people with no specific disabilities or requirements Sample size: Not mentioned	Propose 3 smart-home low cost sensing technology (smart walking monitor, smart joint monitor and smart sleeping environment)	Use of various types of body sensors, motion sensors, accelerometers, gyroscopes, etc. that collect relevant data for required analysis
[35]/HM	Normal elderly people with no specific disabilities or requirements Sample size: Not mentioned	An indoor location tracking system that is used to locate and track an elderly very accurately	Using RFID technology to gather indoor location data and log it into the database for further analysis
[36]/HM	Elderly people suffering from dementia Sample size: Not mentioned	Monitoring and predicting the abnormal behavior of elderly patients residing in homes and suffering from dementia	Implementing motion and door entry point sensors around the house to predict the abnormal behavior by using an artificial neural network technique
[37]/SC	Normal elderly people with no specific disabilities or requirements Sample size: 8	Developing a user friendly technology for home automation based upon voice commands and performance evaluation	Designing a voice command interface for smart home and running the experiment to measure performance and acceptability among elders
[38]/EM	Normal elderly people with no specific disabilities or requirements Sample size: Not mentioned	Creating a smart environment for the elderly at home to improve their QoL by continuous monitoring	Using various types of sensors (weight, light, motion, gas, IP cameras, etc.) to provide an integrated smart environment and provide SOS service in case of emergency
[39]/EM	Normal elderly people with no specific disabilities or requirements Sample size: 25	Various types of activity recognition (normal activity, bad night, fall, etc.) for the elderly in a home environment	Using a Case Based Reasoning (CBR) approach that is integrated with the smart homes to analyze the daily activities of the elderly using different algorithms like t-CNN, t-RENN, etc.
[40]/EM	Normal elderly people with no specific disabilities or requirements Sample size: 13	Exploring the perceptions and thoughts of the elderly people on various Wireless Sensor Network (WSN) technologies used for designing smart-homes	Demonstrating the capabilities of a WSN followed by interviews and discussions to assess the user intention and concerns in using such smart systems
[41]/EM	Normal elderly people with no specific disabilities or requirements Sample size: 1	Multiple sensor based smart home system that can provide daily assistance to the elderly and help them to lead a healthy lifestyle	Using water-flow sensors, IR motion sensors and RFID receivers to monitor the lifestyle activity of an elderly and detect any abnormal condition
[42]/HM	Normal elderly people with no specific disabilities or requirements Sample size: 5	Creation of an home environment that can be used for health monitoring purpose of the elderly using ubiquitous sensors and mobile social networks	Using RFID technology to sense the elderly and propose a Socialized Prompting System (SPS) that can improve the medical adherence
[43]/EM	Elderly people having mixed sample (healthy and non-healthy) Sample size: 12	Investigating the needs related to ageing-in-place and investigating how smart home can improve the elderly QoL	Installation of an automated system that provides a range of functionalities like monitoring, fire detection, etc. and finding the user perception
[44]/RE	Normal elderly people with no specific disabilities or requirements Sample size: 49	Creating a robot '*Hobbit*' that supports the elderly living independently at home	Creation of a multi-modal interface including speech recognition, text to speech, gesture recognition, etc. that enables daily interaction with the robot

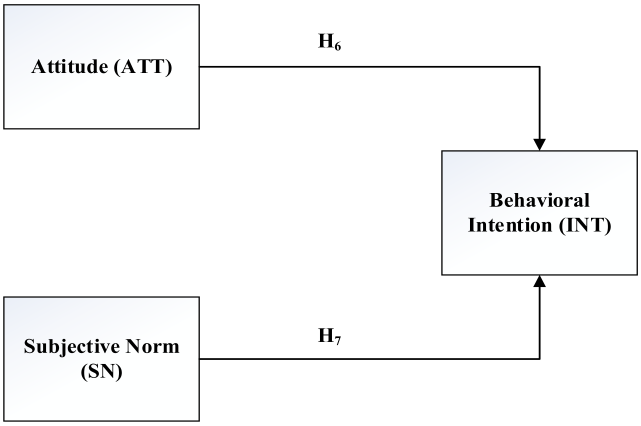

FIGURE 3. Theory of reasoned action.

When any technology is at its beginning stage, the users of such a system lack enough information regarding the usability of such a system. In such cases, the user may be influenced by the opinions or suggestions provided by their friends and/or relatives.

TRA has been extensively used to study various forms of user involvements in a variety of contexts like consumer behavior, work behavior and sociological behavior [49]–[51]. The attitude and behavioral intention factors are the same as presented in the TAM model. The relevant hypotheses can be framed as:

H_6: Attitude has a positive effect on the intention of the elderly adults to use the smart home services.

H_7: Subjective norm is positively associated with the intention of the elderly people to use smart home services.

C. THEORY OF PLANNED BEHAVIOR

The TPB model, an extension of the TRA postulates that the most important determinant of behavior is the behavioral intention (INT). This framework takes into account those situations where one may not have a complete control over behavior and adds a perceived behavioral control (PBC) construct as shown in Fig. 4. In case of this model, as it is evident from the figure, a person's actual behavior when performing a certain action is directly influenced by his/her behavioral intention and determined by three types of specific belief about the behavior: attitude (ATT), subjective norm (SN) and PBC. PBC can be defined as an individual's perceived control over performing a particular action [13]. The corresponding hypotheses are:

H_8: Attitude has a positive effect on the intention of the elderly adults to use the smart home services.

H_9: Subjective norm is positively associated with the intention of the elderly people to use smart home services.

H_{10}: Perceived behavioral control has a positive effect on the behavioral intention towards these services.

As it is evident from the literature review, the main challenge as of today is to clearly understand the extent to which these original theories (without any sort of modifications) are able to explain the usage of technology in the context of smart homes for the elderly. The various smart home technologies and related services are still in their early development stage and hence not yet reached the state of wide spread commercialization. Thus, in order to understand the real user intention towards this new service, an empirical verification of the original theories need to be done. This has never been attempted before which forms the core essence of this work. The extent to which these original theories can explain the real world usage will pave the future path in determining more factors that may be needed for a better understanding of this scenario.

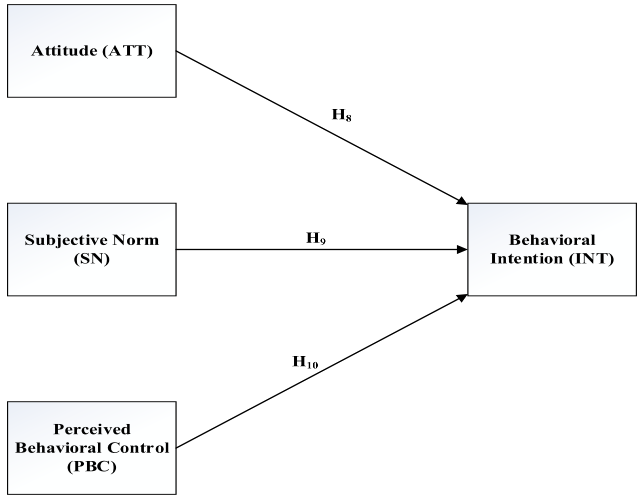

FIGURE 4. Theory of planned behavior.

IV. METHODOLOGY

An online survey instrument targeted towards the elderly people has been developed to measure their perception of the smart home services. The survey instrument has been structured in two parts. Part 1 contains certain socio-demographic questions (respondent age, gender, household size, and household income) and a basic question on the smart home awareness that has been used as a screening question. The screening question has been used in order to minimize the hypothetical response biases from those people who absolutely have no idea or prior knowledge about smart homes. 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. 254 responses have been obtained out of which 15 did not pass the screening criterion. Hence, for the final analysis, we have data from 239 elderly people. The relevant descriptive statistics showing the respondents demographic information has been shown in TABLE 2.

Fig. 5 shows the respondents percentage distribution for the screening question.

TABLE 2. Respondents demographic information (N = 254).

Characteristics	Number: N (elderly)	N (%)
Age		
55-64	112	44.1
65-74	90	35.4
75 and above	44	17.3
Gender		
Male	167	65.7
Female	87	34.3
No of family members		
1	62	24.4
2	69	27.2
3	71	28
4	30	11.8
More than 4	22	8.7
Home ownership		
Owner	217	85.4
Rented	37	14.6
Education		
High school or below	21	8.27
Bachelor degree	164	64.56
Master degree or above	69	27.16
Household income		
Less than 15,000	7	2.75
15,001-30,000	40	15.75
30,001-40,000	139	54.72
More than 40,000	68	26.77

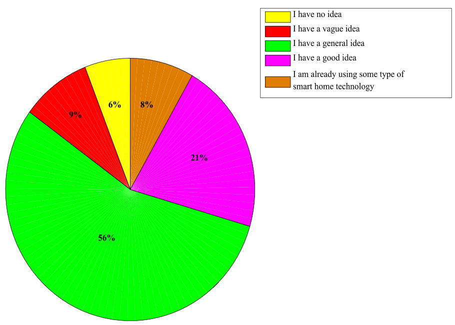

FIGURE 5. Distribution pattern of the screening question.

Part two of the survey contains open-ended questions that measure the attitude of the respondents towards the smart home services. TABLE 3 gives the detail of the questions that have been administered, while TABLE 4 presents the descriptive information of the constructs used in the research models. All the questionnaire items have been evaluated on a 5-point Likert scale (1 = "strongly disagree" to 5 = "strongly agree"). In case of certain questions, an additional "don't know" response option has been provided. All the survey questions were developed, iteratively tested, and refined for clarity prior to their implementation. No background information was provided to the respondents at the beginning of the survey in order to minimize the priming effects on responses. The order of the response options for a particular set of the construct has been randomized to minimize the potential ordering effects on responses as pointed out by current research [52].

The data that is collected from the online questionnaire survey is analyzed using a Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM) approach to test the TAM, TRA, and TPB models. While conducting the SEM, we have used specifically the Partial Least Square SEM (PLS-SEM) algorithm as it is best suited for new exploratory studies like ours where there is less of a theoretical backing to the underlying concepts and hypothesis and also where the sample size is small to medium [53], [54]. In case of PLS-SEM the error variables are not part of the model at all; hence they are un-correlated and uncovariated. It is a powerful technique as it assumes that the individual constructs are variated one by one with the rest of the model and the final model fit indices are monitored in the measurement part of the model. Although this technique enables us to create the measurement model, it does not have any biased parameters for the variables. The results of the analysis are provided in detail in the next section.

V. RESULT ANALYSIS

A. TESTS OF VALIDITY

SmartPLS 3 and SPSS 17.0 have been used to conduct the PLS-SEM and CFA for hypothesis testing and to examine the validity of the three research models. The internal consistency for reliability of the used questionnaire has been measured by using the Cronbach's alpha values and presented in TABLE 5. For all the constructs that have been used for the three research models, the value of Cronbach's alpha obtained is greater than 0.7 that suggests a high degree of internal reliability [67]. The highest alpha value = 0.85 has been obtained for the attitude (ATT) construct, while the lowest one = 0.76 corresponds to the perceived usefulness (PU) construct. In order to measure the convergent validity for each model, the average variance extracted (AVE) and the composite reliability has been calculated. This is shown in TABLE 6. For every construct, the value obtained for AVE is greater than the recommended level of 0.5 [67]. We also test for the discriminant/divergent validity in order to check whether the measurements that are not supposed to be related are actually unrelated. The results of the discriminant validity tests have been reported in TABLES 7, 8, and 9 for the TAM, TRA, and TPB models respectively. In all the tables, the diagonal element (which represents the square root of AVE) has a higher correlation level between any two specific factors. Thus, the discriminant validity test is also sufficed for each model.

B. HYPOTHESIS TESTING

For testing the significance level and obtaining the path coefficients, we followed the bootstrapping procedure. In bootstrapping, 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. This process is repeated until a large number of random sub-samples have been created (we used a maximum iteration value of 300). The results for TAM, TRA, and TPB are shown in Figs. 6, 7 and 8 respectively. The standard

TABLE 3. Questionnaire items used in the current research.

Construct	Item	Explanation	References
Intention to use	INT1	I expect to use smart home services in my house	[11, 55, 56]
	INT2	I am absolutely determined to use a smart home service very soon	
	INT3	I intend to invest and use a smart home service as much as possible	
Attitude	ATT1	Using a smart home service is a good idea	[11, 57, 58, 59]
	ATT2	I like using smart devices in my home	
	ATT3	Using smart devices in my home are beneficial to me in some form of daily activity	
	ATT4	I have a positive feeling towards smart home services in general	
Perceived usefulness	PU1	Using smart home services makes my life more enjoyable	[60, 61, 62, 63]
	PU2	Using smart home services improve the performance of my daily activities	
	PU3	I can accomplish my daily activities more quickly by using smart home services	
	PU4	There is an improvement in my overall quality of life when using smart devices	
	PU5	I have to give less effort in doing my activities when using a smart device	
	PU6	A smart home definitely helps in independent assisted living	
Perceived ease of use	PEOU1	I can operate the smart devices in my home by myself	[11, 64, 65]
	PEOU2	It is not difficult for me to use the smart devices present in my home	
	PEOU3	Using smart home services does not require any special mental or physical effort	
	PEOU4	It is easy and clear for me to use the various smart devices present in my home	
	PEOU5	Using smart devices in my home makes my daily activities more easy and helpful	
Subjective norm	SN1	I will use smart homes if media/government encourages to use them	[12, 66]
	SN2	I will use smart devices in my house if my family members and friends do so	
	SN3	I will use a smart home if people whose opinion I value recommend me to do so	
Perceived behavioral control	PBC1	I will be able to adopt smart home services	[12, 13]
	PBC2	I have the resources, knowledge, and ability to use smart home services	
	PBC3	Using smart home services is entirely under my control	
	PBC4	I have more peace of mind when I use smart devices in my home	

TABLE 4. Descriptive information of the constructs used.

Construct	Mean	Standard Deviation
Intention to use (INT)	4.02	0.72
Attitude (ATT)	3.92	0.81
Perceived usefulness (PU)	3.97	0.75
Perceived ease of use (PEOU)	3.99	0.94
Subjective norm (SN)	3.62	0.70
Perceived behavioral control (PBC)	3.95	1.04

TABLE 5. Internal consistency of the questionnaire used.

Construct	No. of Questions	Cronbach's Alpha
Intention to use (INT)	3	0.80
Attitude (ATT)	4	0.85
Perceived usefulness (PU)	6	0.76
Perceived ease of use (PEOU)	5	0.77
Subjective norm (SN)	3	0.82
Perceived behavioral control (PBC)	4	0.78

TABLE 6. Results of convergent validity of the 3 research models.

Research Model	Construct	Composite Reliability	Average Variance Extracted
TAM	INT	0.879	0.707
	ATT	0.907	0.765
	PU	0.873	0.538
	PEOU	0.836	0.571
TRA	INT	0.879	0.709
	ATT	0.881	0.652
	SN	0.893	0.736
TPB	INT	0.880	0.709
	ATT	0.881	0.652
	SN	0.893	0.736
	PBC	0.879	0.707

path coefficients for the proposed hypothesis along with the significance level and other relevant statistical details have been presented in TABLE 10 for all the three research models.

In case of the TAM model, PU, PEOU, and ATT together can explain 26.2 % ($R^2 = 0.262$) of the observed variance in the dependent variable i.e. behavioral intention INT.

TABLE 7. Discriminant validity test for TAM (diagonal position contains the square roots of ave).

Construct	ATT	INT	PEOU	PU
ATT	0.875			
INT	0.490	0.841		
PEOU	0.498	0.497	0.755	
PU	0.377	0.322	0.198	0.734

TABLE 8. Discriminant validity test for TRA (diagonal position contains the square roots of ave).

Construct	ATT	INT	SN
ATT	0.808		
INT	0.501	0.842	
SN	0.362	0.450	0.858

TABLE 9. Discriminant validity test for TPB (diagonal position contains the square roots of ave).

Construct	ATT	INT	PBC	SN
ATT	0.808			
INT	0.499	0.842		
PBC	0.416	0.625	0.841	
SN	0.362	0.449	0.330	0.858

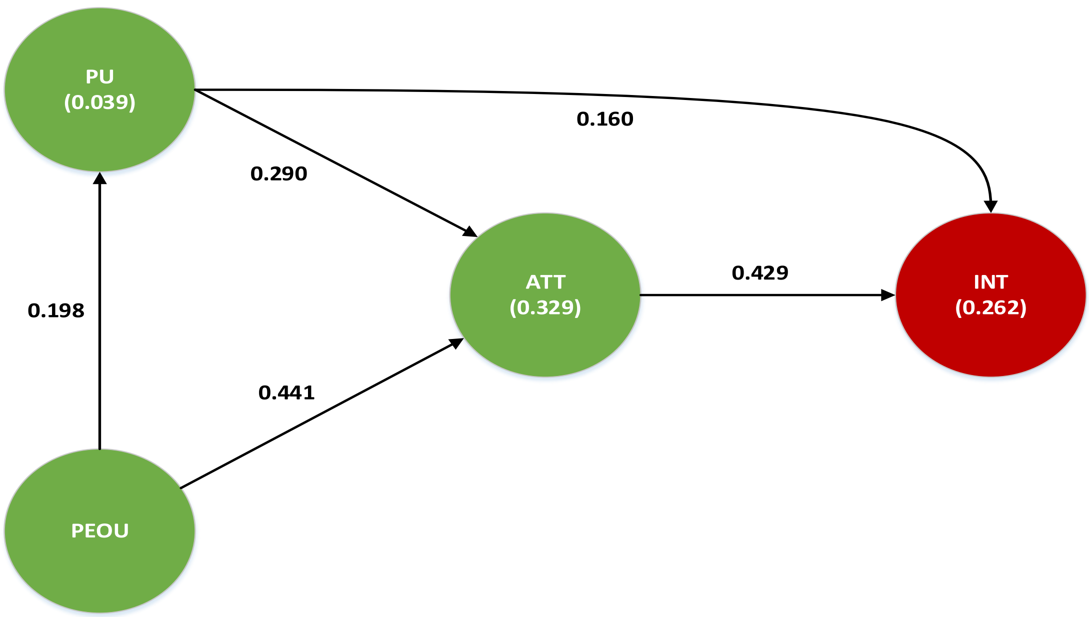

FIGURE 6. Path diagram predicting the intention to use smart home and related technologies by the elderly in TAM perspective.

The result from the path analysis shows that the entire hypothesis proposed by the TAM model is supported in the context of the adoption of smart homes by the elderly. Both PU and ATT have direct positive impacts on INT, whereas PEOU has a strong indirect effect on INT through the ATT construct. For direct effect ATT is the greatest predictor of INT (ATT -> INT, $\beta = 0.429$, t statistic $= 5.570$ and $p < 0.001$) at a 95% confidence interval. The impact of PU on INT is considerably lesser (PU -> INT, $\beta = 0.160$, t statistic $= 2.315$ and $p = 0.021$). These coefficients suggest that for a unit increase in ATT an individual's positive intention INT to use the smart home services will increase by 0.429 units whereas for a unit increase in PU the INT factor increases by 0.160 units. The impact of PEOU on PU (PEOU -> PU, $\beta = 0.198$, t statistic $=$ 2.779 and $p = 0.006$) and PU on ATT (PU -> ATT, $\beta =$ 0.290, t statistic $= 5.161$ and $p < 0.001$) are considerably lesser as confirmed by their standardized coefficient values although both are significant. The highest path value is obtained for the relationship between PEOU and ATT (PEOU -> ATT, $\beta = 0.441$, t statistic $= 6.938$ and $p <$ 0.001). The various relevant model fit statistics for TAM has been presented in TABLE 11. Most of the fit indices i.e. goodness of fit index (GFI), adjusted goodness of fit index

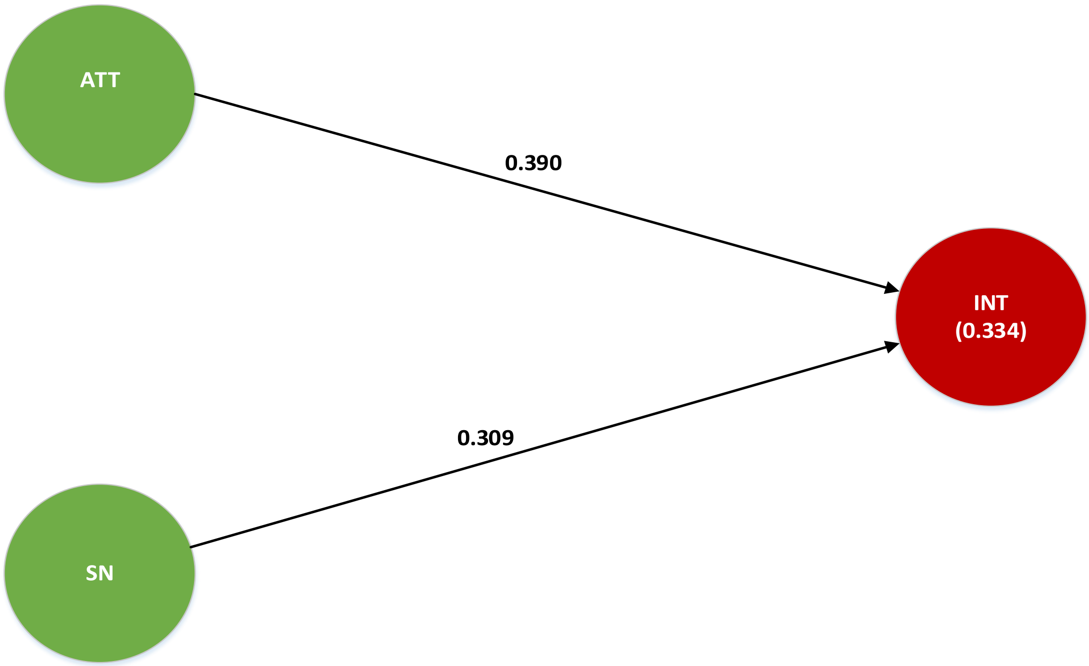

FIGURE 7. Path diagram predicting the intention to use smart home and related technologies by the elderly in TRA perspective.

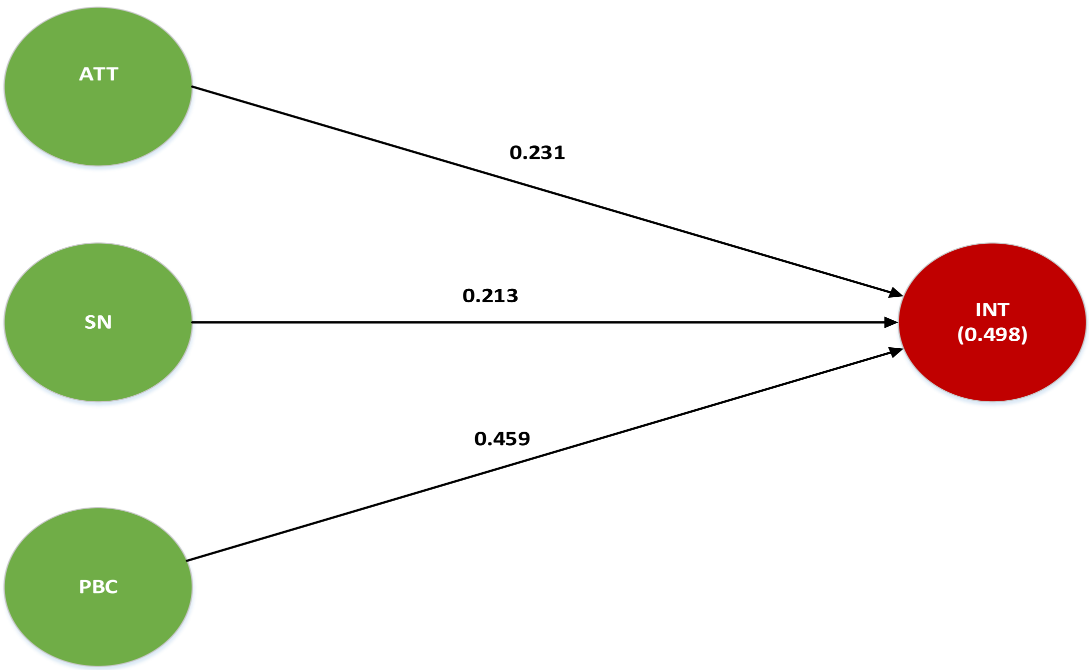

FIGURE 8. Path diagram predicting the intention to use smart home and related technologies by the elderly in TPB perspective.

(AGFI), root mean square error of approximation (RMSEA), normed fit index (NFI), comparative fit index (CFI), incremental fit index (IFI) and *chi − square/degress of freedom* ($\lambda^2/d.f.$) lie within the recommended range. The relevant references are cited in [67]–[71]. From the overall results of hypothesis testing, we can conclude that TAM can satisfactorily explain the intention of the elderly people to use the various smart home services. However, the explanatory power of the model is limited to 26.2 % as evident from the R^2 value suggesting that more factors should be taken into consideration for predicting the behavioral intention.

In case of the TRA model, attitude (ATT) and subjective norm (SN) together explains 33.4 % of the variance in the dependent variable i.e. INT. The contribution of attitude towards the observed explanatory power is slightly more than the subjective norm. Both ATT, as well as SN, has direct

TABLE 10. Results of hypothesis testing for the 3 research models.

Model	Hypothesis/Path	Standardized coefficient (β)	T statistics	P value	Hypothesis status
TAM	PEOU -> PU	0.198	2.779	0.006	Supported
	PEOU -> ATT	0.441	6.938	< 0.001	Supported
	PU -> ATT	0.290	5.161	< 0.001	Supported
	ATT -> INT	0.429	5.570	< 0.001	Supported
	PU -> INT	0.160	2.315	0.021	Supported
TRA	ATT -> INT	0.390	5.555	< 0.001	Supported
	SN -> INT	0.309	4.652	< 0.001	Supported
TPB	ATT -> INT	0.231	3.496	0.001	Supported
	PBC -> INT	0.459	6.756	< 0.001	Supported
	SN -> INT	0.213	3.727	< 0.001	Supported

TABLE 11. Model fit indices.

Fit index	TAM fit value	TRA fit value	TPB fit value	Recommended value	References
GFI	0.889	0.914	0.837	> 0.900	[67, 68, 69, 70, 71]
AGFI	0.846	0.887	0.756	> 0.900	
RMSEA	0.079	0.074	0.077	< 0.080	
NFI	0.881	0.898	0.807	> 0.800	
CFI	0.923	0.906	0.838	> 0.900	
IFI	0.924	0.907	0.840	> 0.900	
$\lambda^2/d.f.$	2.575	4.830	4.790	< 5.000	

positive impacts on the intention to use the smart home services by the elderly. This is evident from the respective path coefficients and significance levels for the ATT (ATT -> INT, $\beta = 0.390$, t statistic = 5.555 and $p < 0.001$) and SN (SN -> INT, $\beta = 0.309$, t statistic = 4.652 and $p < 0.001$) constructs. Literally, the β values suggest that for every unit increment in attitude will strengthen an elderly individual's (positive) intention to use smart home services by 0.390 unit and every unit increment in subjective norm will strengthen an elderly individual's (positive) intention to use the same system by 0.309 unit. All the relevant model fit indices have been reported in TABLE 11 for the TRA model and lie close to the recommended range. It is also observed that the explanatory power of the TRA model is higher than the TAM model.

For the TPB model; attitude, subjective norm, and perceived behavioral control can together explain 49.8 % of the variances observed in the intention to use the smart home services. The contribution of perceived behavioral control is maximum towards the behavioral intention followed by attitude and subjective norm respectively. The entire hypotheses proposed by the TPB model are supported: (ATT -> INT, $\beta = 0.231$, t statistic = 3.496 and $p = 0.001$), (PBC -> INT, $\beta = 0.459$, t statistic = 6.756 and $p < 0.001$) and (SN -> INT, $\beta = 0.213$, t statistic = 3.727 and $p < 0.001$). As with the other models literally, the β coefficients mean that every unit increment in attitude the perceived behavioral control and subjective norm will strengthen an elderly individual's (positive) intention to use the smart home services by 0.231 unit, 0.459 unit, and 0.213 unit respectively. The model fit statistics reported in TABLE 11 also lie close to the recommended range.

Results show that all the three research models are able to explain the intention of the elderly people to use smart homes, but to a limited extent (considering the low to moderate R^2 values). However, among all the three models, the explanatory power of the TPB is highest at 49.8 % followed by TRA and TAM at 33.4 % and 26.2 % respectively.

VI. DISCUSSION

The objective of this paper was to test the three competing models (TAM, TRA, and TPB) in their pure form within the context of the adoption of smart home services by the elderly population. There are a number of observations from this research.

Based on the data collected from 239 elderly people (after screening) all the three research models can explain the actual system usage. According to what is postulated by TAM, both PU and ATT affects INT directly; while there is an indirect effect from PEOU to INT. The impact of PEOU and ATT on INT is more than the effect of PU on INT. The reason behind this could be due to the aging population that we have considered for this research. For the aged people the ease with which they can operate a particular device or use a specific technology far outweighs the usefulness that they get by using those services. In fact, the attitude of these people to use a smart home service is predominantly determined by how much easy it is for them to use such a system. Thus, it will be helpful if the device manufacturers and service providers are not only able to design easy to use systems, but also provide some form of demonstration or training about their products to familiarize the elderly on the actual system usage. This can also help to create a sense of awareness regarding the benefits of using a smart home and the chances of adopting such a technology will increase. PU is the weakest link in the TAM model. A certain extent of computer expertise and exposure to IT systems is needed if the benefits of using a smart home service are to be appreciated by the users. Thus, proper training sessions must be conducted that familiarizes the elderly with the related services and creates a sense of usefulness among them.

From the perspective of TRA, both ATT and SN have an almost equal effect on the usage intention. This implies that the elderly people find the idea of using a smart home beneficial and important. Subjective norm having a positive impact means that the elderly people tend to rely heavily on the opinion of their friends, relatives and other trusted sources regarding the use of smart home services. The strong effect of SN on the adoption intention is surprising because, in prior studies this factor was found to have a relatively weak or insignificant impact on the intention [12], [72], [73]. Thus, it can be inferred that as the target population is elderly and the smart home services are in an early stage of diffusion, potential users have very little experience and are willing to rely on the opinion and behaviors of others. This implies that word of mouth and snowball marketing techniques can be an effective way to propagate the benefits of using such a technology. Large-scale awareness programs and door-to-door campaigning can be initiated on behalf of the government and other relevant agencies that promote the use of smart home services among the elderly and make them understand clearly the benefits such a system can provide in the form of independent assisted living.

ATT, SN, and PBC all have significant positive effects on INT as per the TPB model. The impact of PBC on INT is higher when compared to the remaining two constructs. This finding is interesting and in line with the reporting by the TAM model. These elderly people expect some sort of experience and prior knowledge about using these systems. When the potential users perceive more controllability than obstacles, they feel it suitable to adopt smart home services.

Except for TPB, the R^2 values are medium to low for the remaining two models. However, this does not suggest that TAM and TRA are not able to explain the proposed scenario properly. This is evident from the number of other statistical measures that are used for each model. For example, across all the models each path has a t statistic > 1.96, a GFI value close to 0.9, etc. all indicating a fairly good power of the statistical model [67]–[71]. Thus, we can safely say that both TAM and TRA also helps in predicting the intention to use smart homes by the elderly apart from the TPB model. Overall, we can conclude that instead of focusing on accessibility and resources, the focus should be on designing an easily usable system, creating a positive awareness and conducting training programs that will enable the elderly to get a hands-on experience and feeling about using such a smart system.

VII. CONCLUSION AND SCOPE OF FUTURE WORK

The study that we have carried out is exploratory in nature and the first of its kind that tries to examine the usage intention of smart homes by the elderly population. In order to explain the usage intention, we focus on the framework provided by the already existing theories of TAM, TRA, and TPB; hence using a multi-model approach. All the three research models could well explain the proposed hypothesis; with the explanatory power of TPB model being higher than TAM or TRA (in term of the R^2 value). This implies that there can be some other factors other than what we have considered in this work, which can have an impact on the adoption of smart home services. For example, from the questionnaire data that has been collected, cost of the technology along with security and privacy concerns can be some of the prohibiting factors. The high cost of establishing a smart home can have a negative effect on the elderly mindset specifically because they have a limited income. Similarly, privacy and security concerns also need to be addressed and are potential candidates for further study. Another factor that emerged out from our survey is that of electricity consumption and the availability of uninterrupted power supply (without any outage). Since the smart homes rely a lot on an uninterrupted supply of power for the working of the various devices, there was a serious concern about the reliability of such systems among the elderly in case of power outages. In addition, the increased electricity cost that the elders will have to pay due to using such a system seems to be a cause for concern. This factor is particularly important in an Asian context where this research has been carried out. Similarly, there can be other factors that are unique to the elderly population, which needs a deeper investigation. Keeping in mind the results that emerged out from the study, we plan to create and test a new research model with more control and mediator variables that will have a better predictive power and reliability than what we achieved through this multi-model approach as a part of our future work.

REFERENCES

[1] *Human Development Report 2013. The Rise of the South: Human Progress in a Diverse World*, United Nat. Develop. Program, New York, NY, USA, 2013.

[2] UN. *World Population Prospects 2017*. Accessed: Nov. 4, 2017. [Online]. Available: https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf

[3] M. E. Morris *et al.*, "Smart-home technologies to assist older people to live well at home," *J. Aging Sci.*, vol. 1, no. 1, pp. 1–9, 2013.

[4] WHO and Division of Mental Health and Prevention of Substance Abuse. (1997). *WHOQOL: Measuring Quality of Life*. Accessed: Nov. 4, 2017. [Online]. Available: http://www.who.int/mental_health/media/68.pdf

[5] D. J. Cook, "How smart is your home?" *Science*, vol. 335, no. 6076, pp. 1579–1581, 2012.

[6] R. J. Robles and T.-H. Kim, "Applications, systems and methods in smart home technology: A review," *Int. J. Adv. Sci. Technol.*, vol. 15, pp. 37–48, Feb. 2010.

[7] X. Ma, G. Pogrebna, and I. Ng, "Smart home, smart things and smart me in the smart city: The hub-of-all-things resource integration and enabling tool (HARRIET)," in *Proc. IET Conf. Future Intell. Cities*, London, U.K., 2014, pp. 1–6.

[8] N. Balta-Ozkan, B. Boteler, and O. Amerighi, "European smart home market development: Public views on technical and economic aspects across the United Kingdom, Germany and Italy," *Energy Res. Social Sci.*, vol. 3, pp. 65–77, Sep. 2014.

[9] D. Pal, T. Triyason, and S. Funilkul, "Smart homes and quality of life for the elderly: A systematic review," in *Proc. 19th IEEE Int. Symp. Multimedia*, Taichung, Taiwan, Dec. 2017, pp. 413–419.

[10] C. Siegel and T. E. Dorner, "Information technologies for active and assisted living—Influences to the quality of life of an ageing society," *Int. J. Med. Inform.*, vol. 100, pp. 32–45, Apr. 2017.

[11] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Quart.*, vol. 13, no. 3, pp. 319–340, 1989.

[12] A. Icek, and M. Fishbein, "Attitudinal and normative variables as predictors of specific behaviors," *J. Person. Social Psychol.*, vol. 27, no. 1, pp. 41–57, 1973.

[13] S. A. Brown and V. Venkatesh, "Model of adoption of technology in households: A baseline model test and extension incorporating household life cycle," *MIS Quart.*, vol. 29, no. 3, pp. 399–436, 2005.

[14] S. Cahill, J. Macijauskiene, A.-M. Nygård, J.-P. Faulkner, and I. Hagen, "Technology in dementia care," *J. Technol. Disability*, vol. 19, no. 2, pp. 55–60, 2007.

[15] A. Brandt and A. L. Salminen, "Systematic review: Activity outcomes of environmental control systems and smart home technology," in *Assistive Technology From Adapted Equipment to Inclusive Environments*, vol. 25. IOS Press, 2009, pp. 292–296.

[16] J. Broekens, M. Heerink, and H. Rosendal, "Assistive social robots in elderly care: A review," *Gerontechnology*, vol. 8, no. 2, pp. 94–103, 2009.

[17] B. K. Hensel, D. Parker-Oliver, and G. Demiris, "Videophone communication between residents and family: A case study," *J. Amer. Med. Directors Assoc.*, vol. 8, no. 2, pp. 123–127, 2007.

[18] S. Lauriks *et al.*, "Review of ICT-based services for identified unmet needs in people with dementia," *Ageing Res. Rev.*, vol. 6, no. 3, pp. 223–246, 2007.

[19] R. Schulz *et al.*, "Dementia caregiver intervention research: In search of clinical significance," *Gerontologist*, vol. 42, no. 5, pp. 589–602, 2002.

[20] S. T. M. Peek, E. J. M. Wouters, J. van Hoof, K. G. Luijkx, H. R. Boeije, and H. J. M. Vrijhoef, "Factors influencing acceptance of technology for aging in place: A systematic review," *Int. J. Med. Inform.*, vol. 83, no. 4, pp. 235–248, 2014.

[21] A. N. Aicha, G. Englebienne, and B. Kröse, "Unsupervised visit detection in smart homes," *Pervasive Mobile Comput.*, vol. 34, pp. 157–167, Jan. 2017.

[22] R. Khosla and M.-T. Chu, "Embodying care in matilda: An affective communication robot for emotional wellbeing of older people in Australian residential care facilities," *ACM Trans. Manage. Inf. Syst.*, vol. 4, no. 4, 2013, Art. no. 18.

[23] P. Rashidi and D. J. Cook, "COM: A method for mining and monitoring human activity patterns in home-based health monitoring systems," *ACM Trans. Intell. Syst. Technol.*, vol. 4, no. 4, pp. 64.1–64.20, 2013.

[24] D. E. Iakovakis, F. A. Papadopoulou, and L. J. Hadjileontiadis, "Fuzzy logic-based risk of fall estimation using smartwatch data as a means to form an assistive feedback mechanism in everyday living activities," *Healthcare Technol. Lett.*, vol. 3, no. 4, pp. 263–268, Dec. 2016.

[25] Y. Li, K. C. Ho, and M. Popescu, "A microphone array system for automatic fall detection," *IEEE Trans. Biomed. Eng.*, vol. 59, no. 2, pp. 1291–1301, May 2012.

[26] K. Pangbourne, P. T. Aditjandra, and J. D. Nelson, "New technology and quality of life for older people: Exploring health and transport dimensions in the UK context," *IET Intell. Transp. Syst.*, vol. 4, no. 4, pp. 318–327, Dec. 2010.

[27] K. L. Courtney, "Privacy and senior willingness to adopt smart home information technology in residential care facilities," *Methods Inf. Med.*, vol. 47, no. 1, pp. 76–81, 2008.

[28] G. Demiris, B. K. Hensel, M. Skubic, and M. Rantz, "Senior residents' perceived need of and preferences for 'smart home' sensor technologies," *Int. J. Technol. Assess Health Care*, vol. 24, pp. 120–124, Jan. 2008.

[29] M. Gövercin *et al.*, "Defining the user requirements for wearable and optical fall prediction and fall detection devices for home use," *Inform. Health Social Care*, vol. 35, nos. 3–4, pp. 177–187, 2010.

[30] M. Yu, A. Rhuma, S. M. Naqvi, L. Wang, and J. Chambers, "A posture recognition-based fall detection system for monitoring an elderly person in a smart home environment," *IEEE Trans. Inf. Technol. Biomed.*, vol. 16, no. 6, pp. 1274–1286, Nov. 2012.

[31] C.-C. Lin, M.-J. Chiu, C.-C. Hsiao, R.-G. Lee, and Y.-S. Tsai, "Wireless health care service system for elderly with dementia," *IEEE Trans. Inf. Technol. Biomed.*, vol. 10, no. 4, pp. 696–704, Oct. 2006.

[32] J.-Y. Kim, N. Liu, H.-X. Tan, and C.-H. Chu, "Unobtrusive monitoring to detect depression for elderly with chronic illnesses," *IEEE Sensors J.*, vol. 17, no. 17, pp. 5694–5704, Sep. 2017.

[33] A. Burrows, R. Gooberman-Hill, and D. Coyle, "Empirically derived user attributes for the design of home healthcare technologies," *Pers. Ubiquitous Comput.*, vol. 19, no. 8, pp. 1233–1245, 2015.

[34] M. J. Deen, "Information and communications technologies for elderly ubiquitous healthcare in a smart home," *Pers. Ubiquitous Comput.*, vol. 19, nos. 3–4, pp. 573–599, 2015.

[35] S.-C. Kim, Y.-S. Jeong, and S.-O. Park, "RFID-based indoor location tracking to ensure the safety of the elderly in smart home environments," *Pers. Ubiquitous Comput.*, vol. 17, no. 8, pp. 1699–1707, 2013.

[36] A. Lotfi, C. Langensiepen, M. M. Sawsan, and M. J. Akhlaghinia, "Smart homes for the elderly dementia sufferers: identification and prediction of abnormal behaviour," *J. Ambient Intell. Hum. Comput.*, vol. 3, no. 3, pp. 205–218, 2012.

[37] F. Portet, M. Vacher, C. Golanski, C. Roux, and B. Meillon, "Design and evaluation of a smart home voice interface for the elderly: Acceptability and objection aspects," *Pers. Ubiquitous Comput.*, vol. 17, no. 1, pp. 127–144, 2013.

[38] M. W. Raad and L. T. Yang, "A ubiquitous smart home for elderly," *Inf. Syst. Frontiers*, vol. 11, pp. 529–536, Nov. 2008.

[39] E. Lupiani, J. M. Juarez, J. Palma, and R. Marin, "Monitoring elderly people at home with temporal case-based reasoning," *Knowl.-Based Syst.*, vol. 134, pp. 116–134, Oct. 2017.

[40] R. Steele, A. Lo, C. Secombe, and Y. K. Wong, "Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare," *Int. J. Med. Inform.*, vol. 78, no. 12, pp. 788–801, 2009.

[41] T. Tsukiyama, "In-home health monitoring system for solitary elderly," *Procedia Comput. Sci.*, vol. 63, pp. 229–235, Sep. 2015.

[42] Z. Yu, Y. Liang, B. Guo, X. Zhou, and H. Ni, "Facilitating medication adherence in elderly care using ubiquitous sensors and mobile social networks," *Comput. Commun.*, vol. 65, pp. 1–9, Jul. 2015.

[43] J. van Hoof, H. S. M. Kort, P. G. S. Rutten, and M. S. H. Duijnstee, "Ageing-in-place with the use of ambient intelligence technology: Perspectives of older users," *Int. J. Med. Inform.*, vol. 80, no. 5, pp. 310–331, 2011.

[44] D. Fischinge *et al.*, "Hobbit, a care robot supporting independent living at home: First prototype and lessons learned," *Robot. Autom. Syst.*, vol. 75, pp. 60–78, Jan. 2016.

[45] B. H. Wixom and P. A. Todd, "A theoretical integration of user satisfaction and technology acceptance," *Inf. Syst. Res.*, vol. 16, no. 1, pp. 85–102, 2005.

[46] V. Venkatesh and S. A. Brown, "A longitudinal investigation of personal computers in homes: Adoption determinants and emerging challenges," *MIS Quart.*, vol. 25, no. 1, pp. 71–102, 2001.

[47] K. Pikkarainen, "Consumer acceptance of online banking: An extension of the technology acceptance model," *Internet Res.*, vol. 14, no. 3, pp. 224–235, 2015.

[48] J. C. M. R. Pinho and A. M. Soares, "Examining the technology acceptance model in the adoption of social networks," *J. Res. Interact. Marketing*, vol. 5, nos. 2–3, pp. 116–129, 2011.

[49] H. Barki and J. Hartwick, "Measuring user participation, user involvement, and user attitude," *MIS Quart.*, vol. 18, no. 1, pp. 59–82, 1994.

[50] S. C. Currall and T. A. Judge, "Measuring trust between organizational boundary role persons," *Org. Behavior Human Decision Process.*, vol. 64, no. 2, pp. 151–170, 1995.

[51] J. Hartwick and H. Barki, "Explaining the role of user participation in information system use," *Manage. Sci.*, vol. 40, no. 4, pp. 440–465, 1994.

[52] B. C. K. Choi and A. W. P. Pak, "A catalog of biases in questionnaires," *Prevent. Chronic Disease*, vol. 2, no. 1, pp. 1–13, 2005.

[53] H. Yang, H. Lee, and H. Zo, "User acceptance of smart home services: An extension of the theory of planned behavior," *Ind. Manage. Data Syst.*, vol. 117, no. 1, pp. 68–89, 2017.

[54] M. Del Giudice and M. R. Dell Peruta, "The impact of IT-based knowledge management systems on internal venturing and innovation: A structural equation modeling approach to corporate performance," *J. Knowl. Manage.*, vol. 20, no. 3, pp. 484–498, 2016.

[55] E. Park, H. Kim, and J. Y. Ohm, "Understanding driver adoption of car navigation systems using the extended technology acceptance model," *Behavioral Inf. Technol.*, vol. 34, no. 7, pp. 741–751, 2015.

[56] S. J. Kwon, E. Park, and K. J. Kim, "What drives successful social networking services? A comparative analysis of user acceptance of Facebook and Twitter," *Social Sci. J.*, vol. 51, no. 4, pp. 534–544, 2014.

[57] E. Park and K. J. Kim, "An integrated adoption model of mobile cloud services: Exploration of key determinants and extension of technology acceptance model," *Telematics Informat.*, vol. 31, no. 3, pp. 376–385, 2014.
[58] Y. Sun, L. Liu, X. Peng, Y. Dong, and S. J. Barnes, "Understanding Chinese users' continuance intention toward online social networks: An integrative theoretical model," *Electron. Markets*, vol. 24, no. 1, pp. 57–66, 2014.
[59] E. Park and J. Ohm, "Factors influencing users' employment of mobile map services," *Telematics Inform.*, vol. 31, no. 2, pp. 253–265, 2014.
[60] I. Y. L. Chen, "The factors influencing members' continuance intentions in professional virtual communities—A longitudinal study," *J. Inf. Sci.*, vol. 33, no. 4, pp. 451–467, 2007.
[61] P. G. Schierz, O. Schilke, and B. W. Wirtz, "Understanding consumer acceptance of mobile payment services: An empirical analysis," *Electron. Commerce Res. Appl.*, vol. 9, no. 3, pp. 209–216, 2010.
[62] D. Pal, V. Vanijja, and B. Papasratorn, "An empirical analysis towards the adoption of NFC mobile payment system by the end user," *Procedia Comput. Sci.*, vol. 69, pp. 13–25, Nov. 2015.
[63] D. M. Boyd and N. B. Ellison, "Social network sites: Definition, history, and scholarship," *J. Comput. Mediated Commun.*, vol. 13, no. 1, pp. 210–230, 2007.
[64] H. Son, Y. Park, C. Kim, and J.-S. Chou, "Toward an understanding of construction professionals' acceptance of mobile computing devices in South Korea: An extension of the technology acceptance model," *Autom. Construct.*, vol. 28, pp. 82–90, Dec. 2012.
[65] D. Y. Lee and M. R. Lehto, "User acceptance of YouTube for procedural learning: An extension of the technology acceptance model," *Comput. Edu.*, vol. 61, pp. 193–208, Feb. 2013.
[66] A. Bhattacherjee, "Acceptance of e-commerce services: The case of electronic brokerages," *IEEE Trans. Syst., Man, Cybern. A, Syst., Humans*, vol. 30, no. 4, pp. 411–420, Jul. 2000.
[67] J. C. Anderson and D. W. Gerbing, "Structural equation modeling in practice: A review and recommended two-step approach," *Psychol. Bull.*, vol. 103, no. 3, pp. 411–423, 1988.
[68] R. P. Bagozzi and Y. Yi, "On the evaluation of structural equation models," *J. Acad. Marketing Sci.*, vol. 16, no. 1, pp. 74–94, 1988.
[69] X. Fan, B. Thompson, and L. Wang, "Effects of sample size, estimation methods, and model specification on structural equation modeling fit indexes," *Struct. Equ. Model., A Multidiscipl. J.*, vol. 6, no. 1, pp. 56–83, 1999.
[70] R. B. Kline, *Principles and Practice of Structural Equation Modeling*. New York, NY, USA: Guilford, 2015.
[71] G. A. Marcoulides and R. E. Schumacker, Eds., *Advanced Structural Equation Modeling: Issues and Techniques*. Abingdon, U.K.: Psychology Press, 2013.
[72] M.-C. Lee, "Factors influencing the adoption of internet banking: An integration of TAM and TPB with perceived risk and perceived benefit," *Electron. Commerce Res. Appl.*, vol. 8, no. 3, pp. 130–141, 2009.
[73] I.-L. Wu and J.-L. Chen, "An extension of trust and TAM model with TPB in the initial adoption of on-line tax: An empirical study," *Int. J. Human-Comput. Stud.*, vol. 62, no. 6, pp. 784–808, 2005.

DEBAJYOTI PAL received the B.E. degree in electrical engineering from Nagpur University, India, in 2005, the M.Tech. degree in information technology from the Indian Institute of Engineering Science and Technology, Shibpur, India, in 2007, and the Ph.D. degree in information technology from the School of Information Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand, in 2017. He is currently a Researcher at the King Mongkut's University of Technology Thonburi. His research interests are in multimedia systems, quality evaluation of various multimedia services, Internet of Things, and IT adoption.

TUUL TRIYASON was born in Bangkok, Thailand, in 1983. He received the B.Sc. degree in physics from Mahidol University, Thailand, the M.Sc. degree in information technology from the King Mongkut's University of Technology Thonburi, and the Ph.D. degree in information technology from the King Mongkut's University of Technology Thonburi in 2015. His research interests include quality of experience of multimedia services, IoT, cloud, and virtualization technologies.

SUREE FUNILKUL received the B.Sc. degree in mathematics from Mahidol University, Thailand, the M.Sc. degree in information technology from the King Mongkut's University of Technology Thonburi, and the Ph.D. degree in information technology from the King Mongkut's University of Technology Thonburi in 2008. Her research interests include information systems and database programming.

WICHIAN CHUTIMASKUL received the B.Sc. degree in statistics from Chulalongkorn University, Thailand, in 1985 and the M.Sc. and Ph.D. degrees in data engineering and computer science from the University of Sheffield. He currently is an Associate Professor at the School of Information Technology, King Mongkut's University of Technology Thonburi, Bangkok, and the Senior Associate Dean for Academic Affairs. His research interests are in distributed systems, object oriented technology, management information systems, and systems analysis and design.