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RESEARCH ARTICLE

Integrating Technology Acceptance Model With Maslow's Hierarchy Needs Theory to Investigate Smart Homes Adoption

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ABSTRACT The rapid development of technology has led to the prevalence of smart homes as one of the most prominent intelligent devices. This research aims to identify the factors that significantly influence individuals' intention to use smart homes and provide direction for efficient product positioning and updates. Drawing from the Technology Acceptance Model (TAM), Value-based Adoption Model (VAM), Innovation Diffusion Theory (IDT), and Maslow's Hierarchy Needs Theory, a comprehensive research model is introduced. The model incorporates external factors such as perceived value (PV), price perception (PP), safety perception (SP), social influence (SI), self-esteem (SE), and visual aesthetics (VA), while self-innovation (SINN) is considered a moderator with a conditional effect between perceived usefulness (PU) and PV. The research model was validated with 405 samples, and exploratory factor analysis was conducted. Structural equation modeling (SEM) was used to analyze the results, which indicate that: 1). customers' intention to use smart homes is significantly determined by PV and VA through PU and perceived ease of use (PEOU). 2). Additionally, SINN moderates the relationship between PV and PU negatively within a specific interval. 3). SE and SI have slight effects on PU or PEOU, while PP and SP have no direct effect. These empirical results provide valuable conclusions and implications for understanding suitable smart homes for customers and finding actionable directions for smart home development

INDEX TERMS Smart home, technology acceptance model, Maslow's hierarchy needs theory, technology adoption, purchase intention.

I. INTRODUCTION

With the rapid growth of technology and the economy, smart homes and related services have gained significant attention. The benefits of smart homes applied to the Internet of Things (IoT) are increasingly recognized by more people. According to data from Quest Mobile, it is projected that by 2023, there will be an average of 265 million active customers using smart home applications every month in China, which represents a 28.3% increase compared to 2022 [1]. The three smart home products with the most active online users are MIUI (66.89 million), Fluorite cloud video (36.92 million), and Huawei (28.89 million) [2].

Smart homes were first envisioned as a futuristic way of living in the 1950s, mainly associated with the growth of suburbia [3]. Today, smart homes and related products have expanded to cover various fields such as sports, healthcare, communications, entertainment, and work assistance. The development of fifth-generation (5G) technology is critical in extending the scope of smart homes. For instance, people use smart home products like watches or beds to monitor their physical condition and receive alerts on their phones.

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Customers also use air purifiers and robotic vacuums to efficiently and conveniently manage their daily lives, which can be controlled remotely through smartphones or personal computers. The Chinese smart home market is experiencing steady growth, with a compound annual growth rate of 18.51%, from $37.6 billion in 2016 to $74.2 billion in 2020. Predictions indicate that the market will continue to grow, with an estimated value of $103.2 billion by 2023 [4].

Previous studies have attempted to explain consumers' adoption behaviors to smart homes by extracting technical and representative factors using famous theories and models. For example, the study [5] found that trust, perceived risk, and awareness influence the intention to purchase smart homes. The research [6] conducted a survey of 1039 samples and confirmed the relationships between gender, generation, and use behavior of smart homes. The scholars of [7] found that cultural factors and technology awareness significantly influence the elders' intention to buy smart homes.

However, the previous researches mainly focused on analyzing function, safety, price, or other physical external factors that may affect the intention to use smart homes. Few studies analyze mental factors such as aesthetics and self-esteem.

To address the gap, this research explored various factors that have relationships with the adoption of smart homes via PU and PEOU. The research proposed a comprehensive research model whose structures are basically extracted from Technology Acceptance Model (TAM), Maslow's hierarchy needs theory, Innovation Diffusion Theory (IDT). Perceived value (PV), price perception (PP), safety perception (SP), social influence (SI), self-esteem (SE), and visual aesthetics (VA) were adopted as external constructs to perfect the research model. Attitude to use (ATT), intention to use (ITU), perceived usefulness (PU), and perceived ease of use (PEOU) are primary factors extracted from TAM, which could show clearly how these external factors affect the acceptance of smart homes. Since many previous studies have pointed out that the individual's innovation may also impact technology adoption, the present study proposed self-innovation as a potential moderator [8]. By integrating Maslow's theory into TAM, the physical and mental factors can be investigated simultaneously to provide a more comprehensive survey of smart home adoption. The research proposed the following majority gaps:

- With the current changing environment, as people become accustomed to 5G technology and experience a long-pandemic era, their needs for smart homes will also vary. Furthermore, this study was undertaken mostly in China, whereas most earlier studies on smart homes were conducted in other nations. To research consumers' intentions and behavior for smart homes in China with fresh backgrounds, it is important to design an original model structure and integrate new factors.
- Previous studies have investigated many factors about intention to use smart homes, but few studies pay attention to mental factors, such as aesthetics, self-esteem, and self-actualization. Furthermore, because of the lag period of the development of smart home technology, we should seek guidance from new mental variables and compare them with certain old elements in order to obtain better directions for building products.
- Can the external factors that function as moderators influence perceived usefulness and perceived ease of use?

The research proposed the following novelties to address the problems mentioned above:

- This research first combines Maslow's hierarchy needs theory with TAM, which is rather new within the field of smart homes, providing a creative structure to study smart homes and extending the capacity of original models.
- This research inventively investigates the physical and mental factors and finds what influences customers' intention to use smart homes most. TAM essentially consists of two elements: PU and PEOU, that are also kept in our research model and demonstrate vividly how these independent factors influence individuals' propensity to utilize smart homes.
- This study investigates self-innovation as a moderator to make the structure more comprehensive, according to the Innovation Diffusion Theory. In this research, the Johnson-Neyman (J-N) technique is applied as well to analyze the conditional effect, which is an effective and valuable skill for distinguishing the "better" effect from the "worse" effect. However, few studies utilize it to study smart homes, which is a novelty of this research.

The remainder of this paper is organized as follows: following the review of smart homes and model theories, the research raises hypotheses. Then, after the methodology is explained, the results are discussed. After that, the paper proposes conclusions and discussions to give the complications and suggestions. Finally, the limitations and future work are presented.

II. LITERATURE REVIEW AND THEORETICAL MODELS

A. SMART HOMES

Smart homes are commonly recognized as a cyber-physical system that is centralized and controlled by an internal personal network, and parts of functions need to be installed before their homes are decorated [5]. However, many customers can fulfill this goal by purchasing smart home furniture, which becomes a prevalent trend considerably in China.

As an assistance to help people with their daily life, smart homes are applied for multi-purpose functions. For example, many people use smart homes to receive better audio-visual experiences, which can be controlled by gestures or voice [6]. The health situation, such as heartbeat and blood oxygen, can also be monitored by smart homes like beds or home medical equipment. Smart homes will inform the doctor if individuals' health indexes are abnormal [9].

With the extensive utilization of smart home products, several researchers have explored the significance and causes of user behavior in adopting smart homes. The prior study of

TABLE 1. Summary of prior studies of smart homes.

Product or service	Model	Variables extracted	Reference
Smart home services	TAM VAM	Privacy ; innovation; technically; fee; facilitating conditions; enjoyment	[13]
Smart homes	TAM	Trust; awareness; enjoyment; risks	[5]
Smart homes	UTAUT2 TAM2	Safety; health; convenience comfort; sustainability	[11]
Smart home services	TAM UTAUT2	Price value; well-being; eudaimonic motivation	[14]
Smart home health care	UTAUT TTF	Task characteristics; technology characteristics; task-technology fit	[9]
Smart kitchen	VAM UTAUT	Usage experience; flexibility; reliability; fee; technicality	[12]

smart home services applied the model of TAM and VAM to investigate the adoption of smart homes and find the negative and positive factors related to perceived value [10]. The study [11] on smart homes combining UTAUT2 with TAM2 proved that specific populations could be targeted. The study of smart kitchens applying VAM and UTAUT intends to investigate the effect of key value on actual use [12].

Table 1 summarizes previous studies on smart homes on customer adoption and behavior. These researches prove that it is necessary to investigate the potential factors affecting users' intention to use smart homes, which gives us the direction to formulate smart home products.

B. VALUED-BASED ADOPTION MODEL

Valued-based Adoption Model (VAM), proposed by [15], is a notable theory that can interpret users' decision-making. It proposed that the decision is made depending on the perceiving of cost and the pushing force of enjoyment. VAM was promoted from TAM, eliminating the restriction of using merely two factors, and incorporating other potential factors [16]. VAM includes four main variables: perceived benefit, perceived cost, perceived value, and intention to use. The research [15] suggested that perceived cost and perceived benefit both have impacts on perceived value, which leads to the intention to adopt technology, but according to previous studies, perceived cost and perceived value may affect the adoption of technologies at the same time [17], [18].

VAM is often applied to research new technologies adoption; the research [15] first used it to investigate mobile internet in 2007. After that, VAM was used to study mobile phones, mobile payments, and mobile applications. Few researchers are investigating smart homes by using VAM.

In addition to the factors of TAM, this research also contains parts of VAM: perceived value and price perception that may significantly influence people's attitudes towards smart home adoption. The main aspects of VAM in this model, perceived value and price perception, suggest that customers' attitudes and intentions to adopt technological products were influenced by perceiving value positively. At the same time, the cost, including the fee to pay and the effort paid to learn the new technology, may have a negative effect on the intention to use [19].

1) PERCEIVED VALUE

Perceived value (PV) is a fateful item of VAM that directly causes the intention to use smart homes. PV indicates the benefits that customers can acquire when using smart homes, which can become a judgment of the total value of smart homes [16]. According to a previous study, PV impacts attitudes toward smart homes significantly. For example, [13] reported that customers' perceived value in smart homes determines their intention to purchase them. Moreover, the study [20] also presents that perceived value may have effects on perceived usefulness and perceived ease of use while using mobile payment. It is reasonable that we raise the hypotheses:

H1. Perceived value is positively related to perceived usefulness of smart homes.

H2. Perceived value is positively related to perceived ease of use of smart homes.

2) PRICE PERCEPTION

Price perception (PP) is the most significant portion of perceived cost, which represents the financial aspect of perceived cost. According to the study of [12], the fee of technology products has influenced the intention to use smart kitchens directly. Meanwhile, PP can be seen as the basic needs of Maslow's hierarchy of needs model that individuals are prone to take price into consideration [21]. The high price of technology products may prevent latent customers from purchasing smart homes most of the time, while low price stimulates people to buy them on the grounds of [10] study. Additionally, the scholars of [22] raised the hypothesis that PP could affect perceived usefulness and perceived ease of use of virtual reality technology in VAM and collected 1158 valid respondents to confirm it. Based on the studies above, we could propose the following hypotheses:

H3. Price perception is negatively related to perceived usefulness of smart homes.

H4. Price perception is negatively related to perceived ease of use of smart homes.

C. MASLOW'S HIERARCHY OF NEEDS

Maslow first proposed his hierarchy of needs theory in his paper, a theory of human motivation, in 1943 in order to evaluate hierarchical needs in various physical and mental aspects. Abraham Maslow's hierarchy of needs model includes five levels at the very beginning, in which the basement is the physical demand for survival, such as food, water, air, and space [23]. We concluded the based requirements as PP above because money can often become a standard

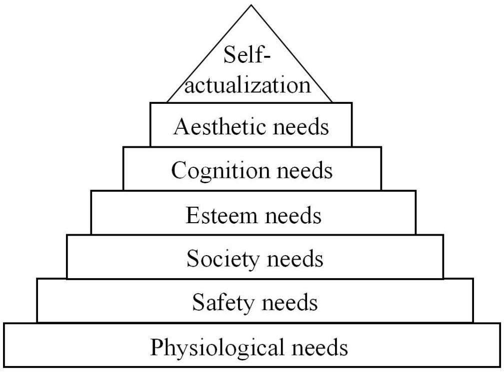

FIGURE 1. Maslow's hierarchy needs theory.

that customers decide whether to buy the product [21]. The following four progressive layers are personal safety needs, interaction and social needs, self-esteem needs, and self-actualization needs. The five-level model was improved in 1981, adding two more layers above that are visual aesthetics needs and self-transcendence needs in Fig. 1 [24]. Once lower hierarchical needs are satisfied, the higher layer of needs will be pursued [25]. For example, research [26] shows that people are willing to share knowledge to fulfill individual values after their based needs are satisfied in online health communities.

Maslow's Hierarchy Of Needs Theory is often used in evaluation and human resources organization studies. Some researchers apply this model to investigate customers' purchase intention for technology products, such as electric vehicles [21], and customers' adoption and behavior toward information technology [27]. Furthermore, more and more studies use this hierarchical needs model to investigate intelligent products like Voice-User Interface (VUI) [28]. This model offers functions that other models cannot research, clarifying the needs hierarchically of specific intelligent products in order that we can know how to improve the product more specifically and efficiently. In conclusion, this research examines the perceptions of price, safety perception, social influences, self-esteem, and visual aesthetics in the investigation of smart home purchasing.

1) SAFETY PERCEPTION

Safety perception (SP) is the secondary-based layer of Maslow's hierarchy of needs model, which is becoming increasingly critical nowadays because of technical information development. Most people are conscious of privacy and information safety, relating to privacy leaks, hacker attacks, and information collection illegally, according to the research on smart wellness wearable that may explore user's location, health situation, and other sensitive information, which makes people worried [29].

Previous research shows that SP is one of the most significant determinants of adopting technology products. For example, the research [30] reported that SP directly affects the intention to use IP-based technologies in smart homes. Moreover, the study [31] indirectly indicates that SP and PEOU have a latent correction effect, with a correlation loading of up to 0.64. The scholars of [10] conducted a survey that received 799 credible answers, proving that safety value significantly influences PU when people use smart home services. Based on the surveys above, the following hypotheses are proposed:

H5. Safety perception is positively related to perceived usefulness of smart homes.

H6. Safety perception is positively related to perceived ease of use of smart homes.

2) SOCIAL INFLUENCE

Social influence (SI) is discussed in smart homes, which can be classified into Maslow's category of interaction and social needs. SI means that peoples are prone to purchase the products recommended by their companions, which is especially apparent in individuals with social demands [21]. In this regard, SI could be one of the potential motivations for purchasing smart homes [9].

A previous study proposed that social influence has a noticeable impact on PU and PEOU of mobile technology. However, he defined social influence, which combined subjective norms with social images that we cannot identify which part was functional [32]. Besides, the research [33] confirmed that SI could influence PU and PEOU of citizens to varying degrees when they use information and communication technologies. Thus, we raise the following hypotheses:

H7. Social influence is positively related to perceived usefulness of smart homes.

H8. Social influence is positively related to perceived ease of use of smart homes.

3) SELF-ESTEEM

Self-esteem (SE) is often assured as the extent that individuals are satisfied with the respect, comments, and status they receive, which can be categorized as Maslow's esteem category [27]. From the societal perspective, self-esteem also represents reputation and decency from others [26]. Indeed, those with high self-esteem are prone to wish to gain acceptance from others, and their needs may signally affect the acceptance of intelligent technologies. Furthermore, people with high self-esteem often possess huge pursuit of acceptance, which motivates them to purchase luxury products [21].

The research of [21] confirmed that self-esteem would affect the purchase intention of electric vehicles significantly, while [32] also supported the hypothesis by investigating products of wireless internet services. Moreover, Karahoca's research in healthcare technology products showed that social image influences PEOU and ITU [34]. The theories above were verified again because of the research on smart connected objects in 2022 [8], [32]. Some scholars point out that individuals with high self-esteem are possible to take constructive behaviors to gain fame and credit [35]. For example, people with high status are prone to accept environment-friendly products to enhance themselves [36]. However, most previous studies just demonstrate self-esteem may influence the intention to adopt products, neglecting how self-esteem affects the adoption to use intelligent products. Thus, we raise the following hypotheses:

H9. Self-esteem is negatively related to perceived usefulness of smart homes.

H10. Self-esteem is negatively related to perceived ease of use of smart homes.

4) VISUAL AESTHETICS

Visual aesthetics (VA) is a higher level of Maslow's needs which becomes more important nowadays because of the economic development that most people could satisfy with the based layers of Maslow's hierarchy of needs. VA refers to the perceived attractiveness of smart homes' appearance in this paper, including issues about colors, shapes, animation, and font. In terms of company, VA seems as a symbol to distinguish itself from other competitors. The best example is Apple Inc, a powerful measure for companies to compete for increasing customers [37].

According to previous research, the fact that VA influences customers' intention to use significantly has been proved. Additionally, the research [37] took VA as an external factor and combined it with TAM, showing that VA affects PU and PEOU slightly in mobile commerce. Furthermore, the investigation of web portals strengthens the result that VA affects PU meaningfully, while the studies [38], [39] also repeated the experiment to study wearable devices in health care and revealed that VA impacts PU and PEOU expressively. However, there are no researches to investigate smart homes with the variable of VA and associate it with TAM, so we raise the hypotheses:

H11. Visual aesthetics is positively related to perceived usefulness of smart homes.

H12. Visual aesthetics is positively related to perceived ease of use of smart homes.

D. TECHNOLOGY ACCEPTANCE MODEL

In addition to VAM and Maslow's Needs Theory, this research applies Technology Acceptance Model (TAM) as the based framework to investigate customers' intention to purchase smart homes. TAM is the most frequently-used model employed to predict and explain customer intention toward new technology adoption and usage, which David first raised in 1989 [40], [41]. Although TAM is developed by follow-up research with different revisions, such as TAM2, TAM3, and UTAUT, TAM still mainly includes four structures: perceived usefulness, perceived ease of use, attitude to use, and intention to use. At the same time, PU and PEOU positively influence ATT [28]. According to recent research, PEOU also affects PU positively [5].

Many researchers use TAM to investigate the receiving of new technology. For example, investigating the voice-user interface of smart homes that combines TAM with Senior Technology Adoption Model (STAM) is creative [28]. Further, another research about smart home health care using a Unified Theory of Acceptance and Use of Technology (UTAUT) was developed by TAM and also performed well during the research [9]. Although TAM shows a powerful function in predicting customers' adoption of technology, there are a few limitations that the constructs of TAM are limited. In order to solve the problem, the model needs to be adjusted according to the specific situation, such as combing TAM with other various models [28].

1) PERCEIVED EASE OF USE

Perceived ease of use (PEOU) is defined as that customers need not pay too much energy to learn and utilize smart homes, which becomes an evaluation of the simplicity degree of smart homes. Some previous studies manifested that perceived ease of use is a positive determinant of attitude to use when customers use information and communication technology [10]. In the research [42] on Internet Of Things (IOT), he found that perceived ease of use affects perceived usefulness positively. After that, more researchers confirm the theories above many times, which proves the relationships between them are stabilized and valid [5]. Therefore, we can propose the following hypotheses:

H13. Perceived ease of use is positively related to perceived usefulness of smart homes.

H14. Perceived ease of use is positively related to attitude toward using smart homes.

2) PERCEIVED USEFULNESS

Perceived usefulness (PU) is the most important concept in the model of TAM. Perceived usefulness means customers can feel the efficiency and convenience the products provide [40]. According to the research on Information and Communication Technology (ICT), it is obvious that perceived usefulness has a substantial influence on attitude to use, which is the same as PEOU [33]. In the region of smart energy technologies, the research [43] also proved that PU has an effect on the intention to use directly. Thus, we raise the following hypotheses:

H15. Perceived usefulness is positively related to attitude to use of smart homes.

H16. Perceived usefulness is positively related to intention to use smart homes..

3) ATTITUDE TO USE

Attitude to use (ATT) is defined as the level that individuals are voluntary to accept new technologies of smart homes, while Intention to use (ITU) means the degree that people are willing to purchase and use smart homes in this research. Many types of research show that attitude to use usually has a significantly positive relationship with Intention to use, especially about technology products, such as smart homes [5]. Therefore, we raise the following hypothesis:

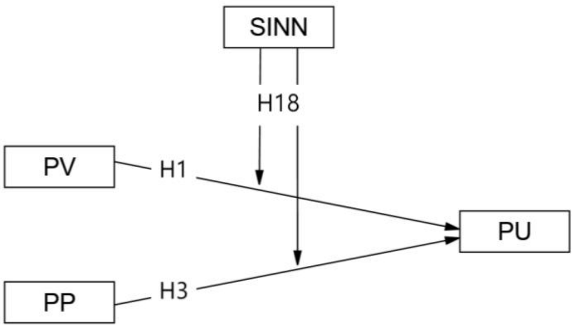

FIGURE 2. The conditional effect of SINN.

H17. Attitude to use is positively related to Intention to use smart homes.

E. INNOVATION DIFFUSION THEORY

Innovation Diffusion Theory (IDT) was explained by Rogers in 1995, exclaiming that it is a process of innovation diffusing over time among the people of a communication group, which includes five stages, knowledge, persuasion, decision, implementation, and confirmation [44]. Further, the author also pointed out that the key part of IDT, intention and adoption to use new technologies, are relative closely to personal characteristics about relative advantage, compatibility, complexity, experimental, and observability [45]. Moreover, various kinds of research afterward improved the theory of IDT and derived new models such as Diffusion Of Innovation (DOI) and Personal Innovation in Information Technology (PIIT) by extracting the key variable of self-innovation.

Self-innovation (SINN) is the most representative construct of IDT, defined as the degree of individuals being willing to accept new technologies [46]. It is also explained why some people would rather take the risk of utilizing new technologies with alacrity while others are unwilling to accept change because of the Diffusion of SI. According to previous research about information technology, SI may affect customers' PEOU, social influence, and perceived control positively, indicating that SINN may have a huge impact on various variables of models about technology adoption behavior [47]. A creative action that the mobile technology study in 2005 took is combining SINN and TAM, successfully confirming the hypothesis that SINN has an actual effect on PU and PEOU [32]. The theories above are proved to be confirmed and valid again by research [48] about the utilization of websites. During the study of wearable devices, the author even confirmed the hypothesis that SINN influences self-efficacy, which means perceived value positively [39]. However, few studies combine SINN with VAM and TAM to study smart homes, causing innovation may become a latent moderator that affects the relationships between them positively, as shown in Fig. 2. Thus, we raise the following hypothesis:

H18. Self-innovation plays a moderator in the relationship between customers' perception of usefulness and perceived value and price.

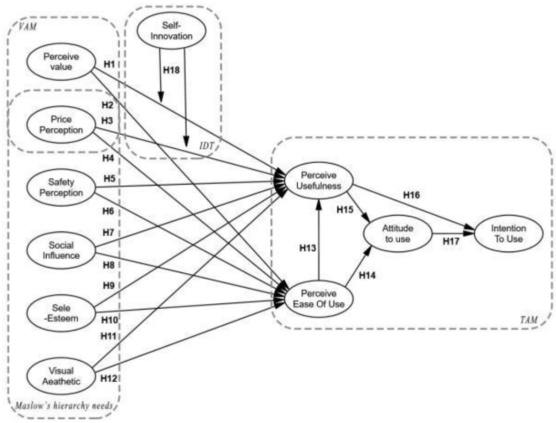

FIGURE 3. The hypothesized model.

F. RESEARCH MODEL

Based on the extant research, we extend TAM model and hypothesized model (Fig. 3), which combines TAM with Maslow's Hierarchy Needs Theory and VAM, proposing self-innovation as a moderator at the same time. In order to discuss and understand customers' intentions to use smart homes, it is necessary to integrate various user-oriented theories into a comprehensive model, which can compare different proportions of variables.

III. METHODOLOGY

A. QUESTIONNAIRE DESIGN AND MEAUREMENTS

This research is based on the questionnaire design procedure proposed by Park [49]. To guarantee the accuracy and comprehensiveness of the 11 constructs in this questionnaire, the 46 questions representing 11 constructs are extracted mainly from professional journals according to the three-indicator rule that there are at least three items per factor [50]. Because the initial questions were made in English, we conducted a double translation method (English-Chinese-English) to ensure that the meaning of the content was expressed correctly [51]. Two professional translators conducted all the translation procedures, and then three professors of relevant specialties revised the translated questionnaire.

Our questionnaire contains two parts. The first part is the background of participants, including age, gender, and marriage. The second part is the question related to the measurement of research subjects. Before the participants answered the questionnaire, we showed some pictures of smart homes related to their lives to scope the definition. Citing the previous studies that a seven-point Likert scale is a better choice to conduct the research as an interval scale, we applied it with scores varying from 1= completely disagree to 7= completely agree to evaluate all potential variables efficiently [52], [53]. After revising items, we conducted a pilot test with thirty participants and four items excluded, leaving 42 valid questions. According to the suggestions above and uuni-dimensionality, the questionnaire is presented in Table 2 [54].

TABLE 2. Questionnaire items.

Construct	Item	Reference
perceived ease of use	PEOU1: Using the smart home would be easy PEOU2: Interaction with the smart home would be clear and understandable PEOU3: I would find it easy to get the smart home to do what I want it to do PEOU4: Overall, I found the various smart homes easy to use	
perceived usefulness	PU1: Using the smart home would improve my overall quality of life (delete) PU2: Using the smart home would help my daily housework PU3: Using the smart home would enhance effectiveness in my daily work PU4: I would find the smart home useful in my life	
attitude to use	ATT1: Use of the smart home in everyday life would be useful ATT2: Use of the smart home in everyday life would be effective ATT3: Use of the smart home in everyday life would be pleasant ATT4: Overall, people feel positive toward using smart homes	[55]
intention to use	ITU1: I intend to use the smart home in the future ITU2: I intend to use the smart home frequently ITU3: I intend to recommend that other people use the smart home ITU4: I intend to buy the smart home in the future	
self-innovation	SINN1: I like to experiment with new information technologies SINN2: If I heard about a new information technology, I would look for ways to experiment with it SINN3: Among my peers, I am usually the first to try out new information technologies SINN4: In general, I am positive to try out new information technologies	[11]
perceived value	PV1: Compared to the fee I would need to pay, the smart home offers value for money PV2: Compared to the effort I would need to put in, the smart home is beneficial to me PV3: Compared to the time I would need to spend, the smart home is worthwhile to me PV4: Overall, the smart home delivers good value	[55]
social influence	SI1: People who influence my behavior would think that I should use the smart home SI2: People who are important to me would think that I should use the smart home SI3: People around me will take a positive view of me using the smart home SI4: If my family and friends use smart homes, so will I use smart home	
price perception	PP1: The fee that I would have to pay for use of the smart home is too high PP2: The fee that I would have to pay for use of the smart home is unreasonable PP3: Using smart home would be a financial risk for me because of the possibility of higher maintenance and repair costs PP4: I am not pleased with the fee that I have to pay for using smart home	[29]
safety perception	SP1: I am concerned that smart home collect too much personal information about me SP2: I am concerned the smart home providers might use my personal information SP3: I am concerned that smart home providers might share my personal information SP4: I am concerned that hackers could access my personal information when I use smart home (delete) SP5: Overall, I am concerned about the privacy of my personal information while using smart home	
self-esteem	SE1: The use of smart home would make people hold me in high regard (delete) SE2: The use of smart home would enhance the image that others would have of me SE3: The use of smart home would help me to show others who I am SE4: The use of smart home would make a good impression on other people	[56]
visual aesthetics	VA1: The interface of smart home is aesthetically appealing (delete) VA2: The interface of smart home is attractive VA3: The interface of smart home is aesthetically designed VA4: The overall look and feel of smart home is visually appealing VA5: The interface of smart home pleases my senses	[57]

B. PARTICIPANTS

This research was conducted mainly in Guangdong province and Zhejiang province, which nearly had half production of Chinese smart homes in 2019 [58]. In these areas, smart home coverage is higher than in other places, and the research also set the restriction that the research subjects must have experience using smart homes.

Before they answered the questionnaire, we introduced the definition of smart homes comprehensively. We provided explanations and pictures of smart homes to our participants to ensure they were fully aware of the objects we investigated. Before data collection, the researchers provided the participants with a summary of the study, instructions on the information collection, and informed consent forms from the participants.

C. DATA COLLECTION AND ANALYSIS PROCEDURE

The open survey was conducted online in China using the primary social applications, including Tencent QQ, WeChat, and Weibo because individuals contacting the internet and technology frequently are prone to get interested in technology products such as smart homes. The online survey was conducted for 15 days by testing 422 individuals' perceptions of smart homes. After deleting incomplete and failed to pass attention testing questions answers, there are 405 questionnaires left. The demographic information of the research participants is in Table 3. Structural equation modeling (SEM) was applied to investigate the relationships between variables

TABLE 3. Participants' information.

Construct	Item	Frequency	Percent
Gender	Male	133	32.8
	Female	272	67.2
	Total	405	100.0
Marriage	Married	123	30.4
	Unmarried	282	69.6
	Total	405	100.0
Age	Under 18	7	1.7
	18-25	230	56.8
	26-30	69	17.0
	31-40	49	12.1
	41-50	42	10.4
	51-60	8	2.0
	Total	405	100.0
Income (RMB)	under 3000	174	43.0
	3001-5000	74	18.3
	5001-8000	71	17.5
	8001-15000	63	15.6
	15001-50000	21	5.2
	Above 50001	2	0.5
	Total	405	100.0
Education	Elementary	11	2.7
	Vocational school	9	2.2
	High school	17	4.2
	Junior college	54	13.3
	College	247	61.0
	Graduate and above	67	16.5
	Total	405	100.0

which is specially invented for complex model research. SEM requires that the ratio of observations per indicator is 1:10, but Bentler suggests that the sample size to the free parameter is 5:1 [59]. According to this, the sample number should be between 210 and 420, so the collection number of 405 valid samples meets the threshold.

Before data analysis, we mainly used SPSS 26.0 to summarize the demographic information and test the validity of the statistics [60]. Further, in order to test the hypotheses, we conducted path analysis to discover the relationships between each variable using AMOS 24.0. The PROCESS plug-in was utilized for testing the interference effect of the moderator.

IV. RESULTS

A. PRELIMINARY ANALYSIS

The preliminary analysis data in the research model are presented in Table 4 and Table 5. The table shows that each item has 405 samples; none has missing data, while the extreme standard deviation and mean values are all in the normal range, indicating no filing errors. According to the standard proposed in 2013, the absolute values of skewness and kurtosis should range less than 1.5 to guarantee that all the constructs are normally distributed [61]. Further, previous research proposed that the absolute value of skewness and kurtosis must be less than 3 and 8, respectively, to fit the data normality requirement [62]. All the skewness and kurtosis data are satisfied with the standard and proved to be normally distributed and continuous, laying the foundation for further research.

TABLE 4. Descriptive analysis of items.

Item	N	Mean	Std. Deviation	Skewness	Kurtosis
ATT1	405	5.70	0.910	-0.897	1.261
ATT2	405	5.58	1.038	-0.670	0.786
ATT3	405	5.57	0.984	-0.674	0.650
ATT4	405	5.61	1.015	-0.551	-0.111
ITU1	405	5.68	0.982	-0.877	1.351
ITU2	405	5.41	1.123	-0.736	0.666
ITU3	405	5.30	1.173	-0.488	-0.209
ITU4	405	5.64	1.082	-0.911	1.121
PEOU1	405	5.44	1.164	-0.802	0.418
PEOU2	405	5.40	1.151	-0.658	0.183
PEOU3	405	5.41	1.158	-0.744	0.531
PEOU4	405	5.44	1.162	-0.776	0.456
PU2	405	5.84	1.031	-0.828	0.453
PU3	405	5.85	1.045	-0.983	1.236
PU4	405	5.77	1.014	-0.751	0.425
PP1	405	5.43	1.246	-0.986	0.844
PP2	405	4.88	1.322	-0.801	0.445
PP3	405	5.08	1.502	-0.880	0.151
PP4	405	5.06	1.389	-0.742	0.118
SP1	405	5.10	1.509	-0.824	-0.064
SP2	405	5.29	1.467	-0.982	0.434
SP3	405	5.32	1.529	-0.990	0.275
SP5	405	5.37	1.521	-1.050	0.507
PV1	405	5.19	1.182	-0.762	0.424
PV2	405	5.41	1.034	-0.703	0.836
PV3	405	5.46	1.061	-0.724	0.724
PV4	405	5.48	1.028	-0.809	1.326
SI1	405	5.41	1.063	-0.901	1.342
SI2	405	5.40	1.164	-0.937	1.155
SI3	405	5.54	1.018	-0.776	1.083
SI4	405	5.56	1.058	-0.664	0.508
SINN1	405	5.55	1.108	-0.835	0.481
SINN2	405	5.38	1.238	-0.751	0.326
SINN3	405	4.83	1.519	-0.557	-0.385
SINN4	405	5.53	1.102	-0.695	0.252
SV2	405	4.98	1.384	-0.663	0.048
SV3	405	4.81	1.413	-0.417	-0.551
SV4	405	4.92	1.400	-0.588	-0.114
VA2	405	5.49	1.100	-0.599	-0.150
VA3	405	5.56	1.055	-0.617	-0.010
VA4	405	5.51	1.100	-0.611	-0.018
VA5	405	5.47	1.180	-0.814	0.552
Valid N	405				

TABLE 5. Descriptive analysis of constructs.

Construct	Mean	Std. Deviation	N
PEOU	5.420	0.975	405
SINN	5.321	1.071	405
PP	5.113	1.185	405
PV	5.385	0.903	405
ITU	5.509	0.922	405
ATT	5.612	0.844	405
SI	5.478	0.906	405
SP	5.271	1.369	405
PU	5.821	0.892	405
VA	5.506	0.970	405
SE	4.902	1.270	405

B. EXPLORATORY FACTOR ANALYSIS

The exploratory factor analysis is used to estimate the factor structures that the standardized factor loading of 42 items

TABLE 6. Exploratory factor analysis.

Item	1	2	3	4	5	6	7	8	9	10	11
SP3	0.890										
SP2	0.882										
SP1	0.867										
SP5	0.865										
VA3		0.823									
VA2		0.816									
VA4		0.800									
VA5		0.737									
SINN2			0.820								
SINN1			0.790								
SINN4			0.764								
SINN3			0.763								
PP4				0.855							
PP3				0.847							
PP2				0.843							
PP1				0.807							
SI3					0.758						
SI2					0.747						
SI1					0.709						
SI4					0.676						
PEOU2						0.749					
PEOU1						0.726					
PEOU4						0.723					
PEOU3						0.690					
ITU4							0.730				
ITU1							0.730				
ITU2							0.730				
ITU3							0.651				
PV2								0.735			
PV1								0.732			
PV4								0.692			
PV3								0.662			
SE4									0.851		
SE3									0.836		
SE2									0.793		
ATT1										0.789	
ATT3										0.671	
ATT4										0.630	
ATT2										0.596	
PU2											0.827
PU3											0.781
PU4											0.644

should be higher than 0.5 acceptably and ideally above 0.6 [54], [63]. The results of factor loading range from 0.596 to 0.890, and they are clearly divided into 11 constructs in Table 6, all of which are above the threshold of 0.5. This demonstrates that the factor structure is appropriate for this research.

C. VALIDITY TEST

Based on previous measurement scales, validity analysis reveals that values above 0.7 for Cronbach's alpha coefficient indicate reliability [64]. According to the regulation of confirmatory factor analysis (CFA), values of composite value (CR) and average variance extracted (AVE) should surpass 0.7 and 0.5, respectively, but we can still accept 0.4 for AVE and confirm the convergent validity of the frame is tenable if CR is higher than 0.6 [54], [65]. Further, in order to examine the discriminant validity, each square root value of AVE in one specific construct must be higher than the correlations between that construct and any other construct [33].

On the basis of the above studies, there are 405 samples, and the values of the mean and standard deviation of each structure are shown in Table 5. The values of Cronbach's alpha shown in Table 7 are all above 0.8, which indicates the favorable internal consistency in each potential structure. The values of CR and AVE are all above the thresholds of 0.7 and 0.4 separately. The numerical values of the square root of AVE on the diagonal in Table 7 are bold and greater than the correlations between structures, proving the convergent and discriminant reliability of this research are both passed.

D. FIT INDICES

The goodness of fit indices is often used to evaluate whether the model is appropriate for the data we collect. Jackson et al., stated that Chi-square (X^2), degree of freedom (DF), and

TABLE 7. Results of internal and convergent reliability.

Construct	Validity	composite reliability	convergence validity	correlation and discriminant validity										
	Cronbach's α	CR	AVE	PEOU	SINN	PP	PV	ITU	ATT	SI	SP	PU	VA	SV
PEOU	0.862	0.813	0.522	**0.722**										
SINN	0.877	0.865	0.616	0.540	**0.785**									
PP	0.889	0.904	0.703	-0.051	0.002	**0.838**								
PV	0.858	0.799	0.498	0.596	0.435	-0.037	**0.706**							
ITU	0.865	0.803	0.506	0.489	0.472	0.010	0.596	**0.711**						
ATT	0.871	0.768	0.456	0.504	0.440	-0.026	0.561	0.658	**0.675**					
SI	0.862	0.814	0.523	0.483	0.418	0.023	0.512	0.580	0.648	**0.723**				
SP	0.930	0.930	0.767	0.049	0.054	0.472	0.037	0.075	0.077	0.172	**0.876**			
PU	0.833	0.797	0.570	0.415	0.380	0.043	0.480	0.521	0.601	0.424	0.162	**0.755**		
VA	0.897	0.873	0.632	0.563	0.455	0.021	0.470	0.418	0.410	0.401	0.091	0.440	**0.795**	
SE	0.893	0.866	0.684	0.406	0.426	-0.064	0.445	0.409	0.365	0.484	0.040	0.227	0.411	**0.827**

The bold diagonal is the square root value of average variance extracted (AVE), and the lower triangle is the Pearson correlation of structures.

TABLE 8. Model fit of the research.

Index	Research model	Criteria
Chi-square (X^2)	1312.62	——
DF	633	——
X^2/DF	2.074	<3
CFI	0.933	>0.90
TLI	0.926	>0.90
AGFI	0.829	>0.80
GFI	0.854	>0.80
RMSEA	0.052	<0.08
SRMR	0.053	<0.08

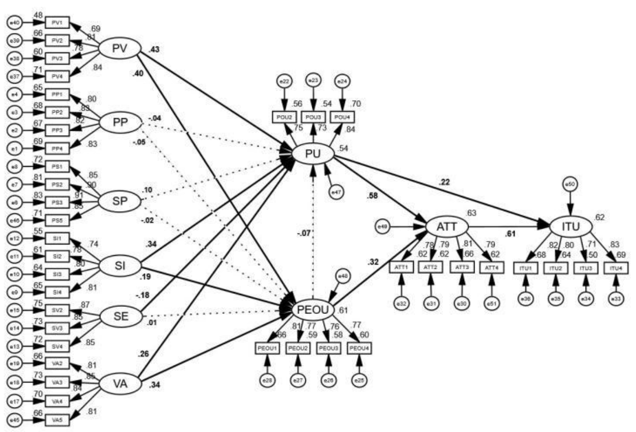

FIGURE 4. The research model.

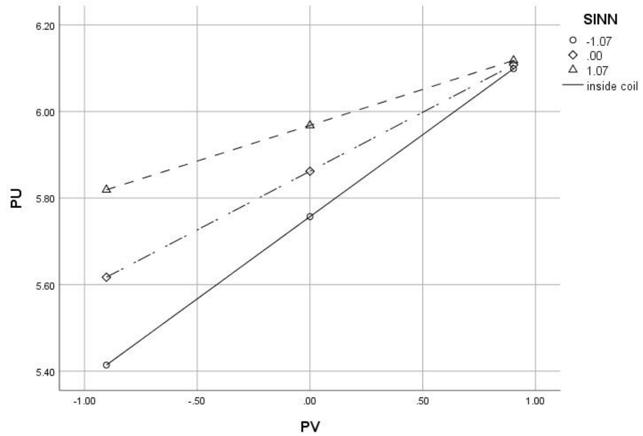

FIGURE 5. Figure of the moderation effect.

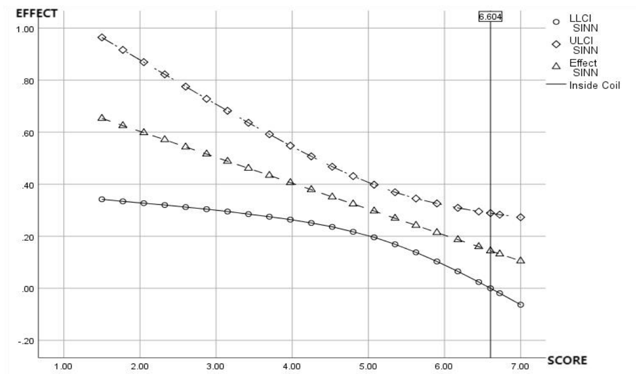

FIGURE 6. Johnson-Neyman confidence of moderating effect.

other fit indices are the common standards to measure the fitness of a model [66]. Based on previous research, the indices of the Comparative Fit Index (CFI) and Tucker–Lewis index (TLI) should ideally surpass 0.9. At the same time, the indices of the goodness of fit index (GFI) and Adjusted GFI (AGFI) are higher than 0.8, which is also acceptable [67]. Kenny suggested that the Root-mean-square error of approximation (RMSEA) and Standardized Root-mean-square residual (SRMR) need to be inferior to 0.08, which represents a good fit for the research model [68]. The indices of the current research model meet the criteria above and are computed in Table 8.

E. HYPOTHESES TESTS

After passing the reliability and validity tests of the research model, the results of the SEM of current research are

TABLE 9. Results of the research model.

Hypothesis	Relationship	Standardized Estimate (β)	Unstandardized Estimate	S.E. (Standard Error)	C.R. (T-Value)	P-Value	Decision
H1	PV → PU	0.433	0.386	0.070	5.518	***	Support
H2	PV → PEOU	0.397	0.410	0.066	6.211	***	Support
H3	PP → PU	-0.040	-0.027	0.036	-0.750	0.453	Not Support
H4	PP → PEOU	-0.049	-0.038	0.038	-1.000	0.318	Not Support
H5	SP → PU	0.098	0.054	0.030	1.815	0.069	Not Support
H6	SP → PEOU	-0.021	-0.013	0.032	-0.425	0.671	Not Support
H7	SI → PU	0.337	0.306	0.065	4.713	***	Support
H8	SI → PEOU	0.190	0.200	0.066	3.037	0.002	Support
H9	SE → PU	-0.183	-0.119	0.039	-3.067	0.002	Support
H10	SE → PEOU	0.013	0.010	0.041	0.244	0.807	Not Support
H11	VA → PU	0.263	0.221	0.054	4.098	***	Support
H12	VA → PEOU	0.336	0.327	0.053	6.212	***	Support
H13	PEOU → PU	-0.066	-0.057	0.071	-0.805	0.421	Not Support
H14	PEOU → ATT	0.322	0.286	0.048	5.979	***	Support
H15	PU → ATT	0.579	0.597	0.063	9.476	***	Support
H16	PU → ITU	0.224	0.260	0.086	3.031	0.002	Support
H17	ATT → ITU	0.605	0.682	0.087	7.804	***	Support

TABLE 10. Moderation effect of SINN between PV and PU.

Variable	Coeff	Se	t	p	Llci	Ulci
SINN→PU	0.099	0.041	2.407	0.017	0.018	0.179
VALUE→PU	0.272	0.051	5.349	0.000	0.172	0.372
VALUE X SINN→PU	-0.100	0.040	-2.507	0.013	-0.178	-0.022

shown in Table 9 and Fig. 4. As the results demonstrate, SE (H9, β = -0.183, t=-3.067, P<0.05) has a negative influence on PU which indicates H9 is supported. In contrast, SE (H10, β = 0.013, t=0.244, P>0.05) shows no significant influences on PEOU. The other three variables—PV (H1, β = 0.433, t=5.518, P<0.001; H2, β = 0.397, t=6.211, P<0.001), SI (H7, β = 0.337, t=4.713, P<0.001; H8, β = 0.190, t=3.037, P<0.05)and VA (H11, β = 0.263, t=4.098, P<0.001; H12, β = 0.336, t=6.212, P<0.001)all affect PU and PEOU positively. On the contrary, neither PP (H3, β = -0.040, t=-0.750, P>0.05; H4, β = -0.049, t=-1.000, P>0.05) nor SP (H5, β = 0.098, t=1.815, P>0.05; H6, β = -.021, t=-0.425, P>0.05) has relationships with PU or PEOU.

The hypotheses of TAM are almost supported. PEOU (H14, β = 0.322, t=5.979, P<0.001) and PU (H15, β = 0.579, t=9.476, P<0.001) both have positive associations with ATT, while PU (H16, β = 0.224, t=3.031, P<0.05) and ATT also affects ITU (H17, β = 0.605, t=7.804, P<0.001) positively representing H14, H15, H16, and H17 all support. Nevertheless, PEOU (H13, β = -0.066, t=-0.805, P>0.05) has no effects on PU.

F. THE MODERATING EFFECTS ANALYSIS

In order to test H18 and estimate the conditional effect of SINN between PV and PU, the research uses the plug-in of PROCESS in SPSS, which was invented in 2013 and conducted the statistical procedure of hierarchical regression by bootstrapping samples more than 5000 times [60]. The P-value is often used to estimate whether the conditional effect exists, as the results of the conditional effect of SINN between PV and PU in Table 10 show that the moderation factor of SINN exists. H18 (p<0.05) is proved to be significant that the effect of PV on POU is moderated negatively by SINN in Fig. 5. In addition to this, the research tests simple slopes and acts by the Johnson-Neyman (J-N) technique to distinguish "better" effect from "worse" effect [69]. Fig. 6 shows that for customers with scores higher than 6.604 of SINN, the moderation between PU and PV does not exist (p>0.05). However, a significant conditional effect appears when the scores of SINN are lower (scores<6.604).

V. DISCUSSION AND CONCLUSION

This research investigated customers' intention to use smart homes via the impact factors of PU and PEOU. The structure is extended primarily from TAM, VAM, and Maslow's Hierarchy Needs Theory and indicates that four variables significantly influence individuals' use intentions and behavior for smart homes. On the other hand, two factors were found not to have any impact on people's willingness to use smart homes, and the results are a little bit out of expectation. Additionally, the moderator does have some effect on the perception of the usefulness of using smart homes for customers to some extent, which gives us the direction to confirm who the potential customers would be.

In the construct of VAM, the research found that PV has considerably significant impacts on PU and PEOU, which follows previous studies of technology products, such as smart homes [13], [20]. The useful values, including emotional value, price value, and effort value, seem as important standards for people purchasing smart homes. It has become a normal sense for sellers that attraction is the embodiment of the value, and the quality is the guarantee of word of mouth, especially the products like smart homes that people will not frequently change [70], [71]. However, the moderator of SINN may interrupt the balance between PV and PU. The research above shows that the interference of SINN affects individuals' perception between value and usefulness negatively. In other words, the more innovative people will negatively affect the perception between value and usefulness. One possible reason is that these people with innovative spirits will have higher technology standards because they are often exposed to new technology and have an adequate reservation of technical knowledge. Nonetheless, the individuals who scored higher (more than 6.604 in Fig. 6) in innovation spirit will have more tolerance and devote themselves to trying every new technology, so the conditional effect disappears when the scores surpass the threshold. Previous research confirmed the theory that innovation resistance has limitations on perceived value of technology products. Further, the current research extends the theory that SINN will negatively influence the relationship between PV and PU.

In Maslow's hierarchy needs model, the current research proved that SI and VA significantly influence PE and PEOU positively, while SE affects PU only. The biggest surprise is that VA has quite an impact on PU and PEOU, which means that the aesthetic design actually decides people's attitudes toward purchasing smart homes to a great extent. According to previous research, the visual design could slightly impact PU and PEOU of other internet products. This study proves that the visual aesthetics of smart home design weighs a large proportion of purchasing smart homes [39]. The above results show that smart homes belong to higher levels of Maslow's hierarchy needs theory; thus, people the need smart homes pay more attention to factors like color, shape, and size rather than price and privacy safety. Furthermore, the standardized estimate of H12 is higher than H11, which indicates that relationship between visual aesthetics and perceived ease of use is stronger than perceived usefulness. According to the result above, the entertainment of smart homes creating by visual aesthetics could be another reason that leads to the consequence. Because of this, further study could consider perceived enjoyment as a potential factor in investigating smart homes. It is not astonishing that SI also impacts the intention to purchase smart homes via PU and PEOU observably because of the findings above. It indicates that customers are prone to social comments when they buy smart homes, in accordance with previous studies [9]. Customers still emphasize public praise nowadays; one potential reason is that the social comments of smart homes are the first impression for customers before they truly experience smart homes. The conclusion could also be confirmed that the standardized coefficient of H7 is higher than H8, which proves that social influence could influence perceived usefulness more than perceived ease of use. According to this research, self-esteem affects usefulness recognition negatively, but there is no correlation with ease of perception surprisingly. The results extended the theory discovered from previous research that self-esteem may predict purchase motivation for people with self-esteem demand via PU rather than PEOU [21]. One latent cause is that people with high self-esteem possess huge pursuit of reputation and acknowledgment, which may motivate them to buy more constructive products to enhance themselves [36]. Individuals with that characteristic would care much about labels of smart homes, such as famous-branded or eco-friendly, rather than the usefulness of smart homes. Besides, most subjects of the current research were young people who are more familiar with new technologies and more skilled in using information and the internet, which offset the potential difficulties of using smart homes. Moreover, PP and SP have no significant effect on PU or PEOU, which is different from previous research on the service of Internet of Things (IOT) and electrical vehicles [13], [21]. One potential reason could be that smart homes are a higher hierarchy product which is different from other products in previous research. People using smart homes are not just satisfied with basic needs but pursue a higher mental demand. The results confirm the theory above once again, which gives us the direction to develop and update smart homes.

In the construct of TAM, most hypotheses proven significant were confirmed to be true many times by previous research on smart homes and other technology products [22], [33]. In this research, the standardized estimate of H15 is 0.579, higher than H14. The result above implies that people pay more attention to the usefulness of smart homes, which is also in accordance with previous studies. One possible reason is that smart homes are functional products, and it is important to extend the functions of smart homes to make the product more competitive. However, H13 was not supported in this research, since PEOU has no positive effect on PU unexpectedly. The potential reason for this situation is that most observations are high-educated college graduates who do not consider learning to use smart homes a tough mission. The characteristic of subjects weakened the perception of the ease of use of smart homes.

VI. CONTRIBUTIONS

From an academic perspective, this study validated the combination of the Technology Acceptance Model (TAM) and Maslow's hierarchy of needs theory to investigate the acceptance of smart homes, extending the structural model's applicability. The study found that when individuals require higher hierarchical products such as smart homes, they prioritize upper-level needs such as visual design, product reputation, and social comments, over lower-level needs such as price, safety, and health. The study's results confirm the timeless relevance of Maslow's hierarchy of needs theory in smart products and future technology.

From an industrial perspective, this study expanded the function of Maslow's hierarchy of needs theory by providing guidance on product positioning. For instance, smart homes should prioritize appearance design over economic or privacy-safe characteristics, which is different from traditional furniture. Additionally, cultural influence may affect people's adoption of smart homes, as demonstrated in Maswadi's research [7]. By employing hierarchical levels of products, smart home providers can identify specific aspects to upgrade and attract more customers.

VII. IMPLICATIONS

A Smart homes could be a popular tendency of interior design in the future, making peoples' daily lives more efficient and intelligent. Based on the research above, reducing negative effects and boosting positive impacts influencing the intention to adopt smart homes directly or indirectly via PU and PEOU is a critical issue. Thus, we proposed the following implications.

The research findings highlight the crucial significance of the visual design of smart homes, which should create an attractive, enjoyable, and entertaining atmosphere, especially for products that people use daily. The smart home designers should focus on controlling colors, shapes, materials, and size to ensure high-quality visual design. Providing individualized design options can create a sense of participation and meet the customers' needs for self-value. Through participation experiences, customers can purchase and design smart homes, which is a new trend in product promotion.

Social influence and comments also significantly affect individuals' purchasing intentions. Smart home marketers can effectively improve their images in the market by using proper propaganda and additional strategies. One useful strategy is the Corporate Identity System (CI), which provides a simple visual image of companies and expresses their spirits and culture to the public, creating a standardized and positive impression. Companies like Apple and Huawei have successfully used their corporate images to attract more customers through social comments.

Further, smart homes belong to the higher levels of Maslow's theory, and providers must focus on satisfying various mental needs of customers. They can create internet communities for customers to communicate about their user experiences with smart homes and hold exhibitions to promote excellent value, meeting their cognition needs.

VIII. LIMITATIONS AND FUTURE WORK

Although this study proposed significant implications, a few limitations still exist, which can serve as a basis for future research. Firstly, this research is limited to the use of an online questionnaire survey method, and other research methods such as experimental methods, document research, and field research could be adopted in future studies. Secondly, most of the participants are high-educated young people in China, which may have an influence on the results of this research. Further research should expand the data collection range and number to ensure subject equilibrium. Thirdly, the constructs need to be more specific. This research focused on smart homes, which can serve as an exploratory basis for further study of specific types of smart homes, such as healthy smart homes or housework smart homes. Further research can also clarify which factors in visual aesthetics design affect customers' purchasing intentions of smart homes.

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