

# CONSUMERS' PERCEPTIONS ON SMART HOME AND SMART LIVING

*Research paper*

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## Abstract

*Internet of Things (IoT) is an umbrella term used for Internetworking physical devices such as vehicles, buildings, home appliances, and other physical objects to the Internet. This technology innovation allows for different objects or devices to be connected to each other, thus transforming the objects from “dumb” to “smart” devices. A central question for researchers and practitioners is whether and how the potential users of smart home technology, a subset of IoT technology, perceive this innovation. To address this question, the present paper seeks to empirically explore the relationships between determinant factors influencing users' intentions. By drawing upon recent studies on smart home technology, this paper argues that multiple factors impact users' perceptions and consequently their adoption decisions. By using a survey data from 156 individuals and applying structural equation modelling (SEM) and Fuzzy-set qualitative comparative analysis (fsQCA), this research suggests that attitudes toward using technology, social influence, perceived usefulness and perceived innovativeness impact users' adoption decisions. Moreover, fsQCA results, while reinforcing and refining findings from the SEM analysis, reveal that there is no single solution that lead to the outcome of interest—smart home technology adoption—but multiple configurations of conditions do. Theoretical and methodological contributions are discussed.*

*Keywords: Internet of Things, smart home technology, smart living, networking device, fuzzy-set qualitative comparative analysis.*

## 1 Introduction

Today, Internet is reportedly used by roughly three and a half billion people worldwide for numerous purposes such as Web browsing, sending and receiving messages, playing games, purchasing or selling items online, to name just a few (ITU, 2016). As the number of Internet users expands even further, it comes as no surprise that the use of Internet takes on new and innovative forms. One particular technology innovation that, along with the rapid growth of the number of Internet users, has gained attention is called the Internet of Things (hereinafter IoT). Ashton (2009), in the context of supply chain management, introduced the term and ever since it has been used in a wide range of domains such as healthcare (Gaul and Ziefle, 2009), cloud computing (Gubbi et al., 2013), and Internet connected cars and automation (Lee and Lee, 2015). Due to the ubiquitous use of sensing devices enabled by wireless sensor network technologies, some researchers have argued that the next wave in the era of computing will be outside of the traditional desktop environment (Gubbi et al., 2013). In essence, the IoT is an umbrella term used for Internetworking physical devices such as vehicles, buildings, home appliances and other physical objects connected to the Internet. With the growing presence of WiFi and 4G-LTE, IoT technology allows for different objects or devices to be connected to the network in one form or another, thus transforming them from *dumb* to *smart* devices. The interaction and interconnection of computing devices via Internet provide an opportunity for creating and developing advanced digital services and applications which could potentially change the lifestyle of a great number of people worldwide. Internet-connected smart objects can be sensed and controlled remotely across an existing network infrastructure making possible, for example, to adjust smart home appliances, devices, and gadgets without being physically at home, and to collect and exchange data for different purposes.

In this paper, the focus is mainly on smart home technology as one particular field within the large field of IoT. Smart home refers to the application of ubiquitous computing, that is, a technology that “recedes into the background of our lives” (Weiser, 1993, p. 76). In other words, it can be described as an application that consists of hardware such as sensors and switches in order to automate devices, appliances, and systems to run in the background and to be controlled automatically or remotely in the residence through a web or a mobile application (Allen et al., 2001). To date, research on smart home technology, specifically in the context of households, is still in its early stages. The lack of studies dealing with factors influencing individual’s intention to use smart home technologies is perhaps one of the main gaps in the current literature as the existing research is largely focused on adoption of smart home technology by elderly people (c.f. Liu et al., 2016; Peek et al., 2014). Some authors such as Harms (2015) showed that by the end of 2019, over half a million households in Germany will have smart appliances or devices. In terms of benefits, it has been argued that smart home technologies provide different benefits such as enhanced entertainment services, enhanced energy management, and improved security (Chan et al., 2008). Moreover, Meyers et al. (2010) studied smart home technology adoption and highlighted that individuals are highly concerned about the cost of smart home technologies. Balta-Ozkan et al. (2013) also showed that in addition to the cost, perceived higher maintenance costs is also an important preventing factor for smart home technology adoption.

To fill the above identified gap, i.e., *lack of research on smart home technology adoption by individuals*, it is crucial to understand the individual’s perception of determinants of smart home technology adoption. Hence, the aim of this paper is twofold. Firstly, the aim is to propose and test a theoretical model that explains the intention to use smart home technologies. Therefore, a key question guiding this research is: *What antecedent factor(s) influence individual’s intention to use smart home technologies?* From a theoretical perspective, this can be investigated through several conventional adoption theories, even having different epistemological roots within the Information Systems field. The literature on individual acceptance and adoption of a technology draws heavily on the technology acceptance model (TAM, Davis, 1986) and on diffusion of innovation (DOI, Rogers, 1983). These frameworks have proven robust across numerous studies and contexts (e.g., de Reuver et al., 2015; Venkatesh et al., 2013). However, given the private and voluntary use of smart home technologies, one may suggest, in addition to determinants of TAM and DOI (e.g., ease of use and relative

advantage), to incorporate other determinants when developing the research model. For example, social influence and hedonic motivation from UTAUT2 (the unified theory of acceptance and use of technology II) developed by Venkatesh et al. (2012) can potentially be used for modelling user intentions to adopt and use of technology (Kupfer et al., 2016). Secondly, in addition to mainstream regression-based analysis (Park et al., 2017), a novel approach, namely, fuzzy-set Qualitative Comparative Analysis (hereinafter fsQCA) which is a configurational thinking method will be employed. The main reason for using fsQCA is to show that it can be effectively utilized to obtain multiple combinations of various causal conditions leading to the outcome of interest (intention to use smart home technology) that could hardly be obtained with conventional statistical methods such as Structural Equation Modelling. Comparison of SEM and fsQCA, from strict analytical perspective, however, is not the aim of this paper. To the best of the author's knowledge, this is the first study to employ, in addition to SEM, a configurational method, at least in the context of smart home technology research. Moreover, this paper does not intend to develop a new theory, therefore, while using existing theoretical frameworks, it contributes to the literature (i) by identifying antecedent factors influencing individual's intention to use smart home technology and (ii) by showing that there are several combinations of conditions (attributes) driving intention to use smart home technology, thus illustrating that there is not one but multiple possible configurations leading to the outcome of interest.

The remainder of the paper is organised as follows: Section 2 presents a review on IoT and smart home technology. Section 3 presents the theoretical discussion, the research model, and formulates a number of research hypotheses. Section 4 outlines the research methodology and describes the fsQCA method in more detail. Section 5 presents the results of both the structural model and fsQCA. The last section presents findings, concluding remarks, implications, and limitations of the study.

## **2 Internet of Things and smart home**

Internet of Things (IoT) is a paradigm envisioned as a global network of devices capable of interacting with one another that has gained ground in the wireless telecommunications field. Internet of Things in its simplest meaning refers to a worldwide network of interconnected objects uniquely addressable based on standard communication protocols (Atzori et al., 2010, p. 2788). IoT enables the transformation of objects into smart objects that react to their environment (Atzori et al., 2010). Lee and Lee (2015) have identified several IoT technologies that are widely used for the development of IoT-based services and products. Of those, smart home technology, as an application of IoT will be the main focus of this paper. Multiple definitions for smart home can be found in the literature, for example, Sharma et al. (2017) define smart home as combining home automation with connected devices using WiFi and IoT, which can be remotely controlled and monitored through a smartphone, tablet, or computer to operate a required process. In this paper, the following definition will be used: A smart home is a residence equipped with a high-tech network, linking sensors and home appliances or devices that can be remotely monitored, accessed, managed or controlled, and that provide enhanced services to its inhabitants (Reinisch et al., 2011; Taylor et al., 2007; Yang et al., 2017, p. 69). Smart home technology enables households to analyse the condition of various parameters in their homes anytime and anywhere and delivers other services such as home security, entertainment, assisted living, and better living standards specially for elderly people living independently at home (Demiris and Hensel, 2008; Orpwood et al., 2008; Pragnell et al., 2000; Sharma et al., 2017). Solaimani et al. (2015) present a general overview of smart home literature and claim that the majority of studies are focusing on technological aspects, whereas studies of nontechnological aspects are still lacking. Assessment of the actual market demand and managerial concerns is something that the authors highly encourage researchers to do. The authors also identified several important unaddressed questions, such as (a) who is actually interested in smart home concepts? and (b) what characteristics can be attributed to these groups? Similarly, Paetz et al. (2012, p. 26) argued that as smart homes technologies and products are not yet widely available on the market, research on consumer experiences with fully equipped smart homes is limited in literature. Literature informs us with handful studies on consumers' perception and intention to use smart home technologies. For example, Balta-Ozkan et al.

(2013) argued that the smart home technology is yet to be realized at scale and despite the benefits it can provide to households, the authors identified several barriers to the adoption such as loss of control, reliability, privacy, trust and cost. Moreover, Friedewald et al. (2005, p. 226) argued that smart home should not fail (server and system failure) or do sudden things, thus, reliability is potentially the main challenge, because it can minimize user-friendliness and empowerment. Furthermore, Gaul and Ziefle (2009), identified personal variables (e.g., age, technical expertise, health status), individual's cognitive concepts toward ageing and perceived usefulness as the main factors influencing the intention to adopt and use of smart home technologies. Moreover, the authors highlighted further that trust, reliability of technology (similar to relative advantage), privacy and security are essential for acceptance of smart home technologies. Wong and Leung (2016, p. 916) also conducted a research on intention to use smart home technology and have found strong government support, efficient backup supporting service and the design of services and devices (user-interface) as the driving factors encouraging the adoption. Finally, Yang et al. (2017) extended the theory of planned behaviour (Fishbein and Ajzen, 1975) and in addition to determinant such as subjective norms, perceived behavioural control and attitude towards using, incorporated other determinants such as mobility, interoperability, security and privacy risk to identify factors influencing the intention to use smart home technology. The findings indicated that mobility, security/privacy risk, and trust in the service provider were important factors affecting the adoption of smart home services. Moreover, they found positive relationships between subjective norm, attitude and PBC to intention to use smart home technology.

Next, in order to understand and explain how individuals' perceived innovativeness and attitude toward using innovations impact their behavioural intentions, we will review conventional frameworks used in prior studies to identify factors commonly used to study users' adoption and acceptance behaviour specifically towards innovations.

### **3 Research model and hypothesis development**

Building on mainstream theories of users' acceptance of technology and in conjunction with recent developments in the IoT and smart home technology literature, a conceptual framework is proposed (see Figure 1). The core theoretical focus revolves around, in addition to TAM and DOI constructs, three concepts: consumer perceived innovativeness (CPI), social influence, a component from UTAUT2 and attitude toward using technology. These three concepts are assumed to play a crucial role in the decision-making of users to adopt and use smart home technology. Prior studies in different contexts have closely studied these concepts (e.g., Moore and Benbasat, 1991; Yi et al., 2006). Gao and Bai (2014) have identified factors determining consumers' acceptance of IoT technology using the technology acceptance model additionally to individual user's characteristics and have found positive relationships between TAM constructs and factors of social influence, enjoyment, and perceived behavioural control. In the following, we define constructs used in the study and develop a theoretical rationale for the causal relationships in the proposed model. Moreover, it can be argued that individual's prior experience with smart home technology may influence their intentions to use it, thus this variable will be considered as a control variable when analysing the data.

***Technology Acceptance Model (TAM)***—since its inception, TAM (Davis, 1986) has been one of the most influential models applied in the study of users' acceptance and use of technology (Venkatesh, 2000). According to Ramón-Jerónimo et al. (2013), TAM is still considered the primary and leading framework used to predict how well users will embrace and accept (or reject) new technologies based on their perceived ease of use (PEOU) and perceived usefulness (PU). In this study, PEOU refers to the extent to which users perceive (believe) that the use of smart home technology is free of effort. If a system is relatively easy to use, users will have more positive attitudes toward using it. Similarly, if users believe that smart home technology is useful, enhances their work performance, and enables constant connectivity, they will have more positive attitudes toward using it. Moreover, perceived ease of use is considered to have a positive impact on perceived usefulness. In

other words, the easier it is to use a technology, the greater the expected benefits will be. Hence, the following hypotheses are postulated:

**H1:** *Perceived ease of use of smart home technology is positively associated with the attitude toward using it.*

**H2:** *Perceived usefulness of smart home technology is positively associated with the attitude toward using it.*

**H3:** *Perceived ease of use of smart home technology is positively associated with perceived usefulness of smart home technology.*

**Diffusion of Innovation (DOI)** —attempts to explain why, how, and how fast new innovations spread, if they spread at all (Rogers, 1983). Rogers (2003, p. 5) defines diffusion as “the process by which an innovation is communicated through certain channels over time among the members of a social system”. According to Rogers (1983), an innovation can be described as an idea, practice, or object that is perceived as new by an individual or other unit of adoption. The characteristics of an innovation, as perceived by participants of a specific social system, determine an innovation’s rate of adoption. These characteristics are relative advantage, compatibility, complexity, trialability, and observability (Rogers, 1983, 1995). In this paper, only relative advantage “the degree to which an innovation is perceived as better than the idea it supersedes” will be used (Rogers 2002, p. 990). The justification of this deliberate choice lies in the fact that smart home technologies are considered to be rather new to users. Therefore, it would be important to assess whether potential users develop a positive attitude toward using it and find new advantages in it compared to existing devices and services. Smart home technologies are most likely to be adopted when individuals realise their relative advantage and construct a positive attitude toward using it (Bae and Chang, 2012). Hence:

**H4:** *Relative advantage of smart home technology is positively associated with attitude toward using it.*

**Consumer Perceived Innovativeness (CPI)** —CPI is a concept that refers to how innovative consumers perceive certain products to be. Midgley and Dowling (1978) and Roehrich (2004) define consumer innovativeness as the tendency to buy new products more often and quickly than others. The CPI refers also to how perceived innovativeness of a product affects consumers’ attitudes toward its use and their behavioural intention to adopt it (Lowe and Alpert, 2015). Lowe and Alpert (2015) sought to find agreement on measurements of innovativeness and models, including determinants of perceived innovativeness, but were unable to find any prior literature on the matter. Hence, Lowe and Alpert (2015) posited the following definition of consumer perceived innovativeness based on the limited prior studies on the subject: “the perceived degree of newness and improvement over existing alternatives” (Lowe and Alpert, 2015, p. 4). Lu et al. (2005, p.251) argued that individuals with higher personal innovativeness are expected to develop more positive beliefs about the target technology, hence:

**H5:** *Consumer perceived innovativeness of smart home technology is positively associated with their attitude toward using it.*

**Social Influence (SI)** — is defined as “the degree to which an individual perceives that important others believe she or he should use the new system” (Venkatesh et al. 2003, p. 451). In the context of smart home technology, it can be argued that the perceived social pressure brought from using a particular technology directly influence one’s decision to adopt and use it, in other words, individual’s behavioural intention increases with a higher social influence, hence:

**H6:** *Social influence is positively associated with the intention to use smart home technology.*

**Attitude toward using Technology** —is defined as “individual’s positive or negative feelings about performing the target behaviour” (Fishbein and Ajzen, 1975, p. 216). Different theoretical models have also confirmed that attitude is a key antecedent of the intention to engage in a particular behaviour (Yang et al., 2017). This study proposes that an overall positive attitude formed through consumers’ perceived innovativeness, relative advantage, ease of use, and usefulness (which are common determinants in smart home studies), in addition to social influence, plays a major role in intention to adopt and use of smart home technology. Park and Chen (2007) conducted a study on the acceptance and adoption of smartphones and found that attitude is a significant predictor of intention. Moreover, Rothensee (2008) found that positive affective attitude toward smart fridges is an important explanatory variable of intention to use such technology. In the current study, Yang and Yoo’s (2004)

approach of measuring attitude will be used, namely by integrating cognitive and affective aspects of attitudes toward smart home technologies. Yang and Yoo (2004) proved in their study that the effect of attitude on behavioural intention becomes significantly more important once cognitive measurement items are added to the variable attitude toward use. The affective aspect of attitude refers to how much the person likes the object of thought, while the cognitive aspect refers to an individual's specific beliefs related to the object (Bagozzi and Burnkrant, 1979; McGuire, 1985), hence:

**H7:** *Attitude toward smart home technology is positively associated with the intention to use it.*

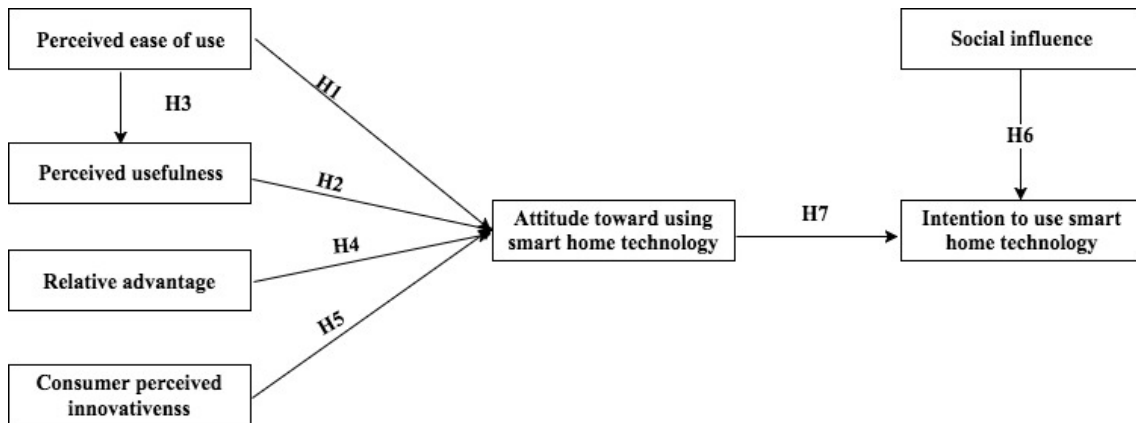


Figure 1. Proposed research conceptual model.

**Intention to use** —the core theoretical focus of this paper is to identify the key driving (antecedent) factors influencing individuals' intention to use smart home technology. In the context of IoT technology, Gao and Bai (2014) used an integrated model to find factors influencing individuals' willingness to use IoT technology and found that perceived usefulness is the most powerful predictor of individuals' intention to use the technology. The construct of intention to use is adopted and considered as a proxy for consumer acceptance because an abundance of studies has reported that it is an appropriate predictor of future usage (Gao and Bai, 2014; Lee et al., 2012; Venkatesh and Davis, 2000). Figure 1 shows the proposed conceptual model.

## 4 Methodology

To examine the path relationships depicted in Figure 1, collected data will be analysed through two distinct methods, one with a correlational approach (structural equation modelling using IBM AMOS v.23) and one with a configurational thinking approach (using fsQCA 3.0 software). A combination of SEM and fsQCA has recently been used by some researchers such as Mikalef and Pateli (2017) and Nikou et al. (2018). FsQCA was introduced by Ragin (1987) and since its conception has been widely used in both variable-oriented and case-oriented studies. In recent years, scholars have increasingly turned their attentions to use fsQCA to conduct various types of business and Information Systems studies (e.g., Krogslund et al., 2014; Nikou et al., 2018; Woodside, 2013).

### 4.1 Data collection

A web-based survey was developed and administered to individuals and households for collecting data. The survey was first pretested with 22 households from different age and background categories who offered constructive comments to improve the clarity of the measurement items and to revise ambiguous expressions. The modified version of the survey was distributed to individuals who were randomly approached through the social networks of the author over the course of six weeks between March and April 2017. Out of 352 distributed questionnaires, 189 questionnaires were returned (response rate = 53.7 percent). After removing the missing or erroneous data (N= 33), 156 usable responses were eligible for further analysis. In terms of sample size requirement, the collected responses exceeded the requirement of “ten times the largest number of structural paths directed at a

particular latent construct in the structural model” (Hair et al., 2011). Participants did not get any incentives for answering the survey. Respondents were assured that data would remain anonymous and would be analysed for research purposes only at an aggregate level. This approach enabled us to control for potential common method bias (Chang et al., 2010). Moreover, to ensure that participants had sufficient information to form an opinion about the use of smart home technology, in addition to a general description of how smart home technologies work, a link<sup>1</sup> to a short YouTube video was provided to participants to familiarize them with smart home technology environments, what a smart home environment consists of and what kind of products and appliances are either currently available or will be available sometime in the near future. Respondents were free to choose whether they watch the video or not. Luor et al. (2015) implemented this approach in their study of smart home and showed that this method effectively helps respondents to form a general understanding about the home automated concept. Moreover, a separate question asking respondents' previous knowledge about smart home technology was also included in the survey. A test for nonresponse bias was performed and no significant differences between responding and nonresponding participants with regard to age, gender, and employment status were found. Respondents also were told that they would receive personalized reports at the end of the data collection period, providing them an in-depth analysis of the research findings; this approach helped to reduce nonresponse bias too (Sax et al., 2003).

## **4.2 Measures**

Items for measuring the constructs within the conceptual model were drawn from previously validated studies; some items were slightly modified to match the specific context of the study. We assessed all the variables included in the model from a general perspective of the smart home technology and no questions regarding a particular smart home technology were asked. Perceived usefulness and perceived ease of use were measured using scales from Davis (1986) and Luor et al. (2015) comprising four items for each construct. Social influence was measured using scale from Bhattacharjee (2000) and relative advantage from (Rogers, 1983, 1985) comprising three and four items respectively. Intention to use and attitude toward using a technology were measured with three and four items respectively (Bagozzi and Burnkrant, 1979; McGuire, 1985; Yang and Yoo, 2004). Consumer perceived innovativeness was measured with three items (Garcia and Calantone, 2002; Lowe and Alpert, 2015). Respondents were asked to evaluate all items on 7-point Likert scales ranging from “Strongly disagree” (1) to “Strongly agree” (7). In the following sections, a detailed explanation with regard to fuzzy-set qualitative comparative analysis (fsQCA) is provided.

### **4.2.1 Fuzzy-set qualitative comparative analysis (fsQCA)**

Qualitative comparative analysis (QCA) is an analytic technique that uses Boolean algebra to implement principles of comparison and that can be used in both variable-oriented (quantitative) and case-oriented (qualitative) methods. Through using Boolean methods of logical comparison, each case can be presented as a combination of causal and outcome conditions, comparable with each other and logically simplified through a bottom-up process of paired comparison, for which a truth table is constructed (Ragin, 2014). The logical minimization is used to represent the information in the truth table regarding the different combinations of conditions that lead to the outcome. Crisp-set QCA and fuzzy-set QCA (fsQCA) are the main extensions of QCA (Schneider and Wagemann, 2007). Fuzzy-set QCA is considered to be the most general variant of the original QCA. Krogslund et al. (2014) stated that fsQCA, as a set-theoretic technique, provides distinct advantages in causal-oriented investigations. A conventional set, known as crisp-set is dichotomous, a case is either “in” or “out” of the set. For example, a set of retired individuals with two binary values: “in” (1 = not retired) and “out” (0 = retired). In contrast to crisp-set, a fuzzy-set allows membership in the interval between 0 and 1, while retaining the two qualitative states of full membership and full nonmembership. For example, a fuzzy-

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<sup>1</sup> <https://www.youtube.com/watch?v=0BcjdavnGU>

set of rich people could include individuals who are “fully in” the set (fuzzy membership = 1), some who are “almost fully in” the set (membership = 0.90), some who are neither “more in” nor “more out” of the set (membership = 0.5, also known as the “crossover point”), some who are “barely more out than in” the set (membership = 0.45), down to those who are “fully out” of the set (membership = 0). Therefore, the main difference between fsQCA and other methods of QCA is that fsQCA allows for outcome (dependent variable) and predictor variables (independent variables) to be on a fuzzy scale (continuous) rather than on a dichotomous scale (binary). Another major difference is that fsQCA identifies patterns of elements that lead to the outcome of interest, unlike correlational methods that identify correlations between independent and dependent variables. Moreover, fsQCA analysis allows examining the complex associations between independent and dependent variables and provides configurations that only include necessary and sufficient conditions (more information in the next section).

#### 4.2.2 Necessary and sufficiency analysis

The main part of the fsQCA is the sufficiency analysis, but before that, one need to examine whether there are any attributes (conditions, in term of the fsQCA approach) that can be identified as necessary for intention to use smart home technology (Ragin, 2006). Attributes are considered necessary if they must be present for an outcome to occur, and sufficient if they can produce an outcome by themselves. The relevance of necessity relationships can be evaluated through the consistency value, where values higher than 0.9 indicate considerable relationships (Schneider and Wagemann, 2007). The necessity analysis results show that there are two attributes (conditions) that can be seen as necessary conditions for intention to use: *perceived usefulness* (0.909) and *attitude towards using innovations* (0.924). This result may imply that in a large number of cases specified by the coverage value, intention to use smart home technology can only be realised if the conditions *perceived usefulness* and *attitude toward using technology* are satisfied. While this initial test offers useful insights, we cannot be sure that high value of these attributes automatically implies high level of intention to use, unless sufficiency analysis is performed.

#### 4.2.3 Procedures in fsQCA analysis

The first step of fsQCA analysis, after the necessity analysis, is calibration. Dependent and independent variables measured on a continuous scale must be calibrated into fuzzy sets with values ranging from 0 to 1. A value of 0 indicates *fully out* or *no set membership* and a value of 1 indicates *fully in* or *full set membership* (Ragin, 2008). Moreover, Woodside (2013) shows that three anchors can be defined to determine the degree of membership for each condition. These anchors indicate fuzzy score = 0.95 for full membership, fuzzy score = 0.05 for full nonmembership, and fuzzy score = 0.50 for cross-over point. Ordanini et al. (2014) also introduced another approach to determine the degree of membership and to transform values into fuzzy-sets. Full membership scores are set to > 6, cross-over points to 4.5, and full nonmembership scores to 2 (Tho and Trang, 2014). After all values were calibrated into fuzzy sets, a truth table of  $2^k$  rows is produced, where  $k$  is the number of predictor variables (conditions), and each row indicates a possible combination (Mikalef and Pateli, 2017). Ragin (2008) suggested to set the consistency levels to > 0.75. In fsQCA analysis, consistency measures the degree to which a subset relation has been approximated and it is similar to significance in correlational methods (Schneider and Wagemann, 2010). Thus, configurations that do not adhere to this rule will be excluded from the analysis. The solution coverage is also an important element of fsQCA that assesses the empirical relevance of a consistent subset, similar to the explained variance ( $R^2$ ) value in regression analysis (Mendel and Korjani, 2012). The fsQCA generates three different solution sets through a logical procedure known as Quine-McCluskey minimization procedure: (a) parsimonious (represents oversimplified solutions), (b) intermediate, and (c) complex (provides the most important alternative). Ragin (2008) recommended to use the intermediate solutions to elaborate the results. The interpretation of intermediate solutions could be tricky and difficult; thus, extensive domain knowledge is required (Ragin, 2008). Conventional statistical techniques such as SEM have a measure to specify the individual importance of each attribute, but in fsQCA there is no such a



measure. To overcome the issue of understanding the importance of each individual attribute (conditions), Fiss (2007) showed that conditions within each configuration can be divided into core and peripheral conditions. Core conditions appear in both parsimonious and intermediate solutions and peripheral conditions appear only in intermediate solutions. The following notations will be used when fsQCA results are discussed. Black circles (●) indicate the presence of a condition and blank circles (○) indicate its absence. Blank spaces indicate “do not care,” in other words, the causal condition may be either absent or present (Ragin and Fiss, 2008). Moreover, large circles indicate core conditions and small circles refer to peripheral conditions. When prior experience with the smart home technology is included in the analysis, operationalized as crisp variables, the following notations will be used: black circles (●) denote “yes (used before)” and blank circles (○) denote “no (not used before)”.

## 5 Results

### 5.1 Descriptive results

The average time to complete the survey was 17 minutes. To assess the nonresponse bias, a test between early and late respondents was performed. To do this, two groups of respondents were selected, the first group included respondents who replied within the first two weeks and the second group included respondents who replied within the last two weeks. The results show that respondents did not differ significantly in their answers. Of the respondents 109 (69%) were male and 45 (31%) were female. The average age of the respondents was 28.5 years and almost two third reported that have watched the video provided to them. One third of them indicated have used smart home technologies before participating in this research project; for instance, one respondent said: “I am sure that this is the future of living. Technology is here to stay and will play a bigger and bigger role in our everyday life.” The respondents who mentioned that they were less familiar or did not know about smart home technology, expressed some interesting opinions as well, for example: “Smart home technologies are partly familiar, but still there were some things that were new to me, I watched the video and most of the things looked really useful, and then some that were in my opinion not necessary.

### 5.2 Measurement model

For data analysis, the two-step approach recommended by Anderson and Gerbing (1988), (a) the assessment of the measurement model and (b) the assessment of the structural model was used. A confirmatory factor analysis (CFA) was run for all the constructs depicted in Figure 1, to examine internal consistency and discriminant validity of the measures. The results show that the measurement model fitted the data ( $\chi^2 = 500.529$ ,  $df = 275$ ; CFI = 0.92; TLI = 0.90; NFI = 0.83; GFI = 0.90; AGFI = 0.80; RMSEA = 0.073). Cronbach's alpha, composite reliability and average variance extracted (AVE) were examined to assess internal consistency. Cronbach's alpha ( $\alpha$ ) values were all above the threshold of 0.70. AVE values ranged from 0.586 to 0.714, CR values ranged from 0.849 to 0.881, all well above the recommended minimum of 0.50 and 0.70 (Bagozzi and Yi, 1988), see Table 1.

Construct	Item	Mean	Factor loadings	Std. Dev.	$\alpha$	CR*	AVE*
Intention to use smart home technology	INT1	5.21	0.835	1.54	0.854	0.881	0.714
	INT 2	5.45	0.886	1.41			
	INT 3	3.58	0.820	1.76			
Attitude toward using technology	ATT1	5.12	0.890	1.64	0.867	0.869	0.625
	ATT 2	4.88	0.869	1.29			
	ATT 3	4.96	0.800	1.21			
	ATT 4	4.60	0.822	1.53			
Perceived ease of use	PEOU 1	4.47	0.818	1.28	0.869	0.871	0.629
	PEOU 2	5.36	0.846	1.32			
	PEOU 3	4.58	0.858	1.38			
	PEOU 4	4.76	0.855	1.29			
Perceived usefulness	PU 1	5.13	0.824	1.17	0.855	0.860	0.607
	PU 2	5.28	0.869	1.19			
	PU 3	5.28	0.874	1.18			

	PU 4	4.28	0.769	1.49			
Relative advantage	RADV 1	5.03	0.876	1.30	0.852	0.849	0.586
	RADV 2	4.55	0.817	1.31			
	RADV 3	4.78	0.856	1.52			
	RADV 4	4.33	0.778	1.68			
Consumer perceived innovativeness	CPI 1	4.15	0.854	1.66	0.855	0.858	0.670
	CPI 2	5.05	0.904	1.60			
	CPI 3	4.60	0.904	1.60			
Social influence	SN1	5.12	0.894	1.22	0.876	0.865	0.621
	SN2	4.99	0.911	1.17			
	SN3	5.33	0.921	1.11			

Table 1. Measurement and internal validity, CR = composite reliability; AVE = average variance extracted.

The standardized item loadings for each construct are shown in Table 1, all exceeding the recommended value of 0.70; some items with lower loadings were removed from the measurement model. Discriminant validity was assessed to see if each construct's AVE square root was greater than its highest correlation with any other construct, and the results showed no discriminant validity issues (see Table 2).

	PEOU	PU	RADV	CPI	ATT	INT	SI
Perceived ease of use	<b>0.793</b>						
Perceived usefulness	0.442	<b>0.779</b>					
Relative advantage	0.535	0.723	<b>0.765</b>				
Consumer perceived innovativeness	0.528	0.413	0.432	<b>0.818</b>			
Attitude toward using technology	0.548	0.785	0.742	0.578	<b>0.880</b>		
Intention to use	0.486	0.690	0.607	0.538	0.831	<b>0.845</b>	
Social influence	0.197	0.393	0.371	0.083	0.349	0.172	<b>0.788</b>

Table 2. Discriminant validity (diagonal values show AVE square root).

In addition, variance inflation factor (VIF) was computed to examine whether multicollinearity was an issue, and the result showed that the highest VIF value is 1.86, well below the threshold of 3.3, confirming that multicollinearity is not an issue (Petter et al., 2007). Moreover, a two-step approach was followed to examine common method bias (CMB), first a Harman's single factor test was computed and the result showed that the majority of variance could not be attributed to one factor; the first factor accounts for 34% of the variance (Podsakoff et al., 2003). Moreover, in the second step, all items were modelled as the indicators of a factor, as Malhotra et al. (2006) recommended, and results showed poor model fit, thus concluding that CMB was not an issue in this research.

### 5.3 Structural model

As the measurement model exhibited good measurement properties, it was examined through structural equation modelling (SEM) using IBM AMOS v.23. According to the model fit criteria suggested by Hair et al. (2010), the structural model fitted the data relatively well ( $\chi^2 = 1705.905$ ,  $df = 858$ ; CMIN/DF = 1.988; CFI = 0.89; TLI = 0.82; NFI = 0.82; GFI = 0.91; AGFI = 0.81; RMSEA = 0.057). Furthermore, the path coefficients were examined to test the hypotheses. As indicated in Figure 2, intention to use smart home technology was explained by a variance of 57%, indicating that the predictors explained a large amount of variation. Attitude toward using technology and perceived usefulness are explained by variance values of 75% and 25%, respectively. The results show that perceived ease of use has no direct effect on attitude toward using technology; therefore, Hypothesis 1 is not supported by the model. However, it is found that perceived usefulness has a direct positive effect on attitude toward using technology, as indicated by the SEM analysis showing a significant path ( $\beta = 0.440$ ,  $p < .001$ ), thus supporting H2. The analysis also shows that perceived ease of use has a direct effect on perceived usefulness, with a significant path ( $\beta = 0.506$ ,  $p < .001$ ), indicating H3 is supported in the model. In Hypothesis 4, it was postulated that relative advantage would have a direct impact on attitude toward using technology; the analysis results confirm the hypothesis, with a significant path ( $\beta = 0.455$ ,  $p < .001$ ). Consumer perceived innovativeness has a positive effect on attitude toward using technology ( $\beta = 0.246$ ,  $p < .01$ ), indicating that H5 is supported by the model. Furthermore, as expected, the results show that there is positive relationship between social influence

and intention to use smart home technology, indicating that H6 is supported by the model ( $\beta = 0.135, p < .01$ ). Lastly, the SEM analysis shows that attitude toward using technology has a strong positive effect on intention to use ( $\beta = 0.874, p < .001$ ), confirming H7. Taking the results of the SEM analysis and the coefficients of the determinants of intention to use smart home technologies, attitude toward using technology emerges as the most powerful predictor relative to other constructs in the model. In addition, relative advantage appears to have the largest effect, through attitude toward using technology on intention to use smart home technology, see Figure 1.

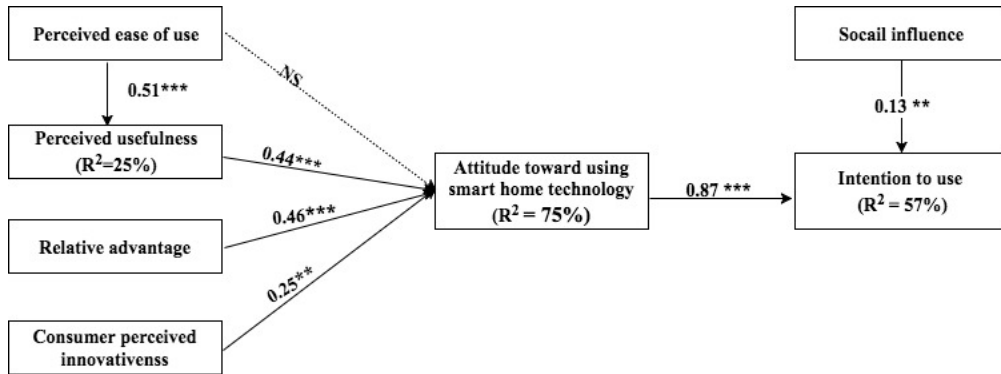


Figure 2. The research proposed conceptual model. Note. \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ .

Previous experience of the respondents regarding the earlier use of smart home technology was examined as a moderator (control variable) in the analysis. The intention was to assess whether there were any differences between users and non-users. The SEM results revealed significant differences in the path model between the users and non-users. For instance, the results show that social influence has a positive impact on the intention to use smart home technology for non-users ( $\beta = 0.125, p < .05$ ), whereas this path is not significant for the users of smart home technology. Moreover, the SEM results show that for non-users, consumer perceived innovativeness has a positive impact on attitude ( $\beta = 0.264, p < .005$ ), whereas for the users this path is not significant. These results imply that for those who have not used smart home technology before, perception about how innovative the technology is as well as social influence play important roles in their decision to adopt the technology and use it.

#### 5.4 Fuzzy-set qualitative comparative analysis results

The fsQCA analysis for intention to use smart home technology revealed six distinct solutions (configurations), without including prior experience of respondents with smart home technology as a condition (moderator). In most of the configurations, attitude toward using technology is present and in two of them is a core condition (Solutions 2 and 5). This outcome, while reinforcing the structural model results, accentuates the influence of attitude toward using technology. The configurations in Table 3 suggest that attitude toward using technology, by itself, is necessary—but not sufficient—for the outcome of interest, while the other five conditions (PEOU, PU, CPI, SI and relative advantage), when taken alone, are neither necessary nor sufficient. Because these six configurations explain almost 81% (total coverage = 0.808) of the intention to use, one could probably argue that attitude is an almost necessary condition for the outcome of interest. It is interesting to note that the TAM determinants—usefulness and ease of use—appear separately in most of the solutions: usefulness appears with consumer perceived innovativeness and negation of social influence and ease of use appears with attitude toward using technology and relative advantage (see Table 3). Solution 1 indicates that the absence (negation) of SI and the presence of CPI and PU lead to the outcome of interest. Solution 2 indicates that the presence of social influence, attitude toward using technology, and the negation of relative advantage, lead to the outcome; and that ATT is a core condition. Solution 3 shows that the presence of PU, attitude toward using technology, CPI and social influence lead to the outcome of interest. This configuration implies another route to intention to use that should appeal to individuals for whom ease of use of smart home technology is not an issue. Solution four is the most

important solution from a consistency value standpoint and indicates that the presence of PEOU and relative advantage in addition to the absence of social influence lead to the outcome of interest. Solution five shows a configuration that the presence of PEOU, relative advantage and ATT together with the absence of CPI lead to the outcome. Finally, in solution six, we can observe that the negation of PEOU and the presence of PU, relative advantage and ATT lead to the outcome of interest. FsQCA results show an overall solution consistency of 0.925.

#	Causal conditions						Raw coverage	Unique coverage	Consistency	Solution coverage	Solution consistency
	PEOU	PU	RAD	CPI	ATT	SI					
1		●		●		○	0.412	0.005	0.956	0.808	0.925
2			○		●	●	0.527	0.007	0.940		
3		●		●	●	●	0.503	0.002	0.948		
4	●		●			○	0.410	0.000	0.967		
5	●		●	○	●		0.546	0.007	0.959		
6	○	●	●		●		0.505	0.003	0.949		

Table 3. FsQCA analysis results, intermediate solutions (without including gender).

A separate analysis was performed to determine configurations of conditions when prior experience of respondents with the smart home technology was included in the analysis as a condition. As Table 4 shows, eight distinct solutions (configurations) that can stimulate intention to use emerged. It is interesting to note that in three solutions, experience is indeed playing an important role. In solution one, for those who have not used smart home technology before, social influence is the only condition leading to the outcome of interest, emphasizing the role of social influence in technology adoption.

#	EXP	Causal conditions						Raw coverage	Unique coverage	Consistency	Solution coverage	Solution consistency
		PEOU	PU	RAD	CPI	ATT	SI					
1	○						●	0.324	0.009	0.869	0.940	0.812
2			●				●	0.833	0.002	0.870		
3						●	●	0.834	0.005	0.903		
4	●	●			○			0.356	0.007	0.883		
5	●		●		●			0.506	0.007	0.861		
6		●	●			●		0.801	0.003	0.937		
7		●		●			●	0.727	0.000	0.917		
8			●	●		●		0.814	0.005	0.934		

Table 4. FsQCA analysis results, intermediate solutions (with experience included as a condition).

Social influence also plays an important role in solution 2 and 3, the presence of this condition (core) in solution 2 with the presence of PU (core condition) and in solution 3 with the presence of ATT lead to the outcome. Solution 4 indicates for those who have used smart home technology before, the presence of PEOU (core condition) and negation of CPI lead to the outcome. Solution 5 shows a configuration of conditions for those who have used smart technology, the presence of PU and CPI lead to the outcome. Solution 6 shows that the presence of PEOU, PU and ATT lead to the outcome of interest. Moreover, solution 7 indicates that the presence of PEOU and relative advantage and SI lead to the outcome. Finally, solution 8 shows that the presence of PU, relative advantage and ATT are enough conditions for the outcome to occur. These results inform us that for those who have not used smart home technology before, social influence is the most important factor encouraging them to use the technology, whereas it is not a significant factor for those who have used the technology before (solution 4 and 5). It is also interesting to note that PU and PEOU (*separately except for one solution, i.e., solution 6*) are important conditions leading to the outcome of interest. Another important observation is solution 2 which has the highest coverage value, given that it covers 83% of the cases. In terms of overall coverage values, the fsQCA results show an overall solution coverage of 0.940, explaining almost 94% of the intentions to use smart home technology. The overall solution consistency is 0.812. In summary, these findings suggest that the impact of antecedent factors is realized differently when experience of the respondents with the smart home technology is considered.

## 6 Discussion and conclusions

In this paper, an application of Internet of Things (IoT)—smart home technology—was studied. One of the objectives of this paper was to develop a comprehensive research model that can explain the individuals' intention to adopt and use smart home technology. For this purpose, this paper employed the TAM theory and enhanced it by incorporating other factors such as relative advantage from DOI and social influence from UTAUT2. This paper, by answering the formulated research question and identifying important factors which have been found to derive intention to use theoretically contributes to this stream of research. For example, the findings show that attitude toward using technology is the dominating factor influencing the intention, while the effects of relative advantage, perceived usefulness and subjective norm on the intention to use, as expected, found to be positive. This is consistent with diffusion theory positing that adopters should have more positive perceptions (*attitude*) of using innovations than nonadopters. Perceived usefulness' (PU) appeal is due to its long history as a construct in the technology acceptance model, and to its predicting power that some researchers believe captures the most important nuances of technology adoption (Gao and Bai, 2014; Taylor and Todd, 1995). All in all, SEM results show that six of the seven hypotheses were supported by the proposed model. When, respondents' prior experience with smart home technology was considered as a control (moderating) variable in the analysis, the results show that this variable play an important role. Based on the finding, for non-users (i.e., no experience with the smart home technology) social influence has a greater impact on the intention to use the technology than the ones who mentioned have used smart home technology before. Surprisingly, perceived ease of use has no significant effect on the attitude toward using technology.

The second objective of this paper was to employ fsQCA, a configurational thinking method, to show that this method can be effectively utilized to obtain multiple combinations of various causal conditions leading to the outcome of interest. The fsQCA analysis results not only reinforced the findings of the SEM analysis, but also demonstrated configurations that can only be realized when different factors are taken together for the occurrence of the outcome. Thus, this paper contributes to the literature by showing that the SEM results do not uncover asymmetric causal relationships, and it is not clear whether variables such as usefulness or attitude toward using technology are necessary conditions for the outcome of interest, only that they are directly significant in the relationship to intention. Taken together, SEM results predict that individuals who have a positive attitude toward technology will be influenced by perceived usefulness, relative advantage, social influence and perceived innovativeness, and will be more likely to use smart home technology. While important insights can be gained from these findings, it is not clear whether there are variations in the combinations of these antecedents. One of the definitive features of fsQCA is that it helps to better understand the causal conditions and asymmetric relationships between variables (conditions) influencing the outcome of interest. Moreover, the fsQCA results reveal a unique association of attitude toward using technology and intention to use and show many configurations which are greatly influenced by social influence and prior experience of respondents with the smart home technology. This application of qualitative comparative analysis (QCA) yielded unique findings that enhance our understanding of consumers' intention to use smart home technology, beyond the widely used linear analyses and show that there are multiple significant routes that may predict intention to use smart home technology, rather than a single linear approach. Finally, the author of this paper would like to stress that comparisons between fsQCA and SEM, while providing new insights, should be made cautiously, and comparisons from a strict analytical standpoint should be avoided. Lastly, this paper has some limitations. Firstly, the data for this study were collected from households in Finland based on the author's personal network and thus the findings cannot be generalized. It is suggested that future studies on the same topic use the proposed model in different countries in order to see if similar findings can be obtained. Secondly, in this study, all the variables included in the research model were assessed in general and participants answered the questions with no particular smart home technology in mind. However, future studies may investigate the intention to adopt and use of smart home technology on the basis of a particular service or a product.

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