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Abstract

Purpose – With recent advances in internet technologies, internet of things (IoT) technology is having an increasing impact on our daily lives, and beginning to offer interesting and advantageous new services. The current research aims to develop and test an integrative model of factors determining consumers' acceptance of IoT technology.

Design/methodology/approach – Based on technology acceptance model (TAM), the authors proposed an IoT acceptance model that consists of three technology factors (perceived usefulness, perceived ease of use, and trust); one social context factor (social influence); and two individual user characteristics (perceived enjoyment and perceived behavioral control). Data from 368 Chinese consumers were used to test the research model through the use of structural equation modeling.

Findings – The results showed particularly strong support for the effects of perceived usefulness, perceived ease of use, social influence, perceived enjoyment, and perceived behavioral control. However, trust played an insignificant role in predicting the intention. In addition, perceived ease of use and trust were found to affect perceived usefulness. Compared with the individual TAM model, the integrated model provides more explanation on user behavioral intention toward IoT usage.

Originality/value – The integrated model explores the driving factors of individuals' willingness to use IoT technology from the perspectives of the technology itself, social context and individual user characteristic. It links the constructs of social influence, enjoyment, and perceived behavioral control to the TAM and successfully extends TAM in the IoT technology context.

Keywords Information systems, Innovation diffusion, Hybrid intelligent business systems, Innovation adoption behaviour, RFID application to logistic

Paper type Research paper

Introduction

The term internet of things (IoT) was coined in 1999 by Ashton (2009), a British technology pioneer who helped develop the concept (Gubbi *et al.*, 2013). The IoT aims to extend the benefits of the regular internet – constant connectivity, remote control ability, data sharing, and so on – to goods in the physical world (Peoples *et al.*, 2013). On the most basic level, the IoT involves fitting objects with a microchip and a communications antenna (Deutsche Welle, 2012). Using radio frequency identification (RFID), every real object in the analogue world could have a unique identifying number, like an IP address (Gubbi *et al.*, 2013). Today, RFID chips are used by many companies to

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manage their inventories. They also make passports scannable by Homeland Security, and enable farecards to be read at subway terminals. Farmers use the chips to keep track of livestock. In 2011, the world spent an estimated $6.37 billion on RFID chips, but that market is expected to balloon to more than $20 billion by 2014 (RFIDWorld.ca, 2012). According to Cisco Internet Business Solutions Group (Deutsche Welle, 2012), the number of objects connected to the internet exceeded the number of people on earth in 2008. ABI Research (2013), a market research firm, predicts that more than 30 billion devices will form an IoT by 2020. Having lots of things connected will change our life and the IoT technologies have the potential to change the world, just as the internet did (Schlick *et al.*, 2013).

IoT technologies have been given wide attention and had the large number of applications in many fields (Schlick *et al.*, 2013). The development of IoT has increased rapidly not only in the world but also in China in particular. The market scale of China IoT industry reached $29.41 billion in 2010, and is expected to reach $114.38 billion by 2015 with the annual growth rate of over 30 percent (IoTworld, 2010). China has been seeking breakthroughs in key technologies of the IoT and will strengthen the industry over the next five years (IoTworld, 2010). The country plans to step up IoT research in its 12th Five-Year Plan period, to build a comprehensive technology system as well as a set of internationally recognized standards. The country will work to promote IoT-related manufacturing, communication and service industries as well as scale up technology application to create an extended value chain (Zhao *et al.*, 2013). China has mastered a raft of self-developed key IoT technologies, and made preliminary applications in several fields including transportation, logistics, finance, environment protection, healthcare and national defense (Zhao *et al.*, 2013). However, IoT is still a fledgling industry worldwide, and China is facing various obstacles as it attempts to gain new ground. Although China continues to fund and support developmental research in the field of IoT, applications of the technology are still primitive and limited, and there are risks regarding information safety (Atzori *et al.*, 2010). From the individual users' perspective, the IoT technologies spark concerns such as privacy, security and who has access to data collected by governments and companies (Medaglia and Serbanati, 2010; Weber, 2010). Given the huge investment by the Chinese Government and low adoption rate of IoT products/services, it is imperative to understand consumer acceptance of this new technology and identify the factors affecting IoT user adoption among Chinese users.

Extant research tends to focus on the IoT design, architecture and implementation from the technical standpoint (Khan *et al.*, 2012; Gubbi *et al.*, 2013; Sundmaeker *et al.*, 2010; Uckelmann *et al.*, 2011). For example, Tan and Wang (2010) provided a skeleton of the IoT and addressed some essential issues of the IoT like its architecture and the interoperability, etc. Haller *et al.* (2009) identified major technical issues, including internet scalability, heterogeneity, identification and addressing. The majority of existing IoT studies has investigated the application of IoT business model from the firm and government perspectives (Haller *et al.*, 2009; Peoples *et al.*, 2013; Weber, 2010; Zhao *et al.*, 2013). The research into the IoT acceptance from consumer perspective is still in its infancy. User acceptance toward a technology is the major determinant of actual usage behavior (Yi *et al.*, 2006). Additionally, investigation into the user acceptance of information technology (IT) has always been an important issue in information management (Bandyopadhyay and Bandyopadhyay, 2010; Luarn and Lin, 2005;

Mathieson, 1991; Venkatesh *et al.*, 2012). Nevertheless, prior research has provided a limited understanding of the key drivers in consumer acceptance of new IT technology (i.e. IoT technology). Considering the significance of attracting and retaining IoT users, it is necessary to identify the factors influencing consumer acceptance of IoT products/services. A comprehensive study on such factors offers the potential to derive important managerial implications regarding how IoT products/services could be marketed more effectively, thus leading to greater consumer acceptance.

A variety of models have been developed to explain consumers' acceptance of a new technology. One well known approach, based on the technology acceptance model (TAM), has generated an extensive stream of studies exploring consumers' usage intentions and actual usage (Davis, 1989). Indeed, TAM has proven to be a parsimonious model with high explanatory power of the variance in users' acceptance related to IT adoption and usage across a wide variety of contexts (Ha and Stoel, 2009; Park *et al.*, 2009). Therefore, this study uses TAM as a theoretical base.

For IoT technology practitioners, a more practical question is: what attributes increase consumer perceptions that IoT technology is easy, useful, fun, and safe? This study draws on the theoretical domains of the TAM, trust, social influence, enjoyment, and behavioral control from the technological, social contextual and personal perspectives, to develop an integrated framework that incorporates the driving influences of these variables on consumer acceptance of IoT technologies. A closer look at the consumer behavior literature shows that there currently exists no empirical research concerning the explanation of consumer acceptance of IoT technologies, in which the above theoretical domains are combined and studied in an integrated framework. The study allows us to draw a broader and more holistic picture of the drivers of consumer acceptance of IoT technologies compared to previous research. The knowledge this study generates will be useful to IoT technology practitioners. A more thorough understanding of the impact of consumers' beliefs about IoT technologies on their acceptance of the technologies could help practitioners learn more about how to entice consumers to use IoT appliances more frequently, and entice non-users to initiate their first usage.

Literature review

IoT technology

The IoT describes objects that are able to communicate via the internet (Uckelmann *et al.*, 2011). Historically, the IoT referred mainly to RFID tagged objects that used the internet to communicate. The IoT technology is used in many areas at present, such as, supply chain management, urban planning, library management, retail tracking, stock control, digital logistics, efficient transportation, home automation, mobile payment, warehouse management, healthcare and the private domain (Ding, 2013; Zorzi *et al.*, 2010). The IoT technology will provide great efficiencies across many industries and their benefits to consumers are substantial (Uckelmann *et al.*, 2011). For example, users may benefit from IoT technologies used in smart fridges that autonomously monitor the consumption of food and beverages and re-order goods (Sundmaeker *et al.*, 2010). In this context, IoT technologies will affect consumers' behavior on several aspects of the users' daily life (Li and Wang, 2013).

Current studies have examined the technical issues of implementing IoT technology (Shang *et al.*, 2012). For example, researchers (Hancke *et al.*, 2010; Medaglia and Serbanati, 2010) identified the security and privacy issues as the major challenges for user-oriented IoT applications. Uckelmann *et al.* (2011) systematically explained the architecture of IoT. Guinard *et al.* (2011) described the IoT's best practices based on the web technologies (e.g. HTML, JavaScript, PHP) and proposed several prototypes using the web principles, which connect environmental sensor nodes, energy monitoring systems, and RFID-tagged objects to the web. Much prior research has focused on the design and usage of IoT technologies from the organization or industry's point of view (Schlick *et al.*, 2013), while little attention has been devoted to understanding the acceptance of IoT technologies from the perspective of individual consumers (Li and Wang, 2013). Furthermore, previous research has not yet investigated the impacts of technology characteristics, social context and individual user characteristics on consumer acceptance of IoT technologies. Given the high practical relevance and dearth of prior empirical work, the current research aims to develop and test an integrative model of factors determining consumers' acceptance of IoT technology.

TAM

In the IT/IS literature, a variety of models have been advanced to explain innovation usage (Venkatesh *et al.*, 2003). Among them, the TAM, proposed by Davis (1989), has evolved as the most popular (Chau and Hu, 2001; Svendsen *et al.*, 2013). TAM suggests that two variables, perceived ease of use and perceived usefulness, are significant determinants of behavioral intention to use a system/technology. Specifically, perceived usefulness is defined as the degree to which one believes that using the technology will enhance his/her performance (Davis *et al.*, 1989). Perceived ease of use refers to the degree to which one believes that using the technology will be free of effort. TAM also proposes that perceived ease of use can explain the variance in perceived usefulness. TAM have applied to a wide range of research questions, including adoption of internet banking (Al-Ajam and Nor, 2013), online shopping (MccloKcy, 2003), mobile financial services (Lee *et al.*, 2012), mobile advertising (Zhang and Mao, 2008), 3G mobile value-added services (Kuo and Yen, 2009); online community participation (Wang *et al.*, 2012), adoption of e-health (Dünnebeil *et al.*, 2012) and e-learning (Lee *et al.*, 2012). Therefore, even if TAM was originally intended to predict IT system use in the workplace, the TAM variables can also be employed to predict consumer acceptance in a variety of settings. TAM can serve as a useful foundation for investigating consumer acceptance of IoT technology, as IoT system is a type of new IT.

Although previous research has found TAM to be a parsimonious and robust model, TAM only employs two user beliefs (perceived usefulness, perceived ease of use) to explain consumer acceptance. However, a user's acceptance towards adoption of IoT will also be affected by other factors such as the opinions of other important persons (social influence) (Venkatesh *et al.*, 2012). Furthermore, even if users have a strong intention to perform a behavior, they will not be able to do so without the necessary resources and skills (perceived behavioral control (PBC)) (Ajzen, 2011). Thus, the original TAM variables may not adequately and accurately explain important factors influencing consumer acceptance of IoT technology. As such, we argue that certain extensions to the model are required to explain the acceptance of IoT technology.

Schierz *et al.* (2010) indicated that the TAM should be expanded by factors particularly relevant to the specific technology under investigation. Marketing research suggests that beliefs about enjoyment, trust, social influence, PBC are key factors influencing consumer acceptance of new technology (Childers *et al.*, 2001;

Koufaris, 2002; Van der Heijden and Verhagen, 2004; Zhang and Mao, 2008). For example, researchers (Van der Heijden and Verhagen, 2004; Lu and Su, 2009) suggested factors, such as enjoyment and PBC may affect one's attitude toward using the technology. Within the consumer behavior literature, Childers *et al.* (2001) and Koufaris (2002) also augmented the TAM with the enjoyment of adopting e-shopping. In addition, social influence has been incorporated into TAM and further showed significant effect on consumer's intention toward technologies as according to Hsu and Lu (2004). Shih (2004) proposed a model that integrates previous work by incorporating trust into the TAM. The results showed that the integrated model provided a better understanding of consumers' behavioral intention relative to other established models (Shih, 2004). Similarly, Zhang and Mao (2008) further expanded TAM by adding more links, from perceived trust to intention toward using.

Researchers have proposed modifications in order to improve TAM's predictive capability by adding more antecedent factors deemed to be of utmost importance regarding new technologies (Svendsen *et al.*, 2013). As such, by drawing on these discussions, this study integrates trust, social influence, perceived enjoyment, and perceived behavior control into the TAM, to better explain consumer acceptance of IoT. The integrated version of the TAM incorporates prior work into one model which explores the driving factors of individuals' willingness to use IoT technologies from the perspectives of the technology itself, social context and individual user characteristic. The TAM is regarded as a starting point of our research and extended with additional constructs important to IoT technology acceptance. In doing so, this study heeds the call for additional research that broadens and deepens TAM by introducing new variables, as well as explaining and re-conceptualizing existing variables in the model (Bagozzi, 2007).

Conceptual framework and research hypotheses

In this study, consumer acceptance is defined as the relatively enduring cognitive and affective perceptual orientation of an individual. Similar to previous work, the construct of intention to use is adopted and considered as a proxy for consumer acceptance (Mathieson, 1991; Venkatesh and Davis, 2000). This is a particularly suitable concept since empirical findings underscore the idea that intention to use is an appropriate predictor of later usage (Lee *et al.*, 2012; Sheppard *et al.*, 1988). A model depicting the relationship between antecedents' variables and intention to use IoT technologies is presented in Figure 1. The attitude construct in the original TAM has been removed from the model for simplicity purpose (Luarn and Lin, 2005). On the theoretical front, an abundance of research studies have reported a strong and significant causal relationship between user beliefs and behavioral intention of technology (Lee *et al.*, 2012; Lu and Su, 2009; Song *et al.*, 2008; Zhang and Mao, 2008). It is therefore theoretically justifiable to use behavioral intention as a single dependent variable to examine the acceptance of IoT. This study expects that perceived usefulness, perceived ease of use, trust, social influence, perceived enjoyment, and PBC will be positively related to behavioral intention toward the use of IoT technologies. In addition, perceived ease of use and trust will be positively related to perceived usefulness.

Perceived usefulness

One of the main reasons for the slow diffusion of IoT technology applications could be a failure in communicating a clear benefit to potential users. According to the innovation

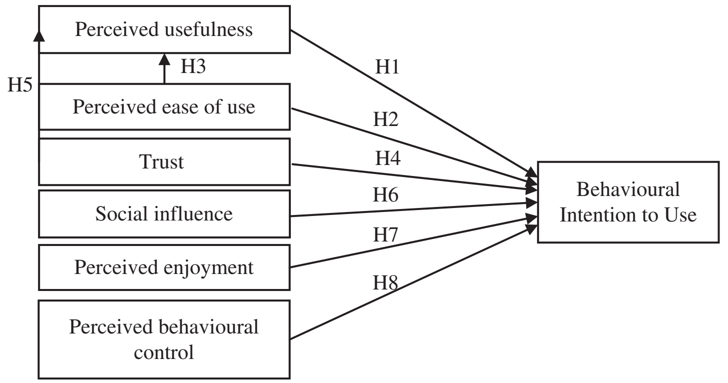


Figure 1.
Research model

diffusion theory (IDT), users are only willing to accept innovations if those innovations provide a unique advantage compared to existing solutions (Rogers, 1995). In the context of TAM, this view is reflected by the perceived usefulness construct. In this study, perceived usefulness is similar to performance expectancy of the unified theory of acceptance and usage of technology (UTAUT) and the relative advantage of IDT (Venkatesh *et al.*, 2003, 2012). It refers to users' feelings of improved performance when they use the technology. IoT technologies can supply retail stores with faster processes, lead to less queuing time, and improve service quality perceived by users. Also, applied IoT technologies to railway section, maintenance staff can receive data from the transponders installed in trains through a mobile reader in their hand to decide whether or not they need maintenance, thereby improving the efficiency of maintenance tasks (Wang *et al.*, 2013). The system automatically keeps an inventory, and plans maintenance schedules based on accurate mileage for each part of the train, rather than just age. Accordingly, the perceived usefulness of IoT technologies is likely to be high. Extant research has shown that service convenience increases the satisfaction level of consumers and affects the intention of consumers. IoT technologies are supposed to achieve better adoption rates if they could facilitate the consumers' daily life. The TAM indicates that perceived usefulness is a significant determinant of behavioral intention to use IT (Davis, 1989; Hart and Porter, 2004; Lee *et al.*, 2012; Lu and Su, 2009; Song *et al.*, 2008), and therefore, the following is proposed:

H1. Perceived usefulness has a positive impact on the behavioral intention to use IoT technologies.

Perceived ease of use

Perceived ease of use is similar to effort expectancy of UTAUT and the complexity of IDT (Venkatesh *et al.*, 2003). It is concerned with users' perceived exerted efforts when using the IoT technologies/services. For IoT users to adopt IoT, they need to feel that IoT is easy to use. Extensive previous studies state that perceived ease of use is a significant determinant of behavioral intentions to the technology (Davis, 1989; Davis *et al.*, 1989; Lee *et al.*, 2012). According to TAM and UTAUT, perceived ease of use also positively affects perceived usefulness (Kuo and Yen, 2009; Lee *et al.*, 2012; Venkatesh *et al.*, 2012). Hence, we propose:

H2. Perceived ease of use has a positive impact on the behavioral intention to use IoT technologies.

H3. Perceived ease of use has a positive impact on perceived usefulness of IoT technologies.

Trust

Besides, perceived benefits (i.e. perceived usefulness and ease of use), innovations usually also come with risk (Cho, 2004). As such, the perceived risk associated with a product or service has gained significance in consumer research on innovations (Kim and Lennon, 2013; Luo *et al.*, 2010). In the context of IoT usage, many people's inexperience with new electronic services, such as road toll payment by automatically scanning the chip installed in the car when users pass the station, has been found to be a particularly critical concern in regards to the security of financial information (Weber, 2010). Making pass toll payment by using IoT services is often associated with a relatively high loss potential related to personal data and the transaction itself, increasing the perceived risk of IoT services usages. Because of the unique characteristics of the IoT technologies (i.e. inability to directly see and touch a product, high level of IT involvement), users feel greater uncertainty and heightened risk in their adoption decision. Trust is one of the most effective tools for reducing uncertainty and risks and generating a sense of safety (Lin, 2011). Therefore, consumer trust of IoT technologies and service providers is believed to play a pivotal role in adoption intention. Due to the importance of trust in terms of reducing risk and facilitating adoption usage behavior, we incorporate trust in TAM and further propose a positive link between trust and the behavioral intention to use IoT technologies. Also, given the implication that IoT is technology-driven and associated with environmental uncertainty, trust in IoT technology may influence usefulness perceptions about IoT services. Previous research demonstrated that trust influences usefulness (Ha and Stoel, 2009). Thus, this study suggest that:

H4. Trust has a positive effect on the behavioral intention to use IoT technologies.

H5. Trust has a positive effect on the perceived usefulness of IoT technologies.

Social influence

When assessing the acceptance of technological innovations, the social context of the decision maker should not be neglected. The social context plays an important role in the decision process (Hsu and Lu, 2004). This is particularly the case for products and services in an early stage of development or diffusion. Here, most users lack reliable information about usage details. Thus, the relevance of the social network opinions for individual evaluation of the products increases. Consistent with Venkatesh *et al.* (2012), we incorporate social context in our research model by including the factor of social influence, defined as a users' perception of whether other important people perceived they should engage in the behavior. Social influence is similar to subjective norm of theory of reasoned action (TRA) (Venkatesh *et al.*, 2003). Influence from peers, family, and even media such as television, might influence users' intention to adopt IoT technologies and services. Many users have used mobile IoT devices because it is portrayed as a trend by the media. Social influence has received considerable attention in the IS field. For example, Davis *et al.* (1989) emphasized the role of social influence in IT acceptance and usage behavior. Chong *et al.* (2012) argued that the social influence significantly impacts consumer intention to adopt mobile commerce. In accordance with previous studies, we contend that:

H6. Social influence has a positive influence on the behavioral intention to use IoT technologies.

Perceived enjoyment

We further extend the original TAM by including the perceived enjoyment of IoT technologies as an additional factor. Perceived enjoyment as a major intrinsic motivation has been found to drive users to adopt a new technology (Bruner and Kumar, 2005). It is defined as the extent to which the activity of adopting IoT technologies is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated (Deci, 1971). When the use of IoT technologies can bring fun and pleasure, users will be intrinsically motivated to adopt them. Evidence from previous studies has shown that enjoyment of shopping is regarded as an important determinant of why consumers shop (Doolin *et al.*, 2005; Lu and Su, 2009). Furthermore, research on the role of enjoyment in mobile commerce suggested the importance of enjoyment on usage intentions and behaviors (Song *et al.*, 2008). Kim *et al.* (2008) indicated that perceived enjoyment significantly affects intention to use short message service. By extending these results to the context of IoT adoption, we postulate that:

H7. Perceived enjoyment has a positive influence on the behavioral intention to use IoT technologies.

Perceived behavioral control

PBC is another element that facilitates people's engagement in seeking relevant information. It is similar to facilitating conditions of UTAUT and describes users' perception if they have the necessary resources, capability, and a sense of control in successfully performing the behavior. Users need to possess the basic skills to use IoT systems/devices. For example, when the railway staff use mobile IoT devices for maintenance of the train's mechanic parts and monitoring the temperature of the wheels, if they do not have the capabilities needed to operate the IoT systems, anxiety of control and negative evaluation of the IoT technology could be aroused. Casaló *et al.* (2010), Lu *et al.* (2009) and Mathieson (1991) provides support for the positive role of PBC on behavioral intention. Thus, in the context of IoT technology, we posit that:

H8. PBC has a positive influence on the behavioral intention to use IoT technologies.

Methodology

Data collection

The survey was conducted over the course of 12 weeks through visiting schools, universities, research institutes, companies, and internet cafes in China from October through to December 2012. Data were collected from existing IoT users in a northern China city, where IoT technologies are relatively developed than other regions (Ministry of Transport of the People's Republic of China, 2013). There were plenty of IoT users at these places and this will expedite our data collection process. The study utilized electronic toll collection (ETC) as a specific application category for IoT usage. Since IoT is a broad concept and IoT technologies have a wide range of applications, focusing on a specific application could enhance the rigor of this study. Moreover, by 2013, analysts expect ETC to be the first largest application of IoT technology in China, with five million users projected (Chinese Business Research Center, 2013). ETC uses passive RFID technology to scan the tag mounted on the windshield of the vehicle to collect toll electronically on toll roads or toll plazas where the reader is placed in a strip which is laid beneath the lane. The oncoming vehicle is detected by the sensor which is placed on the side of the road, and then the reader reads the financial and personal information embedded on the tag and the toll payment takes place through a centralized database and the aftermath details of the transaction is intimated to the user's mobile (Kamarulazizi and Ismail, 2010). The efficiency in paying toll fees can be significantly improved by using the ETC system as users can drive through without stopping.

To ensure that participants has sufficient information to form an opinion about their use of IoT technology, we provided participants in our study with descriptions of how IoT technologies work in general, and for what they can be used in transportation sector[1]. This approach was taken to overcome any lack of familiarity with IoT technology and could avoid the unclear understanding of ETC that might have existed among our participants due to its technological novelty. We contacted users and inquired whether they had ETC usage experience. Then we asked those with positive answers to fill the questionnaire based on their usage experience.

Among the 2,300 questionnaires distributed, 419 questionnaires were initially collected for input. Later, 51 of the collected questionnaires were dropped due to missing data or invalid responses. Ultimately, 368 questionnaires were utilized for empirical analysis. In relation to respondents' ages, 12.1 percent were under 20 years old; 28.9 percent were between 20 and 24 years old; 33.2 percent aged 25-34 years old; 13.0 percent aged between 35 and 44; 8.2 percent between 45 and 54; with those aged over 55 years old representing 4.6 percent of the sample. In relation to education level, 34.2 percent were high school qualified; 22.3 percent completed college; 35.1 percent had university degree; and 8.4 percent held a master or PhD degree. On average, respondents are experienced ETC users with 3.25 years of usage experience and 2.63 times a week of usage frequency.

In order to address the potential non-response bias, the study adopted Lau *et al.'s* (2010) method, and used the *t*-test to compare the average scores for main variables of the first 10 percent of the respondents found and last 10 percent of the respondents. The results of the *t*-test showed no significant difference between mean scores of the two compared response groups. Therefore, it was determined that non-response bias was not a main concern in this study.

Measures

Items to measure the focal constructs of the study were drawn from previous research and slightly modified to suit the specific context of the study. These items were first translated into Chinese by a researcher. Then another researcher translated them back into English to ensure consistency. When the instrument was developed, it was tested among 15 users that had IoT technologies usage experience. We then used their comments to revise some items in order to improve clarity and understandability.

Davis' (1989) scales were adapted to capture perceived usefulness and perceived ease of use. Items of perceived usefulness reflect the improved toll payment efficiency and convenience when using ETC. Items of perceived ease of use reflect the ease of learning to use or skillfully using ETC devices. Items of trust were adapted from Wang *et al.* (2004) and reflect the reliability and credibility of ETC devices/systems perceived by users. Items of social influence and PBC were adopted from Mathieson (1991). Items of social influence reflect the influence of people important to the user on the adoption behavior. Items of PBC reflect the resources and capability of the user. Items of perceived enjoyment were adapted from Moon and Kim (2001) and reflect the fun, pleasure and enjoyment of using ETC. Items of behavioral intention were adapted from Venkatesh (2000). All items (Table I) were measured via seven-point scales ranging from strongly disagree (1) to strongly agree (7).

Results

Following the two-step approach recommended by Anderson and Gerbing (1988), we first examined the measurement model to test reliability and validity. We then examined the structural model to test the research hypotheses and model fitness.

Measurement model

The overall measurement model produced an excellent fit (χ^2/df = 1.231, GFI = 0.934, CFI = 0.968, TLI = 0.955, RMSEA = 0.022). To assess convergent validity, the standardized factor loadings, average variance extracted (AVE), and composite reliabilities (CRs) were examined. As displayed in Table I, all factor loadings were larger than 0.7 and critical ratio indicated that all loadings were significant at 0.001. All AVEs and CRs exceed 0.5 and 0.7, respectively. Thus, the scale has a good convergent validity (Bagozzi and Yi, 1988; Gefen *et al.*, 2000). In addition, all α-values were larger than 0.7, suggesting a good reliability (Nunnally, 1978).

The discriminant validity of the constructs was assessed in two ways. First, in terms of the method adopted by Fornell and Larcker (1981), discriminant validity is achieved if the square root of the AVE is higher than the correlations between two composite constructs. As indicated in Table II, the square roots of the AVE are consistently greater than the off-diagonal correlations. Second, based on the work of O'Cass and Ngo (2007), it is suggested that discriminant validity is exhibited when the corresponding correlation (the off-diagonal entries) is not greater than two constructs' respective reliability value. The results presented in Table II demonstrate that all individual correlations (0.353-0.729) were lower than their respective reliabilities (0.792-0.895), which show good discriminant validity.

We conducted two tests to examine the common method bias. First, using Harmon's one-factor test (Podsakoff *et al.*, 2003) we found no single factor emerged, and the first factor accounted for 21.245 percent of the 62.463 percent explained variance. Second, we modeled all items as the indicators of a factor representing the method effect, and re-estimated the model (Malhotra *et al.*, 2006). The results indicated a poor fitness (χ^2/df = 13.245, CFI = 0.736, GFI = 0.665, TLI = 0.457, RMSEA = 0.164). With both tests, we conclude that the problem of common method bias was not evident in this research.

Structural model

To analyze the causality between the antecedent factors and consumers' intention to use IoT technologies, structural equation modeling (SEM) techniques were used. The results are shown in Figure 2. Fit indices (χ^2/df = 2.012, CFI = 0.936, GFI = 0.965,

Construct/indicator	Stand. loadings	Critical ratio	AVE	CR	α-value
Perceived usefulness (PU)			0.77	0.87	0.82
PU1: using the ETC would enable me to accomplish toll payment more quickly	0.72	22.97*			
PU2: using ETC would make it easier for me to pay toll fees	0.78	23.14*			
PU3: using ETC would significantly increase the quality or output of my life	0.84	25.42*			
PU4: overall, I would find using ETC to be advantageous	0.83	25.22*			
Perceived ease of use (PEOU)			0.74	0.85	0.85
PEOU1: learning to use ETC is easy for me	0.74	20.57*			
PEOU2: I find my interaction with the ETC device clear and understandable	0.86	27.51*			
PEOU3: I think using ETC is easy	0.80	23.63*			
Trust (TR)			0.86	0.92	0.90
TR1: the ETC device/system is trustworthy	0.85	23.84*			
TR2: the ETC device/system provides reliable information	0.83	24.76*			
TR3: the ETC service provider keeps promises and commitments	0.90	34.45*			
TR4: the ETC service provider keeps my best interests in mind	0.81	22.22*			
Social influence (SI)			0.74	0.85	0.86
SI1: people who are important to me would recommend using ETC	0.86	25.35*			
SI2: people who are important to me would find using ETC beneficial	0.79	19.21*			
SI3: people who are important to me would find using ETC a good idea	0.82	20.95*			
Perceived enjoyment (PE)			0.69	0.83	0.83
PE1: I have fun with using ETC	0.71	20.06*			
PE2: using ETC is pleasurable	0.87	29.28*			
PE3: using ETC gives enjoyment to me	0.85	24.14*			
Perceived behavioural control (PBC)			0.72	0.84	0.84
PBC1: using ETC is entirely within my control	0.81	23.69*			
PBC2: I have the resource, knowledge and ability to use ETC	0.77	21.32*			
PBC3: I am able to skillfully use ETC	0.72	20.13*			
Behavioral intention to use (BI)			0.76	0.81	0.79
BI1: given the chance, I intend to use ETC	0.78	23.27*			
BI2: I am willing to use ETC in the near future	0.92	36.09*			
BI3: I will frequently use ETC	0.91	33.59*			
BI4: I will recommend ETC to others	0.90	32.19*			
BI5: I will continue using ETC in the future	0.87	28.06*			

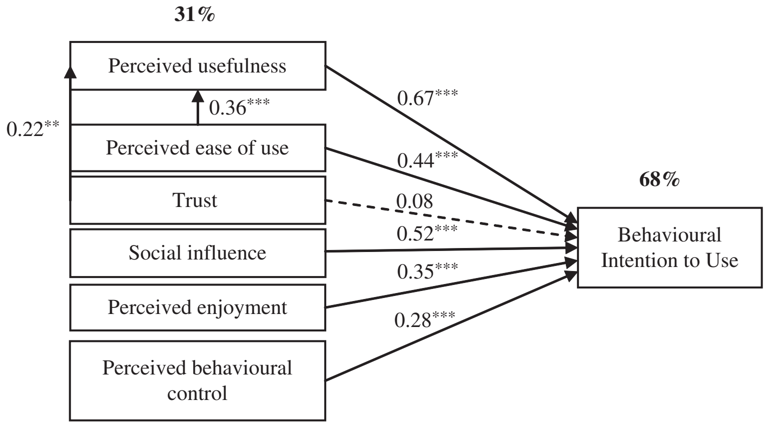
Notes: Significant at: $^{*}p < 0.001$; CR – composite reliability, AVE – average variance extracted

Table I. Results of the measurement model

Table II.
Discriminant validity assessment results

	IC	PU	PEOU	TR	SI	PE	PBC	BI
PU	0.816	0.877[a]						
PEOU	0.845	0.627	0.860					
TR	0.895	0.525	0.496	0.927				
SI	0.863	0.431	0.353	0.410	0.860			
PE	0.827	0.612	0.536	0.729	0.642	0.831		
PBC	0.839	0.546	0.597	0.586	0.441	0.552	0.849	
BI	0.792	0.553	0.598	0.432	0.446	0.646	0.602	0.872

Note: [a]Diagonal elements show square root of the AVE



Model fit: χ^2/df = 2.012, CFI = 0.936, GFI = 0.965, TLI = 0.957, RMSEA = 0.034

Notes: *$p <$ 0.01 and **$p < 0.001$; the bold numbers are the explained variances

Figure 2.
Structural model showing results of analysis

TLI = 0.957, RMSEA = 0.034) indicated that data set was acceptable (Schumacker and Lomax, 2004). As indicated in Figure 2, perceived usefulness ($\beta = 0.67$, $p < 0.001$) and perceived ease of use ($\beta = 0.44$, $p < 0.001$) positively affect the behavioral intention to use IoT technologies, supporting *H1* and *H2*, respectively. The results also show significant and positive effect of perceived ease of use ($\beta = 0.36$, $p < 0.001$) and trust ($\beta = 0.22$, $p < 0.01$) on perceived usefulness and perceived ease of use, thereby confirming *H3* and *H5*, respectively. *H6*, predicting the positive effect of social influence on the behavioral intention to use IoT, was supported ($\beta = 0.52$, $p < 0.001$). Also as expected, perceived enjoyment ($\beta = 0.35$, $p < 0.001$) and PBC ($\beta = 0.28$, $p < 0.01$) had a positive effect on consumers' intention to use IoT, supporting *H7* and *H8*. Nevertheless, the results showed insufficient evidence ($\beta = 0.08$, $p > 0.05$) in support of *H4*, suggesting that trust played an insignificant role in predicting the intention to use IoT technologies in the presence of the other variables, thereby rejecting *H4*. The explained variance of perceived usefulness and behavioral intention were 31 percent and 68 percent, respectively.

We also performed an *ad hoc* analysis to compare the explained variances of the individual TAM model to that of the integrated model. The results showed that the explained variance of behavioral intention of the individual TAM model was 42 percent, of which was lower than that of the integrated model (68 percent). This showed the explanation advantage of the integrated model over the individual TAM model.

Discussion

The study aims to analyze the factors that influence users' acceptance of IoT technologies in an integrated manner. The results confirm the robustness of the TAM, explaining technology acceptance behavior for users within the context of IoT technologies. Suggesting an extended TAM to which one social context variable (i.e. social influence) and two individual user characteristic variables (i.e. perceived enjoyment and PBC) are added, the study finds that a consumer's perceptions of usefulness, ease of use, behavioral control, enjoyment, and social influence are predictive of his/her intention toward using IoT technologies.

In comparing path coefficients of antecedents of the behavioral intention toward IoT technologies, usefulness emerges as the most powerful predictor relative to the other belief factors. This supports prior TAM research finding usefulness to be the primary determinant of one's use of a technology while ease of use, trust, and enjoyment are secondary determinants (Davis, 1989; Davis *et al.*, 1989). However, this is inconsistent with findings from previous studies that observed a stronger effect of enjoyment on behavioral intention than ease of use and/or usefulness within the context of handheld internet device use (Bruner and Kumar, 2005). This inconsistency suggests the need for further investigation. For instance, Childers *et al.* (2001) proposed that different atmospheres (e.g. Hedonic vs utilitarian usage environments) cause differential importance of usefulness, ease of use, and enjoyment, which in turn influence intention differently.

In addition, social influence has the second largest effect on behavioral intention. As respondents in this study are mostly between the age of 20 and 34, they are considered to be easily vulnerable to social influence and more sensitive to the new trends and normally involved in rapid shift of trends and styles (Lu *et al.*, 2003). Influence that comes from mass media or peers may easily influence their decision to use IoT technology. Hence, it is important for the IoT services providers to consider the social influence factor to encourage the adoption of IoT technology. IoT practitioners can also take advantage of earlier adopters of IoT services, whose opinions and reviews may generate positive word-of-mouth effects on subsequent adoption behavior (Wiedemann *et al.*, 2008). Publicizing such testimonials and obtaining celebrity endorsements will help promote user adoption intention.

Supporting Wu and Liu's (2007) assumption, the study found that perceived enjoyment positively influences the acceptance of the new technology. The integrated TAM model reveals the direct effect of perceived enjoyment on IoT usage acceptance. The results indicate that consumers expect to have a kind of "fun" that can be achieved from the interaction with the IoT items. The findings suggest that marketers should critically evaluate the degree of hedonic value in their IoT appliances. The more enjoyable an IoT appliance is, the stronger the likelihood that it will appeal to consumers and make them actively involved in the interaction. Moreover, the significant relationship between PBC and consumer acceptance is consistent with our prediction. IoT service providers need to run marketing campaigns to enhance users' knowledge about IoT usage and skills in using it. Thus, users' perceptions of behavioral control and facilitating conditions can be improved.

Unexpectedly, in contrast with the proposed hypothesis, trust is not a significant predictor of acceptance of using IoT technologies. One explanation for the insignificant effect of trust on behavioral intention lies in the lack of the interaction between consumers and IoT devices/systems. IoT technologies are relatively new in China, and as a result, users' familiarity with these technologies and their relevant products is low. For instance, many people may not have the basic knowledge of how to use the ETC and how it operates. Consumers hardly know this technology, thus they are not willing to assess whether this type of technology is secure or trustworthy. In addition, as Yoon (2002) indicated that trust may influence behavioral intention indirectly via attitude, several studies (Byoung *et al.*, 2011; Tan *et al.*, 2010) found a significant direct effect of trust on attitude, although no direct effect of trust on intention was observed. Future research could add attitude into the proposed model to test if trust has a significant and positive effect on attitude.

Perceived ease of use and trust are both found to affect the perceived usefulness. Perceived ease of use has a larger effect. The constraints of IoT mobile terminals highlight the necessity to present a well-designed interface to users as, if mobile IoT usage systems are of poor interface and difficult to use, users will be less likely to use them. Thus, IoT service providers need to improve users' perception of ease of use in order to evoke their intention to use IoT. Although trust has no direct effect on the behavioral intention, its indirect effect on the usage intention through perceived usefulness should not be ignored.

Implications

This study has both theoretical and practical implications. The main theoretical contribution is it theorizes the factors influencing the consumer acceptance of IoT technologies, from a unified perspective, including technology perceptions (perceived usefulness and perceived ease of use), social context variable (social influence) and user characteristics (perceived enjoyment and PBC). It links the constructs of social influence, enjoyment, and PBC to the TAM and successfully extends TAM in the IoT technology context, which differs from the context of other information systems. This integrated model achieves the greater understanding of consumer acceptance of IoT technologies in China while remaining the parsimony of the model in the same time. The study contributes to current knowledge pertaining to consumer behavior and marketing in two ways.

First, academic inquiry on the drivers of consumer acceptance of IoT technologies is largely neglected in past consumer behavioral and IT research. The study addresses the gap in the literature by identifying social influence, perceived enjoyment, and PBC, as the three additional antecedents of consumer acceptance of IoT technologies. It expands the boundary of the TAM, while at the same time answering the call for further studies on exploring consumer acceptance of IoT usage. It also examines the simultaneous effects of the belief drivers on consumers' IoT technology acceptance. The results showed that, compared with the individual TAM model, the integrated model provides more explanation on user behavioral intention. By using TAM as the basic theoretical foundation and adding the beliefs using TPB, we also incorporate all of the four constructs in the UTAUT into our research model, thus the results add to current knowledge in the consumer behavior literature, and provide a robust insight into the factors driving the formation of technology acceptance.

Second, the vast majority of prior studies on consumer acceptance of new technologies have been geographically concentrated in Western countries, such as the USA. Even though many researchers have identified the importance of studying cross-cultural applicability of existing theories and models in the context of new technologies, there were very few studies to date designed to address this call. The present study makes an initial attempt to address this call by examining an existing conceptual model of consumer acceptance within the setting of a developing nation's IoT context.

Practically, this study explores the importance of IoT as an innovative technology in everyday lives and emphasizes its contribution to the workplace and marketplace. For practitioners, the research provides some guidelines for improving their products and services in order to attract and acquire users. The study revealed that IoT users are concerned with both extrinsic and intrinsic motivation. They not only expect a useful and ease-to-use IoT function, but also expect to obtain fun and enjoyment out of the experience. Therefore, IoT service providers are advised to offer users a useful and entertainment function and its related service. With respect to usefulness, practitioners are expected to provide more efficient and effective services through designing a user-friendly and trustworthy IoT interface and platform. Moreover, marketers should not overlook the effect of the social influences on consumer acceptance of this technology, given that IoT is still new for most Chinese consumers. Although social influence is unchangeable by the management, it can be implied that reference groups play an important role in the diffusion of IoT technologies. Thus, IoT practitioners need to identify early adopters and stimulate their usage of IoT services, so that they can serve as a reference for facilitating broad diffusion in the future.

Limitations and directions for future research

This research has some limitations. First, this study did not incorporate actual usage behavior into the proposed model. However, substantial empirical evidence exists regarding the causal link between intention and usage behavior (Lee *et al.*, 2012). Second, it should be noted that a cross-sectional research design does not provide as much insight as does a longitudinal research design. For this reason, future research should adopt longitudinal data, in order to further analyze the time sequence of the relationships among constructs. Third, although the study aims at exploring the area of consumer acceptance of IoT technologies in emerging economies, the focus was only on one such economy – China. As there may be very different sociocultural beliefs, governmental regulations and business norms compared with other developing economies, it is recommended that future research should expand the boundaries to investigate IoT acceptance in other developing economies (e.g. India, Russia), in order to verify the validity of the model established in the present study. In addition, future research needs to replicate the study using different IoT product categories to improve generalizability of the research model. Qualitative research is also encouraged for future research to gain better understanding of what consumers' perspectives towards IoT technology.

Note

1. The following information was described in the first part of questionnaire. "The internet of things (IoT) describes objects that are able to communicate via the internet. Things are starting to talk to each other and develop their own intelligence. Imagine a scenario where your meeting was pushed back 25 minutes, this information was then communicated to your

alarm clock, which would allow you 25 extra minutes of sleep. It would also signal your coffee maker to turn on 25 minutes late and your car to start 25 minutes late to melt the ice accumulated in overnight snow stores. Having lots of things connected will change our life. The IoT technology has been used in transportation industry. For example, the electronic toll collection has been widely adopted. The signal transmission between the tags mounted on the windshields of vehicles and the readers placed beneath the lanes help complete toll payment easily and efficiently".

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