People, Process, and Technology Dimensions of Smart Home Adoption

Completed Research

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Abstract

Smart Home Ecosystems consist of multiple IoT devices (Internet of things) that communicate with each other to increase the ease of everyday activities. Though there are many advantages to adopting smart homes, the uptake has been slow. Smart homes have been the focus of interest for governmental as well as private organizations as there is a promise for costs to be saved and reduction of energy use if implemented. Though smart homes are filled with many smart devices, there are certain characteristics and requirements that makes adopting the technology more feasible. This paper will investigate the major requirements for a smart home ecosystem under three dimensions; people, process and technology. Understanding these requirements and identifying the current challenges will allow solutions to be formed on how to increase the rate of adoption. These potential solutions will be shown through a proposed artefact which will show the requirements, challenges and solutions.

Keywords

Smart homes, IoT, adoption, smart home ecosystem, requirements, challenges, solutions, framework

Introduction

Alrich (2003, pp. 17) defines a smart home as “a residence equipped with computing and information technology which anticipates and response to the needs of the occupants, while working to promote their comfort, convenience, security, entertainment healthcare, education, and communication through the management of technology within the home and connections to the world beyond”. The adoption of smart homes has been stagnant and in many countries the smart home market has been seen to not be taking off, with some vendors of smart home devices filing for bankruptcy as the uptake of the devices has been very slow (Alam Ali Reaz 2012). Currently the smart home market is considered to be stuck in the adoption curve where it is struggling to get past the early adopters of smart homes and move to the mass market phase of adoption (Cinegration 2015). Many challenges and barriers have been identified which is preventing the move into the adoption phase, with one of the factors being that the smart devices are still considered to be reasonably pricey. The current adopters of smart homes are considered to be early adopters, and there is a direct correlation of income, education and occupation of the early adopters and the current smart home adoption rate (Carson 2017). One of the biggest factors that has impacted the successful uptake of smart home adoption has been the fragmentation of the smart home ecosystem where multiple applications are needed for successful use of the smart devices. The multiple applications has been considered a nuisance and therefore has not been accepted by the mass market (Carson 2017). The motivation for this research paper is to identify the drivers, characteristics, and/or requirements for smart home adoption. We will explore the smart home ecosystem in order to formulate solutions that will help the industry increase the rate of smart home adoption.

With organizations advocating the need the increase adoption of IoT within our society, it is important for consumers to understand the use of the technology within their own households which will allow them to build their own smart home ecosystems. With many countries believing that for a city to become smart,
households also need to become smart, society needs to understand the transformation that their households can go through which allows them to become active participants within a Smart City ecosystem. Understanding the main challenges for smart home adoption will allow us to understand the main requirements for an ideal smart home ecosystem. While there is ample literature on technology adoption generally the perspective is predominately a process view. We chose to take a broader perspective and look at the phenomenon using a people process and technology lens (Leavitt 1964).

This leads us to asking the following questions; What are the different perspectives of a smart home? What are the current challenges preventing the adoption of a smart home ecosystem in society? Can these challenges be viewed from people, process and technology perspectives (Leavitt 1964). What solutions are needed to overcome these challenges? After these research questions are answered, the following research objective should be achieved; to develop a framework which clearly shows the people, process, and technology requirements, which will lead to the identification of solutions to increase the adoption of smart homes.

**Smart Homes**

The adoption of a smart home enables the inhabitants to be more independent, while also gaining more information through the use of multiple smart devices. Each user of smart homes has different requirements depending on the amount of assistance that they need in their daily lives or what they find personally important in the design of their smart home. What is important, is that each individual likes their smart home to be tailored to their individual needs. Hence, more individualism of smart homes will increase the adoption of the smart home ecosystem (Chan Campo Esteve and Fourniols 2009). Consumers, the industry and literature have different ideologies of what impact smart homes have on society resulting in different definitions due to the different needs that have been identified. The way each party has structured their perspective, understanding and definition of smart home is based upon how valuable they have found smart homes within their daily lives, production of components or research. Understanding the value of a smart home lies in the fundamentals. This means understanding the meaning of “smart”. Techterms has defined “smart” as “Self-Monitoring Analysis and Reporting Technology” (Christensson 2006). An extended version of this definition is the perspective that inanimate objects (wearables, cars, phones, cities and homes) are able to communicate with the consumer, which leads to a change in a person’s behavior.

According to Cinegration (2015), users of smart homes are confused to what extent a home can be considered to be “smart”. The confusion lies over the comparison between a “connected home” and the term “smart home”. If consumers understand the meaning of smart homes it will enhance their knowledge on how to automate more aspects within their household, and overall, could increase the adoption of smart homes. The main problem lies in the consumer’s understanding of the term “smart”.

PwC conducted a study where they interviewed multiple users of smart devices to gage their understanding of the concept of IoT and smart homes. The customers understood smart homes as “something that helps everyday and makes life simpler” and “the ability to connect to other devices” (Bothun and Lieberman 2017).

The idea of smart homes came about when home automation enthusiasts had the idea of going wireless in devices that they considered should communicate to solve daily problems within households (Harper 2003). These enthusiasts were people who built solutions for office spaces, who also thought that some of the issues that were being solved within businesses could also solve the same problems within households. These ideologies started the industry of smart homes, but the industry recognized early on that it would be hard to convince consumer’s the need for smart homes, which has indeed still been a problem to this date in many countries (Peine 2008). Also, Peine (2008) stated that the concept of smart home crosses over three main industries; home automation, information and communication technology, and finally household products and services. More recently, the integration and function of these three industries has led to the smart home industry of today (Feng and Klingvall 2016).

Literature has developed the definition of a smart home over time, but it needs to be noted that many of these definitions are from a technology perspective (Feng and Klingvall 2016). Furthermore a majority of the research on smart homes is in the technology domain. The notion of a smart home as an ecosystem that includes people and processes to support the ecosystem is not considered to a large extent.
The aforementioned definition of a smart home by Aldrich (2003), takes it even further by looking at the connection of a smart home to the outside world, which implies the connection of the home with a Smart City, which is the aim for major cities around the world (Harper 2003). This also allows us to connect the term “smart living” to “smart homes”, which allows us to explore the option of residents to not only thrive to live in a smart home, but to explore the possibility to live in a smart environment overall, which extends beyond households (Feng and Klingvall 2016).

It needs to be noted that analyzing the smart home ecosystem alone is not enough, as it does not consider other external factors which impact smart home adoption. Studying the ecosystem as a whole is important, which means including the processes that impact the adoption of a smart home ecosystem and the people’s requirements that need to be met when they are seeking a smart home. It is also important to look at the interaction between the three dimensions of people, process and technology to see how each dimension affects the other. The final analysis needs to show how all three dimensions work together in the acceptance and adoption of smart homes. The people, process and technology dimensions can give many insights if it is successfully used to assess a problem domain and is then used to resolve the problem and implement solutions that is beneficial to the organization or industry (Decker 2015). An in depth analysis of the people, process and technology dimensions will be done in the next three sections.

People Dimension

Understanding the people dimension, allows researchers to identify the type of people who are likely to adopt a Smart Home ecosystem. Well-developed processes and technologies may be in place, but if the target market and the correct people are not present to accept the ecosystem, then the solution that has been developed will be of no use (Decker 2015). Prodan, Prodan, Andurcarea (2015) have stated that if we understand the consumer, then the chance of a technology being successful is guaranteed. The people dimension looks at issues such as; do people know the benefits of smart home technology? Do people know how to work a smart home ecosystem? Do consumers have the skills and knowledge to perform certain activities needed to be able to maintain a smart home? Are the users motivated to have a smart home? For those who have a smart home, are they engaged in the new technologies that are constantly being released which can improve their smart home ecosystem?

Different age groups, countries and genders adopt smart homes for different reasons. Bothun and Lieberman (2017). Researchers have found that some age groups and genders are more likely to adopt the use of these devices and are more driven to have a smart home ecosystem than others. The 18-34 age group, those born between the early 1980s to the early 2000s, are considered to be the millennials and approximately 29% of this age group owns a smart home device. However, 13% don’t use it anymore (Bothun and Lieberman 2017). What is more interesting is that the millennials are the least interested in owning a smart home device or ecosystem in the future. Millennials adopted a smart home ecosystem as they expect it to help them be more productive, if this need is not met then the chances of them adopting a smart home is much less. Understanding if it was worth the money spent on the devices was also considered very important for this age group, but they were very open to the smart home ecosystem idea (Bothun and Lieberman 2017).

Digital immigrants, those who are over the age of 35, are those who were born before the era of worldwide use of technology and now have been forced to adapt and evolve to the digital devices surrounding them. The survey done by PwC showed that the largest proportion of survey participants who currently own a smart home device for automation is those in the age group of 35-49 (Bothun and Lieberman 2017). While the age group 50-64, seem to be the least likely to adopt the use of a smart home device in the future, as they do not seem to understand the future benefit for the device or an ecosystem (Bothun and Lieberman 2017).

The Acquity Group (2014) found that the perception of smart home adoption differed between the male and female genders, where males are twice as likely to adopt a smart home ecosystem compared to females (Acquity Group 2014). A similar study by PwC (Bothun and Lieberman 2017) showed similar findings to Acquity Group (2014) where males were more likely to own a smart home device. Furthermore, the study showed that females did not see the likelihood of adoption of a smart home device in the future. One factor that drives adoption is the promise of increase security of the household, which
lead to the identification that males and females who were parents were more likely to adopt at least one smart home device, mainly a security device (Acquity Group 2014).

Early adopters and current users alike have a high affinity towards technology, they understand the social and social benefits of owning a smart home (Mennicken and Huang 2012). Many of these current smart home owners not only buy smart home devices but they also tweak them to fit their specific need. Studies have been done with those who own smart homes, and many of the participants are those who have tech related jobs and who have a reasonably large income (Mennicken and Huang 2012). This supports the findings of Parks Associates and CEA (2014) who found that income of inhabitants is a main driver in the current adoption of smart homes and that the current smart home owners have incomes well above the national average, and are happy to indulge in technology.

Understanding the different ways that Smart Homes are used by consumers, will allow us to understand what drives the adoption of the ecosystem. The users of smart homes have different desired services that induces them to purchase the ecosystem. Understanding what the users’ expectations are helps tailor smart homes with specific devices (Alam et. al 2012). Furthermore, governmental organisations invest in smart home projects which allow organisations and users to control features within their households without physically being present. Alam et. al (2012) found that smart home projects tend to fall into three uses; for comfort, healthcare and security.

A main idea of the smart home ecosystem is that the inhabitants have transparency of what is happening around their households, while also controlling physical attributes such as temperature and lighting to increase their comfort levels (Alam et. al 2012). A general component of smart home ecosystems is the expectation of increase control of the level of comfort of inhabitants. Due to the increase business of users, the expectation that comes with smart homes is that it will ease the difficulty of everyday activities (Alam et. al 2012) such as home entertainment. A smart home entertainment system, for example, offers a cinema experience where there is touch screen buttons for either visual or audio and quick links via the web to online information, e-commerce and news (Luo Lu Yu and Lu 2015). A main driver of adopting a smart home being is the idea of making life simpler and easier.

The need for extra healthcare facilities for patients and elderly has been considered to be one of the driving forces for adoption of smart home ecosystems. Many governmental health agencies are facing issues of the lack of personnel and resources within the medical system and have turned to smart homes to build an environment that can sense the health conditions of inhabitants and call for health support if needed (Bothun and Lieberman 2017). The aim of local monitoring of the smart home ecosystem within healthcare is to monitor patient health within their home environment by using sensors to monitor their health conditions and if needed to give warnings via alarms if the patient's health disintegrates. The Smart homes ability to collect health data about the patients over time is analyzed either by the by either the patient (smart home user) or an external health professional. Algorithms within software are built specifically for health purposes which analyses long term trends and helps to alert medical services if anything looks abnormal (Alam et. al 2012). There are Health Integrated Smart Home Information System (HIS) which contains sensors which track the blood pressure, heart rate and weight of an inhabitant where data is collected hourly (Virone Noury and Demongeot 2002). Homes specifically built to support healthcare in local monitoring usually have three main features; sensing, planning and prompting.

A fundamental aspect of acquiring a Smart Home is maximizing safety and security. Many of the users who adopt smart homes emphasize that safety and security is the main component that causes them to adopt a smart home. With devices such as smart smoke alarms and smart alarms which are controlled by smartphones, the users feel more in control of what is happening within their households. There are different types of devices that increase the safety from a normal home to that of a smart home. There are two main types of security; physical and house security (Luor et. al 2015). Physical security states as preventing the inhabitants of a house from being harmed, and house security is stated as preventing unauthorized access and entry to a property and preventing damage, harm, theft or terrorist activity within a household. Physical security normal means the use of body guards, CCTV and physical barriers or gates (Chan et. al 2009). What smart homes adopts in the context of security is it uses warning signals and mechanisms to deter anyone intending to intrude a property, which can all be controlled by smart applications on smartphones (Feng and Klingvall 2016).
Process Dimension

The American Society of Quality (2014) have defined a process as “a set of interrelated work activities characterized by a set of inputs and value added tasks that make up a procedure for a set of specific outputs.” When dissecting this definition in the context of smart home adoption, the processes that support the adoption of the ecosystem needs to be studied. Identifying the processes that support the technology and the customer’s needs is crucial for a new technology to be successful (Hopson 2017). The process dimension will state what the trigger event are, which leads to a chain of events so that at the end a product or service has been formed for a customer. These processes can start of extremely high level, and can then be broken into smaller key steps which are considered to be important to implement a process successfully (Davies 2007). Delivering what is expected by the customer when they expect it is what will lead to successful acceptance and adoption of a Smart Home ecosystem (Prodan et. al 2015). The process dimension looks at the formation of robust, but importantly flexible processes which can be adapted when changes are needed. This is specifically important when smart homes are customized for the needs of smart home inhabitants.

One of the processes that are currently in place which induces the adoption of smart homes is the customizing the design of smart homes to the needs of smart home. As discussed, a factor that increases the chance of adoption of smart homes is customization (Louis Calo Leiviska and Pongracz 2015). The user likes to be part of the designing process of the smart homes. Usually this is an iterative process and is done over time. Industry experts who built multiple smart homes are involved in the building of the houses and try to accommodate the users (Acquity Group 2014). There are standardized designs for healthcare houses, which allows practitioners to access data of those who they are monitoring. This allows them to track the movement of the inhabitants, while giving other members of the family access to the data (Mennicken and Huang 2012).

Knowledge management is where organisations and industries recognize, optimize and manage resources that will increase value and will give organisations within an industry a competitive advantage (Hosseini Tahsildari Hashim and Tareq 2014). With this definition in place it is important for vendors to have processes in place which help the new smart home users or those who are intending to adopt smart homes. If the ease of adoption is high through a knowledge management process where the users understand what they are doing, the chances of more people adopting smart homes in the future will increase (Bothun and Lieberman 2017). Platforms that are currently around are not always that most easiest to use, especially with the people who able to afford a smart home ecosystem in this current day and age are the digital migrants, who are not considered to be as digital savvy as millennials as they are still learning about the vast amount of technology that is a core function of daily activities.

Technology Dimension

Understanding the technology dimension is extremely important in the use of smart homes. If users do not know how the devices interact with each other and how a smart home is connected then the chances of adoption becomes very slim. The users need to know what value they can gather from a smart home ecosystem. The smart homes are created to form smart solutions for its inhabitants by created better network connection between the devise while also providing better data management and protection.

Internet of Things role in Smart Homes

The building blocks of a smart home ecosystem is the Internet of Things. Without these IoT devices, there would be no smart homes. These IoT devices which have been built specifically for smart homes have now been replaced by the term “smart home devices” which are considered to be specialized devices for home automation purposes (Alam et. al 2012). It is important to understand how IoT devices work, so that it can help us understand what the main interactions are within a smart home ecosystem. Internet of things are considered to be devices that contain inbuilt sensors which allow them to connect with other objects and exchange data (Chan et. al 2009). Each device can be uniquely identified through the embedded computer system when it operates with the protocols put in place by the device developer. These devices can be controlled remotely but can also be integrated into platforms where they can communicate with other physical devices (Luor et. al 2015).
**Components of Smart Homes**

Smart homes have multiple IoT devices which contain inbuilt sensors which should be connected within one platform so that they can integrate and share data from each other (Demiris Hensel Skubic and Rantz 2008). The integration will allow smooth data analytics so that useful information can be gathered for decision making. It must be noted that the smartness within all these applications comes directly from the platform that the device is reliant upon and where the data feeds to (Alam et. al 2012). The general theory of how smart homes work is reasonably simple. It contains receivers and transmitters where the receiver detects specific signals from the transmitter and issues commands that will be answered by the device. The infrastructure of a “smart home” is split into four sub categories: safety and security; infotainment where entertainment devices connect to the internet and other smart devices; environmental controls including thermostats and alarms; and metering using meters by utility organisations and inhabitants of households for charging and budgeting of energy and water usage. The smart meter is considered to be a main and permanent component of a smart home ecosystem (Louis et.al 2015).

**Devices Used**

For an ecosystem to survive there are different devices can be used. Some of the environmental controls present within smart homes are many. The temperature of a household can be controlled remotely via smartphone applications used by smart pumps for example. There are smart system which detect any water leaks within a household before they become an expensive problem for home owners. Furthermore it detects moisture and will alert occupants if moisture levels are high enough to stimulate mould growth (McCormack 2017).

As mentioned in the discussion within the human dimension, one of the main features that is considered extremely important for smart homes is the security feature. The security feature does not only include physical safety of the inhabitants but also privacy of the data of the smart devices within the smart home ecosystem. Some of the devices that are used for safety and security purposes are; smart smoke alarms, security alarms, doorbells and locks, door and window sensors and meters (McCormack 2017).

The smart security alarm allows the user to alarm and disarm their household via applications on their smartphone or tablets. They also get alerts if there are any intrusions within the household, no matter where they are in the world. Having a smart alarm "combines the reassurance of physical security with the convenience of personal mobile device management, empowering you to a more secure lifestyle (Woodberry 2011). While the smart doorbell allows the users to see who is at the door and allows them to communicate with people who press the doorbell. If are presently unavailable to get the door or are not at home, they can communicate with the person at the door and tell them that they are not there (McCormack 2017). All the communication occurs through an application. This also allows them to monitor the people who are approaching their property. The smart lock on the doors can be unlocked either by using a key or an application on the phone. The door can be unlocked and can grant other people access through an application, no matter where the person is around the world.

Users can remotely secure and monitor their households through this device where the sensors will monitor anything that a user wants opened or closed and can then be controlled through an application. It will also give information to the application when doors or windows are open, so that the user knows if the doors or windows have been accessed. An alert will be sent to the application if a sensor has been broken after it has been set (McCormack 2017).

**A Framework for understanding Smart Home Adoption**

In the previous sections we have explored the different aspects that affect the human dimension when relating to smart home adoption. One of the main requirements for driving the adoption of smart homes is that there needs to be a recognized need by the smart home user. These varying needs are different according to the age, gender and socio-economic status of individuals. Though there are these amazing smart devices, many individuals do not want to go through the extra hassle of learning how to work these smart devices, therefore do not lean towards adopting the good. So specific devices with the complexity at each age group can handle needs to be made. Furthermore, due to the expensive nature of smart home
devices, simpler featured devices should be made to increase the likelihood of adoption. Another challenge in the adoption of smart devices and homes is that it does not meet the specific needs of the individual. This is especially common with those who want to push the boundaries of smart devices and the specification that they want are not present in the market. A proposed solution is allowing the consumer to upgrade the good on a flexible platform or can manipulate the device without it affecting other smart devices on the integrated platform. Figures 1 - 3 help to illustrate the relationship between the three dimensions of smart home adoption. Identifying the relationship between the people (Figure 1), process (Figure 2) and technology (Figure 3) dimensions and their solutions will help the smart home industry to identify if there an overall solution can be implemented to increase the rate of adoption. Furthermore, this will allow the users and the industry to see which problems can be solved straight away.

**Figure 1: People Aspects of Smart Home Adoption**

A major requirement for the successful adoption and implementation is knowledge. This knowledge is not only about how to work the devices, but increase awareness of the valuable contribution that a smart home ecosystem can have to everyday activities. The only solution is education. There has been a large amount of resources put in place by many countries to increase the awareness of smart devices, but not enough work has been put into place to educate how to use the devices. What has made it especially hard is that many of the smart devices used within smart homes come on multiple different applications, making it hard as you need to learn how to work each device separately instead of having all the devices on one integrated platform.

One of the biggest concerns of smart homes users is their security and privacy. With the large number of smart home users devoted to increasing the physical security of their houses, this is a requirement that needs to be at the forefront of vendors implementing a smart home ecosystem. The biggest barrier here is trust. Internet of things devices are known to be easily hackable, therefore allowing personal information to be leaked and cameras to be hacked. Users of security smart devices should know what the security laws and protocols of their devices, while vendors try to increase the level of security of their devices.
Many smart home adopters only adopt a full smart home ecosystem if its meets their specific needs. So, smart home vendors work closely with users who are intending to adopt multiple smart home devices to customize it to their needs and integrate it onto one platform. One of the major challenges is that having a fully integrated smart home is extremely expensive which prevents users from actually going forward in adoption. A solution is that the government needs to encourage homes to be built smart. If a developer builds multiple smart homes at once, the vendor costs will be less which will decrease the overall cost of smart homes. Another barrier in smart home adoption is if a user wants to integrate new devices after the smart home has been built. As mentioned previously, there is a major problem where platforms are unable to accept new devices, especially with latest devices. This brings about the doubt of whether the smart home would get outdated and if constant upgrades are going to be needed, which would be constant costs in the foreseeable future.

Another requirement of great importance is the need for cohesion between the users of smart homes, the vendors who are customizing the house, the engineers who are adapting the software to users’ needs and aftercare. This is very important for the increase chance of acceptance of smart homes. Unfortunately, currently there is no cohesion between all these parties when a smart home is implemented which causes the inhabitants to have issues with their homes. A customized process needs to be put in place for each user so that they can learn and adapt to their new smart homes.

There are many technological requirements that need to be in place for successful adoption of smart homes. There needs to be communication between all the devices as the integration between all the devices increases the successful chance of acceptance of the smart home ecosystem. One of the challenges is that the central hub that many of these smart devices are connected to, do not make the decisions that is wanted by the users. Currently users override any decisions that is made incorrectly by the users, but the algorithms need to be tweaked so that the correct decisions are being made. Another requirement for users is the need for the devices and the smart home to be used in the long term. Unfortunately one of the aspects of smart homes is that it is a technology and technology is constantly evolving. Due to this there is an expectation that though there is a lot of money spent, the smart home can become outdated.
Furthermore, users want to be able to expand their smart home with extra devices and should have the flexibility to do so.

**Figure 3: Technology Aspects of Smart Home Adoption**

**Conclusion**

Smart Home Ecosystems consist of multiple IoT devices that communicate with each other to increase the ease of everyday activities. There are three key dimensions to be considered when we think of adopting smart home ecosystems: people, process, and technologies. Forming separate artefacts for each of these dimensions, allows us identify the main requirements and challenges within each dimension. Understanding how the requirements that are needed for smart home adoption allows a solution to be formed. These solutions now need to be implemented and can be changed according to the relevance of importance of the barrier to the smart home user.

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