Understanding Smart Home Adoption: The Roles of Users, Engineers, and Mass Media in the Social Construction of the Smart Home

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Due to recent advancements in sensor-based technologies and the accelerated growth of the Internet of Things (IoT), smart home technologies (SHTs) are becoming more widespread throughout society every year. This rapid diffusion of the technology is highlighted by the expected increase in the value of the smart home market from about $85.6 billion in 2021 to approximately $137.9 billion by 2026 (Zion Market Research, 2021). The growth in the smart home market can be attributed to the increasing diffusion of the smart home into many domains of the domestic space, which enables smart homes to provide users with a host of health-related, environmental, financial, and psychological benefits (Chang & Nam, 2021, p. 2; Li et al., 2021, p. 6; Marikyan et al., 2019, p. 147).

Despite the numerous benefits users can received from adopting SHTs, researchers have found that the current smart home adoption rate is relatively low and that the smart home market is currently stuck at a transitioning point from the early-adopter phase to the mass-market phase (Greenough, 2016). The slow nature of the smart home's diffusion can be attributed to a variety of adoption barriers, which undermine potential users' intentions to adopt the technology. For example, many smart home users perceive a high risk associated with the security and privacy of SHTs (Marikyan et al., 2019, p. 149). This heightening of users' perceived risk overshadows users' perceived utility associated with the adoption of SHTs, which ultimately acts as a barrier hindering users' intentions to adopt the technology. It is therefore important to identify the factors that influence smart home adoption and those that contribute to the existence of adoption barriers.

To tackle the factors hindering the adoption of SHTs, this study will look at different aspects of smart home adoption, specifically (1) the current state of smart home adoption, (2) factors influencing the technologies' diffusion, (3) user perceptions and problems associated with

SHTs, (4) adoption barriers derived from user perceptions of the technology, and (5) the relationships between social groups, producers, and communicators of the smart home. This research will be done using the Diffusion of Innovations (DOI) theory (Rogers, 1983), and the Social Construction of Technology (SCOT) framework (Pinch & Bijker, 1984). The Diffusion of Innovations theory will be used to analyze the current state of smart home adoption and the main mechanism under which the smart home diffuses through society. The Social Construction of Technology (SCOT) framework will be used to look at how SHTs are constructed by various relevant social groups, as well as the relationship between different user groups and producers of SHTs in the development process. By establishing what factors influence users' perceptions of SHTs, and how different social groups affect the development of the smart home, the barriers to adoption can be identified and appropriate sociotechnical solutions can be proposed to dissolve the adoption barriers and facilitate smart home adoption.

The Smart Home: An Overview of Potential User Benefits

A smart home is a residential space containing a network of sensor-based technologies that are used to monitor, control, and automate processes within the home environment (Marikyan et al., 2019, p. 139; Wilson et al., 2017, p. 1). Current applications of SHTs include supporting the disabled and aging populations through health-care related services, monitoring and controlling home energy consumption, providing home security, and improving comfort through the automation of daily routines (Marikyan et al., 2019, p. 146). The potential user benefits associated with these smart home applications are discussed so that it can later be seen where user perceptions of these benefits diverge from the envisioned benefits made by the producers of the technology.

Health Related Benefits

The first class of benefits that is covered is health related benefits, which are provided through the integration of home-based health care services. By incorporating different types of sensors, cameras, and other health monitoring systems throughout the home environment, the well-being of users can be monitored in real time. Some health related measurements that can be made on smart home occupants include physiological measurements, activity and inactivity detection, detection of falls and accidents, and the monitoring of health related routines (Birchley et al., 2017, p. 2). Through the collection and transmission of user health-related data, health-care workers can provide medical care to users remotely, leading to more timely and personalized care (Li et al., 2021, p. 5). While these services still need to be further developed before their potential benefits are fully realized, some forms of home-based health-care services are already being widely adopted. One example that has been popularized in response to the COVID-19 pandemic is telehealth, which is "the use of two-way telecommunications technologies to provide clinical health care through a variety of remote methods" (Koonin et al., 2020).

The integration of home-based health care services may be particularly beneficial for the elderly and users with disabilities who are generally more dependent on external services for maintaining their health. According to an AARP survey, about three quarters of adults who are over the age of 50 would like to remain in their current homes for as long as possible (Binette, 2021), however the physiological and psychological changes that result from aging make it increasingly difficult for people to safely and independently reside in their homes. To facilitate the increasing senior population's desire to "age-in-place", home-based health care services and other sensor based technologies can be embedded into the home environment to monitor occupants and automate daily processes (Tural et al., 2021, p. 1). Therefore, the implementation

of home-based health-care services through the adoption of SHTs may partially alleviate the burden that is put on society in caring for the increasing elderly population while providing these users the ability to independently age in place.

Environmental Benefits

The next class of potential benefits that smart homes can deliver are environmental benefits. With growing concerns over climate change, global warming, and volatile energy prices, the implementation of smart services to monitor and control energy consumption using energy efficient devices is becoming more and more attractive (Marikyan et al., 2019, pp. 145, 146). In addition to automatically optimizing a home's energy usage, smart technology can help residents more intuitively visualize their energy consumption patterns, which according to Li et al. (2019), "can incentivize them to change behavior patterns more sustainably" (p. 5). Thus, by implementing energy monitoring and energy control smart systems into the home, users can reduce their environmental impact while saving on energy expenses through the optimization of home energy consumption.

Financial Benefits

The third class of potential user benefits are financial benefits. The financial benefits provided by SHTs are mostly associated with the previous two classes of benefits, namely the health related and environmental benefits. With regard to the health related benefits, the implementation of home-based healthcare services allows users to age in place, which can yield reduced costs on healthcare and ultimately lower the socioeconomic burden that has resulted from the increasing elderly population (Li et al., 2021, p. 6). Using smart home systems to manage energy consumption in the home also provides financial benefits since these systems can reduce and optimize the amount of energy that a home uses. Energy management services can

also provide residents with energy consumption information, allowing users to make more informed decisions about their energy consumption habits (Chang & Nam, 2021, p. 2; Li et al., 2021, p. 5; Marikyan et al., 2019, p. 148).

Quality of Life Improvements

The fourth and final class of benefits relates to the enhancement of a user's quality of life. While smart home devices can be used to maintain health and improve home energy consumption, they can also be used to control many other domestic appliances and devices to improve the convenience of daily tasks and provide comfort to residents. Using an array of smart services and devices, residents have full control of their living environment, which includes "the ability to remotely control or automatically schedule components of the house, such as thermostats, ventilators, lighting equipment, kitchen appliances, and various household appliances" (Chang & Nam, 2021, p. 2). As an example, homes can be equipped with adaptive lighting systems that can change the level of lighting in the home based on real time outdoor lighting and conditions (Catalbas, 2017). Smart security systems that use various sensors and cameras can also be implemented to improve home security. Therefore, by adopting SHTs, users can potentially improve their quality of life.

The Current State of Smart Home Adoption Under the Diffusion of Innovation Theory

While SHTs have the potential to deliver many benefits to users, the adoption rate of the smart home is relatively low. This situation is best summarized under the Diffusion of Innovation (DOI) theory, which was created by Everett M. Rogers (1983). The Diffusion of Innovation theory explains how an innovation diffuses through a population or social system over time. In this theory, an innovation is described as an idea, behavior, or product that is perceived to be new by an individual (p. 11), which for this analysis is smart home technology.

The diffusion or spread of an innovation requires that the innovation be communicated to members of a social system over time through different communication channels (p. 5). A communication channel is the means by which messages get from one individual to another and can include a pair of individuals exchanging information or mass media channels that rapidly spread information to audiences (pp. 17, 18). People within a society are categorized based on their innovativeness, or the degree to which an individual is relatively earlier in adopting new ideas than the other members of a system. The categories of adopters, from the highest degree to lowest degree of innovativeness are (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards (p. 22). The most notable characteristic of this theory is the s-shaped cumulative adoption curve, which portrays the general proportion of adoption of an innovation over time (p. 23). The slope of this curve represents the rate of adoption and has the shape of a bell curve. The rate of adoption is largely dependent on which adoption group is in the process of adopting the innovation. The adoption curve for SHTs is shown in Figure 1.

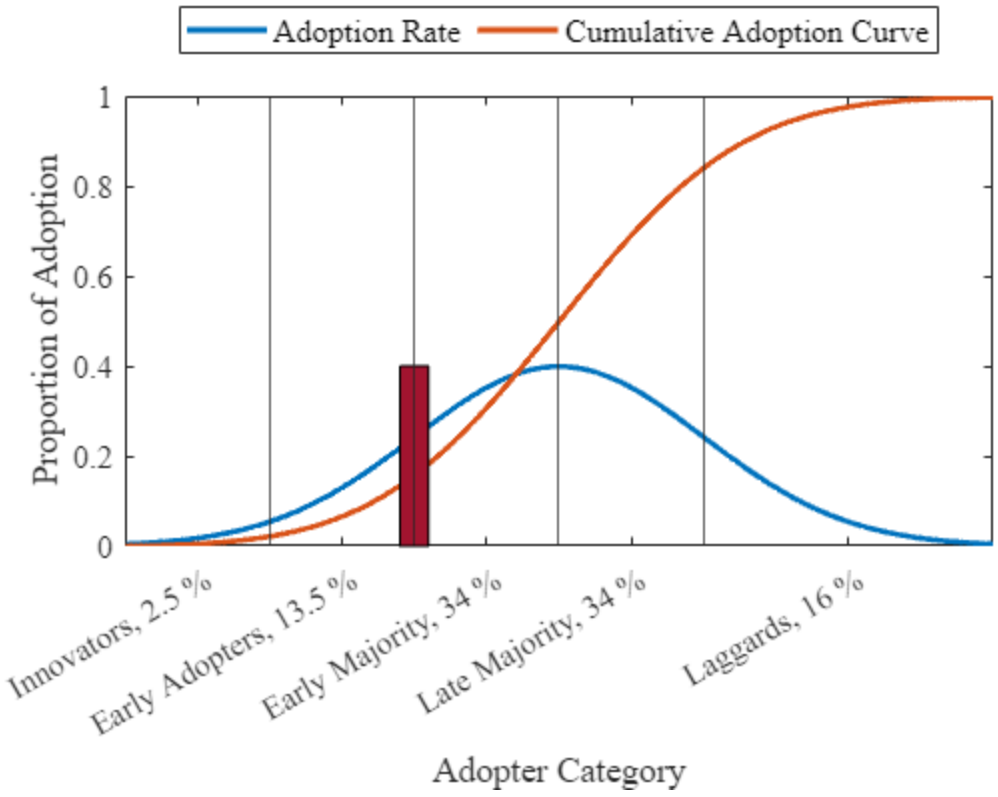

Figure 1: Smart home DOI adoption curve. The adoption of SHTs increases over time as the technology transitions between the different adoption groups, from most to least amount innovativeness. Each group makes up a percentage of the population that will eventually adopt the technology. The red box represents the chasm between early adopters and the early majority and is where adoption is currently taking place. (Orioli, 2022a)

Applying the Diffusion of Innovation (DOI) theory to the analysis of smart home adoption, it is clear that the current state of adoption is near the base of the s-curve, where the rate of adoption is relatively low compared to the maximum adoption rate found at the center of the s-curve. This conclusion is suggested by the research of Shin et al. (2018), which found that the current observed growth in the adoption of SHTs is largely attributed to the early adopters of the technology. Recall that early adopters only represent the second category of adopters within the DOI theory, which means that SHTs must diffuse through several other adoption groups before society sees widespread adoption of the smart home. Compounding this problem is an observation made by John Greenough (2016) from Business Insider:

> At its current state, we believe the smart home market is stuck in the 'chasm' of the technology adoption curve, in which it is struggling to surpass the early-adopter phase and move to the mass-market phase of adoption.

This chasm refers to the transition from the early market (ending with the early adopter group) to the mainstream market (starting with the early majority group). It represents a critical point in the adoption of the technology where successfully bridging the chasm will lead to the eventual successful adoption of the technology. If early adopters should fail to bridge the chasm, the technology is likely to lose traction and remain unadopted. Therefore, it is critical that the factors that affect the adoption of SHTs be identified so that the proper actions can be taken to facilitate the smart home's adoption.

The Social Construction of the Smart Home

In the previous section, it was shown that the adoption of the smart home is currently in the process of crossing the "chasm" between the early adopter and mainstream market phases of adoption, and that communication channels are the mechanism by which individuals of a society become aware of the existence of a technological artifact. Even so, the process that leads an individual to adopt the technological artifact after learning about it is not answered by the previous DOI theory. One framework that can be used to describe "how" technologies are adopted by individuals and social groups is the Social Construction of Technology (SCOT) framework, which was developed by Trevor Pinch and Wiebe Bijker. Under this framework, technology and society are interpreted as being cocreated (Pinch & Bijker, 1984). More specifically, SCOT says that society influences the development of a technological artifact such that the artifact furthers the interests of different social groups.

The social construction of a technological artifact is reliant on four main concepts, which are relevant social groups, interpretive flexibility, closure, and stabilization. Relevant social groups are made up of people or organizations that ascribe similar interpretations or meanings to a technological artifact. The existence of different relevant social groups, or stakeholders, is characterized by each groups' interpretive flexibility of the same artifact (Pinch & Bijker, 1984). Since each relevant social group has a different interpretation of a technology, different problems often arise, and various designs can be implemented to fit a technological artifact to a single relevant social group's interpretation. The closure and stabilization of a technological artifact occurs when the artifact has successfully been altered such that it solves problems for each of the relevant social groups and the groups choose to accept the technological artifact in its current form (Pinch & Bijker, 1984).

Applying SCOT to the smart home, several relevant social groups can be identified including early adopters, mainstream users, smart home companies, manufacturers, suppliers, engineers, government bodies, health care workers, energy suppliers, environmentalists, and mass media. These different social groups and their relationships with SHTs are illustrated in Figure 2. Each of these groups ascribe different meanings and interpretations to the smart home as part of their interpretive flexibility of the technology. Since this analysis is mainly concerned with the interpretations of smart home users, the different relevant user groups of the smart home will be the primary focus.

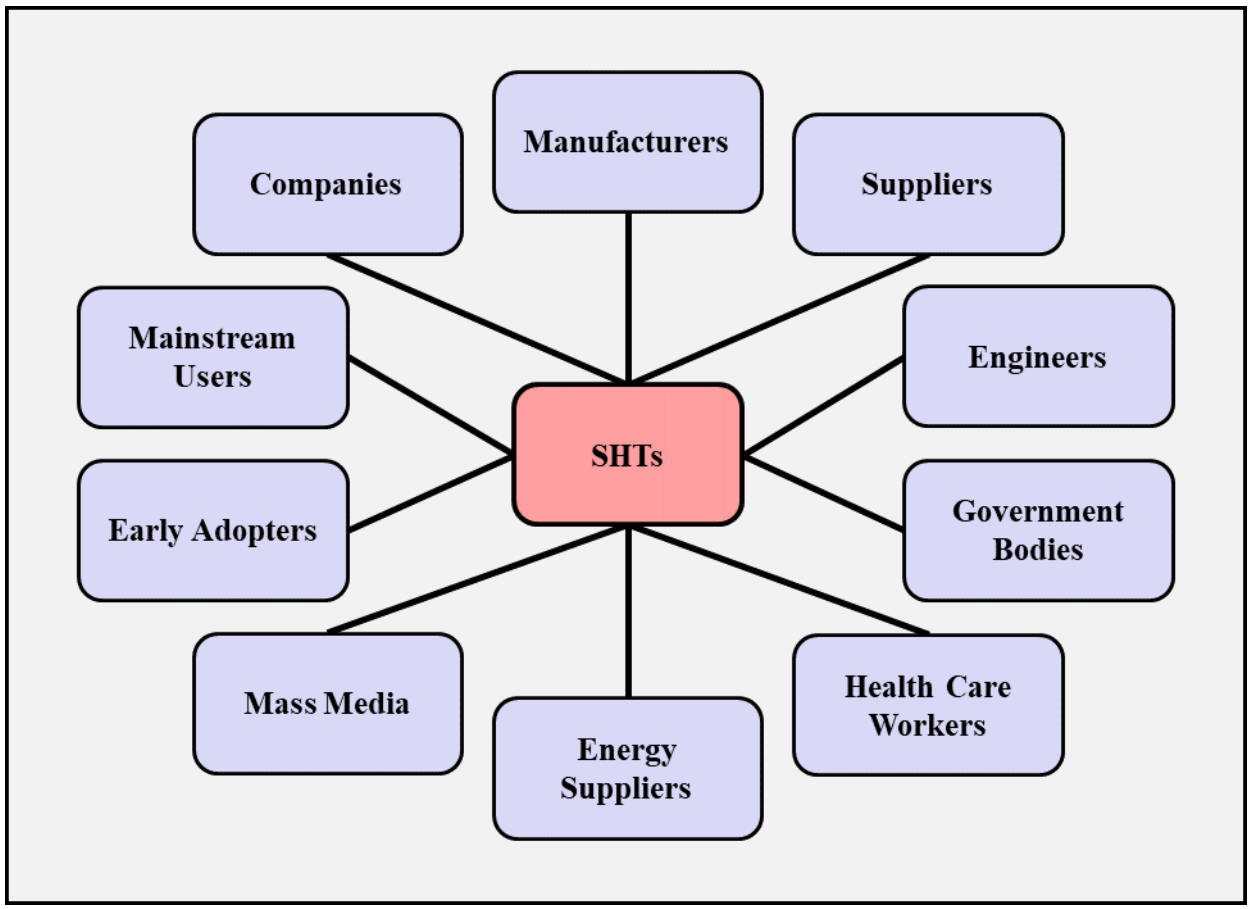

Figure 2: Smart home technology SCOT model. Each relevant social group has its own interpretive flexibility of the smart home, giving each group a stake in the technology. (Orioli, 2022b)

One way in which SCOT clarifies the adoption of SHTs is that the framework helps establish a theoretical relationship between the users and the producers of the technology. In the case of the smart home, the engineer is the ultimate producer of the technology and is the individual responsible for embedding each relevant social group's meanings into the technology. This means that the engineer should be aware of different user groups' interpretations, perceptions, and problems associated with their technological artifact. By acknowledging these relevant social groups and altering the design of SHTs to fit the needs of as many relevant social groups as possible, the engineer can help facilitate the adoption of SHTs and help overcome the

"chasm" between the early adopter and mainstream market phases of adoption. This relationship between the engineer and the relevant social groups of SHTs is shown in Figure 3.

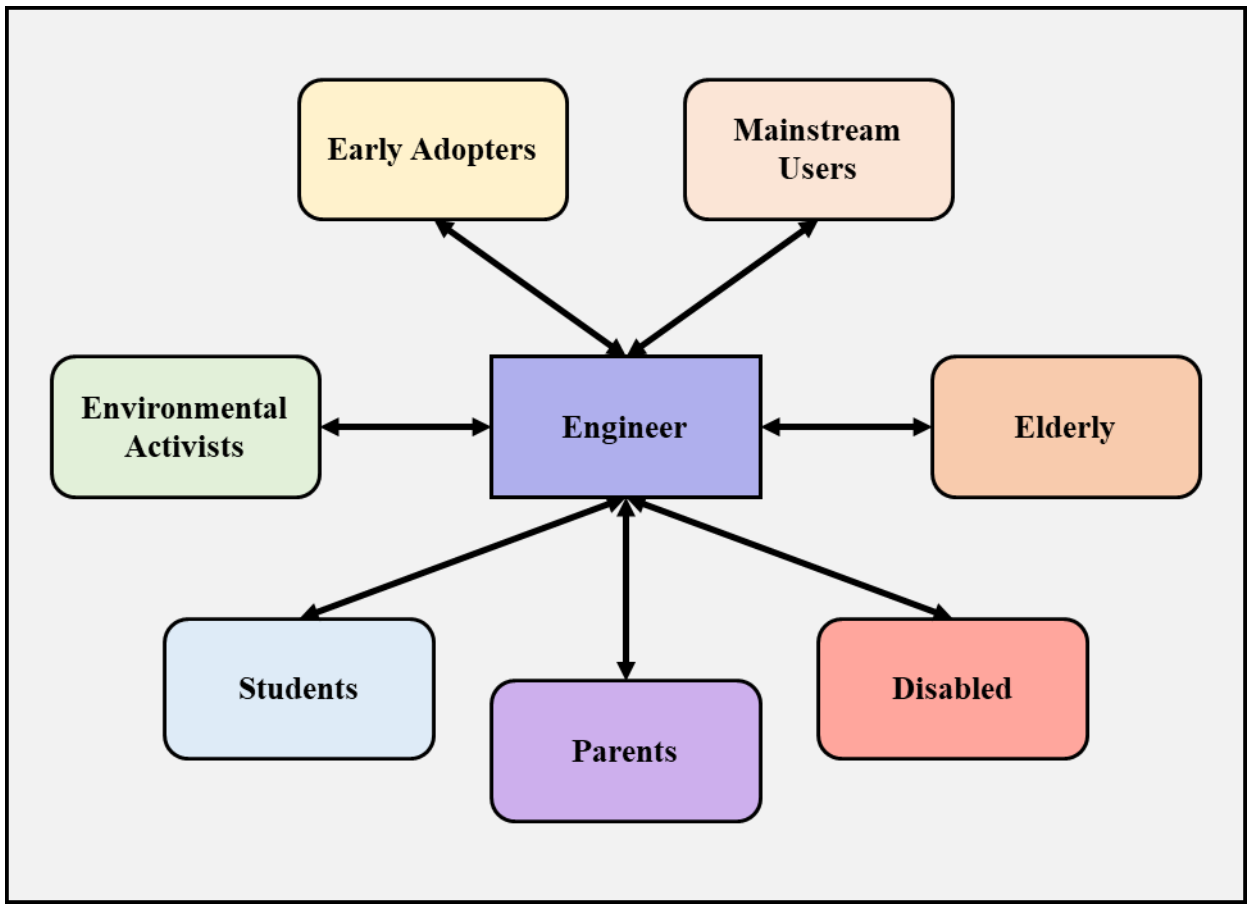

Figure 3: Smart home technology development and feedback SCOT model. The engineer acknowledges the concerns of each relevant user group and embeds each group's values into the design of the SHT. (Orioli, 2022c)

Now that the mechanism by which technological artifacts are developed and adopted in society has been established, the factors that influence the adoption of SHTs can be identified. The SCOT framework stresses the importance of acknowledging user problems and perceptions regarding a technology and embedding user values and needs into a technology so that closure and stabilization may be reached. With this being the case, there are a couple high-level factors that may be hindering the adoption of the smart home: (1) Users' perceptions of SHTs do not match producers' intended visions of the technologies, and (2) the problems that users have that

are associated with SHTs are not being properly acknowledged or addressed. The first observation is supported by research carried out by Marikyan et al. (2019), which determined that there is a mismatch between users' perceptions of benefits and the potential benefits associated with the adoption of SHTs. The second observation is supported by the existence of many sociotechnical barriers that capture both the problems and the perspectives that different social groups have regarding SHTs (Balta-Ozkan et al., 2013; Chang & Nam, 2021; Li et al., 2021; Marikyan et al., 2019; Wilson et al., 2017). The mismatch in perceptions and the problems associated with the different user groups of SHTs are addressed in the subsequent sections.

Smart Home User Groups and Perceptions

In the previous section, several relevant social groups that are associated with SHTs were identified. It was pointed out that for the successful adoption of SHTs to take place, engineers should acknowledge the values, perceptions, and problems that each of these relevant social groups have with respect to the technology so that appropriate changes can be made to the technology. Therefore, it is necessary to identify the perceptions that the different social groups have since each group has a unique set of values and perceptions regarding the technology in question. While the perceptions of many of the mentioned social groups require additional research, common perceptions from some of the groups are mentioned in this section.

The first relevant social group that is discussed is the early adopters of the technology. In general, early adopters of SHTs perceive a relatively large amount of utility associated with the technology when compared to other groups of users. According to Wilson et al. (2017), early adopters' increased perception of utility is due to their tendency to actively seek out information associated with SHTs. Even so, early adopters' increased knowledge does not significantly reduce their perceptions of risks associated with the use of SHTs (p. 80). This means that

perceived risks associated with privacy, security, and trust are relatively similar to other groups of users.

One relevant social group that arguably benefits the most from adopting SHTs is elderly residents. In general, the perceptions of the elderly regarding the utility of SHTs are positive, especially towards technologies that allow them to age in place, providing them a greater sense of independence (Lorenzen-Huber et al., 2011). According to Lorenzen-Huber et al. (2011), controllability of smart home devices is particularly important to elderly users as it allows them to keep their autonomy:

> If older adults are reliant on others to manage the technological devices in their homes, it may place them at a disadvantage and may reduce their ability to stay in control of decision-making (pp. 249, 250).

Another important technological characteristic that elderly users value is usability of SHTs, particularly with respect to the ease-of-use and low perceived complexity of the technology (Jo et al., 2021, p. 17). This requirement follows from the elderly's relatively low computer literacy (Li et al., 2021, p. 8). Studies also show that the elderly's perception of security risks associated with SHTs is relatively low, and that usability is much more important in determining whether to adopt SHTs (Jo et al., 2021, p. 18). While many older adults have a positive perception of the benefits associated with adoption of the smart home, there are some barriers that specifically hinder adoption within this social group. In a study performed by Li et al. (2021), it was found that older individuals and those who were less well educated were the most distrustful of the IoT and SHTs compared to other groups (p. 7). This lack of trust undermines the elderly's intention to adopt despite their desires to age in place.

Another relevant social group associated with SHTs that has been researched is college students. While results are mixed regarding students' willingness to adopt SHTs, it does seem that students perceive some benefits, however they have many concerns regarding the use of smart devices (Wania, 2019, p. 70). In a study performed by Wania (2019), college students were found to commonly perceive convenience and usefulness as benefits of adopting SHTs. Even so, students were mostly concerned with trusting associated companies with their data and potentially not having full control of their devices. A little less concerning to college students was the privacy, reliability, and cost of the technology (p. 70). Another study made similar observations, finding that college students were not very interested in the capabilities of SHTs since the technology was not perceived as beneficial (Wright, 2019, p. 95).

Parents represent another relevant social group associated with the adoption of SHTs. While research is limited on the perceptions of parents with respect to the smart home, parents' opinions regarding smart toys and digital multimedia use by children are well documented (Brito et al., 2018). Research suggests that parents have positive views regarding the use of digital devices and smart toys by children since they are seen as educationally beneficial, however parents are concerned about privacy since it is possible for strangers to gain access to cameras within the devices (Brito et al., 2018, p. 810). This concern is likely applicable to smart baby monitors and home surveillance systems that families use for home security purposes.

In addition to the different social groups that have already been mentioned, researchers Shin et al. (2018) have found differences within user groups based on demographics, which can be seen as distinct relevant social groups associated with SHTs. From their research, it was found that older and male groups valued perceived usefulness of SHTs, while female and highly educated groups valued compatibility (p. 251). The study also found that income and user

concerns over privacy did not have a significant effect on user intention to adopt (p. 252), which implies that users with different levels of income are just as likely to adopt and that privacy is not significantly valued by user groups. It should be noted that while elderly users generally perceive less security and privacy risk associated with SHT use (Jo et al., 2021, p. 18), this statement is contradictory to other studies that identified financial cost and privacy to be barriers to adoption (Li et al., 2021; Marikyan et al., 2019). Marikyan et al. (2019) also found users from rural and urban areas to be distinct user groups due to their different attitudes regarding the environmental benefits associated with SHTs. In particular, environmental sustainability is valued by users in rural areas, however users in urban areas value the economic benefits from adopting SHTs (p. 146).

In this section, several of the relevant social groups associated with the social construction of the smart home were identified and their values, perceptions, and problems with the technology were discussed. The problems that each of the mentioned social groups have with respect to SHTs are shown in Figure 4. From the common values, perceptions, and problems shared between the different relevant social groups, the barriers to smart home adoption can be derived. These adoption barriers are the subject of the next section.

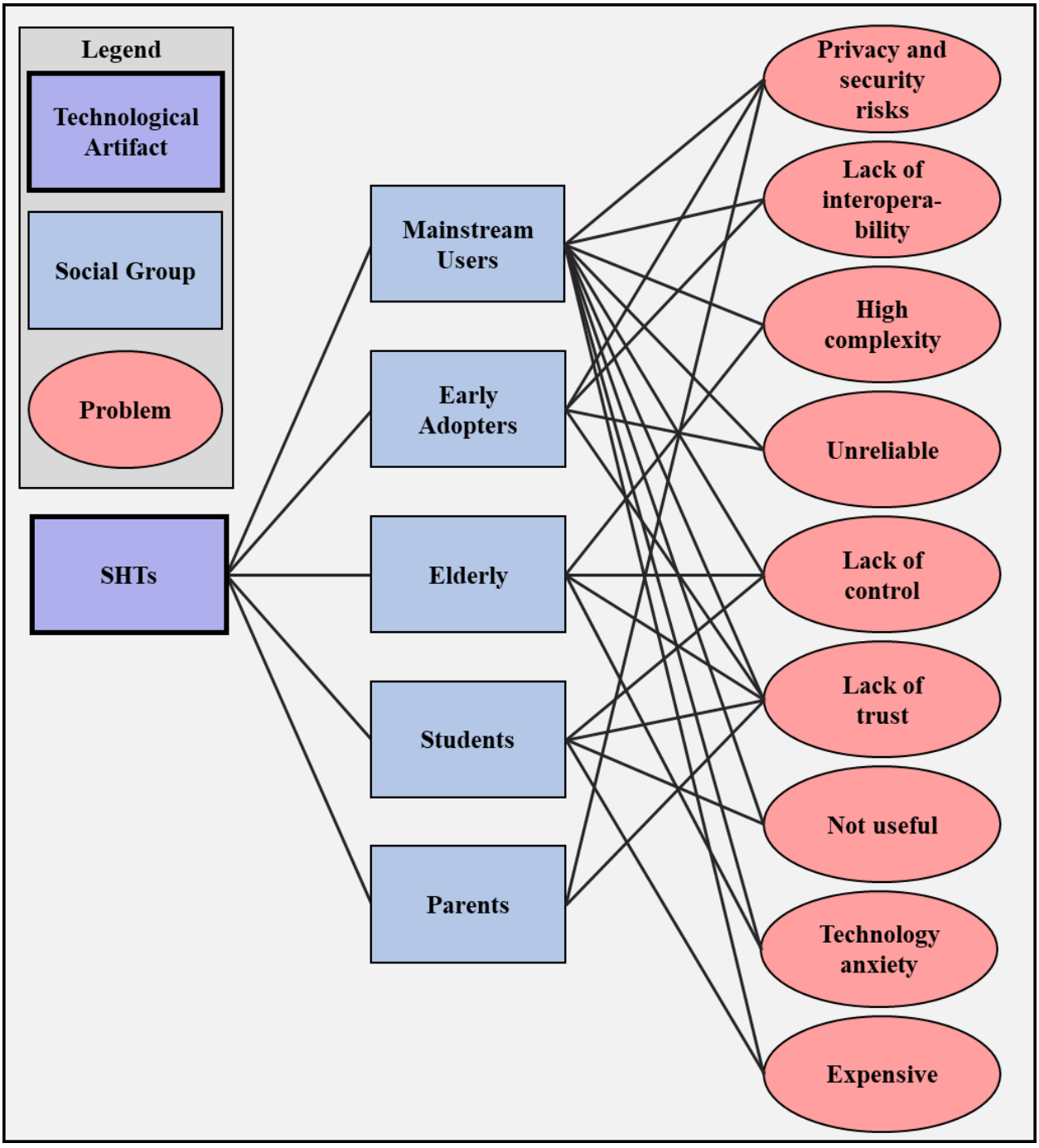

Figure 4: Smart home technology user groups and problems. (Orioli, 2022d)

Sociotechnical Barriers to the Adoption of the Smart Home

In this section, several barriers that hinder the development of SHTs are identified and discussed in detail. The goal of this discussion is to derive the perceptions and problems that are common among different relevant social groups. Through the SCOT framework, producers of SHTs can use these barriers as starting points for acknowledging the user perceptions and technological issues that are associated with each relevant social group. While there are many different barriers to adoption that have been identified by researchers (Balta-Ozkan et al., 2013; Chang & Nam, 2021; Li et al., 2021; Marikyan et al., 2019; Wilson et al., 2017), three major categories capture the majority of these barriers: (1) Technological barriers, (2) financial barriers, and (3) psychological barriers.

Technological Barriers

The first class of smart home adoption barriers is technological barriers, which relate to the usability, controllability, compatibility, interoperability, reliability, privacy, security, and other technological aspects of SHTs. This class of barriers is arguably the most important since the degree to which technology conforms to users' expectations regarding these technological factors ultimately determines whether the user is likely to accept the technology or not. According to Marikyan et al. (2019), technology fit, or "the users' perception of the technology compatibility, connectedness, and the system's reliability… [is] strongly associated with the perception of the technology's usefulness" and is therefore "the most important factor to address when developing smart homes" (p. 148).

While it is important for producers of SHTs to consider these technological characteristics when developing their technological artifacts, research suggests that current and prospective users are not satisfied with the current state of SHTs when it comes to these

characteristics. When it comes to usability, many different smart devices are relatively complex to use, and are therefore perceived by many users to have low ease-of-use. This is especially the case from the perspective of elderly users, who are generally not as experienced in using smart technologies (Li et al., 2021, p. 8). Many users also feel that they lack control of their smart devices, which negatively affects their perception of device controllability.

Another barrier within the category of technological barriers is the interoperability of smart home devices, which refers to the ability of different devices to connect and communicate with each other (Balta-Ozkan et al., 2013, p. 366). In an ideal smart home setting, all devices within the ecosystem should be able to properly communicate with each other and should be controllable from a central node or device. In reality, this is not always the case since different device manufacturers use different communication protocols to communicate between devices and other networks (Balta-Ozkan et al., 2013, p. 366). These different communication protocols include Wi-Fi, Bluetooth, Zigbee, Thread, HomeKit, and many others (Basen, 2020). Some of these connection protocols are proprietary meaning that devices from different manufacturers may not be able to communicate with each other. Adding complexity to this issue is the existence of various hubs that can be used to connect all smart devices to a central node, however these hubs do not support every communication protocol or device. Finally, there are several smart phone applications that are necessary to control all the different types of smart devices a user may have within their home, which adds to the complexity of SHTs.

The final technological barrier to smart home adoption is the privacy and security of SHTs. For smart home devices to behave in a way that benefits the user, it is necessary that smart home devices collect user data in real time, “including very private data such as location, behavior, and health data” (Li et al., 2021, p. 8). Using different connection protocols and

algorithms, collected data is transmitted to company servers and processed so that appropriate responses may be performed by the smart device and so that users may control their devices wirelessly using smart phone or web applications. However, the collection of sensitive data by companies constitutes a possible invasion of privacy for many potential users of the technology, thus users may distrust smart devices and companies as a result, lowering their perception of smart home devices, and ultimately their intention to adopt (Marikyan et al., 2019, p. 149). The implementation of smart devices within the home also constitutes a security risk since it may be possible for bad actors to gain access or control devices, leak personal data, cause physical accidents or financial loss, or perform other criminal activities (Li et al., 2021, p. 9).

Financial Barriers

The second set of barriers to smart home adoption are financial barriers, particularly the initial purchase cost of smart devices or services, the cost of installation, maintenance, repair, and energy consumption, and investment feasibility (Li et al., 2021, p. 7). While users have much to gain in using SHTs in their home environments, the cost of entry into the ecosystem of the smart home remains relatively high for most users, and is generally "perceived as worthwhile only for longer term homeowners who [have] the necessary funds" (Balta-Ozkan et al., 2013, p. 370). This may be especially true for home-based health care solutions since health industry technology is generally cost-intensive (Marikyan et al., 2019, p. 149). Thus, for lower income households or people living in rented properties, installation costs may be a barrier to smart home adoption.

Psychological Barriers

The final set of barriers to smart home adoption that is discussed are psychological barriers. The psychological barriers are the user's limited perception of the smart home, user

distrust and resistance towards the smart home, and technology anxiety. The barrier of limited perception of smart home technologies exists due to the relative novelty of SHTs. Thus, it is often the case that users are not fully cognizant of the functions or benefits associated with SHTs (Marikyan et al., 2019, p. 150).

In a study performed by David Wright (2019), who is an Associate Professor of English and Technical Communication at the Missouri University of Science and Technology, several college students participated as residents of a student-built solar village, which was made up of six houses containing an array of SHTs. Residents were only given a brief overview of the technologies within their homes and were instructed to fill out surveys over the span of their eight month stay within the village. It was found that the residents made very little effort in learning how to use several of the SHTs even though they rated the technologies as being highly capable. The study concluded that (1) the residents were unlikely to understand the technology and the range of benefits without support for learning to operate the technology, and (2) the technological capabilities that were understood were underwhelming (p. 95). These conclusions support the existence of the limited perception barrier and show that training resources should be provided to both potential and current users if they are to get the most out of adopting SHTs.

The second barrier within the psychological barrier category is user distrust and resistance towards the smart home, particularly towards smart home devices or services, the technologies embedded in these products, and the associated companies. This barrier is closely related to the smart home technological barriers since a user's trust in a smart home device is largely dependent on technological characteristics that make a technological artifact trustworthy. According to Li et al. (2021), "The adoption intention [is] impacted by reliability, performance, and controllability of [a] device" (p. 6), therefore a trustworthy device is one that is reliable,

controllable, and has adequate performance. User trust in companies associated with SHTs is also very closely related to the technological barriers, namely the privacy and security barriers. This user trust issue is rooted in user concerns over risks associated with the collection of personal and private data. While the collection of private user data may be performed by companies rather than bad actors in this case, users may find it difficult to trust that companies will not repurpose user data for nefarious purposes or that user data will not be leaked (Li et al., 2021, p. 7), thus user trust in associated companies constitutes an additional barrier.

The final barrier within the psychological barrier category is technology anxiety. While SHTs have the potential to improve users' lives in various ways, many users feel uneasy or anxious towards the technology for a number of different reasons (Li et al., 2021, p. 8). The elderly population is particularly affected by this barrier due to their lower computer literacy and their tendency to use technologies that they are personally familiar with, which leads them to reject technologies that they consider "too radical, disruptive and new" (Li et al., 2021, p. 8). This is consistent with the findings of Marikyan et al. (2019), where they point out that users may be unwilling to adopt a technological artifact if that artifact does not fit into their current environment, or if adoption requires a user to change their lifestyle or behavior (p. 150).

Communication Channels: A Double-Edged Sword to Smart Home Adoption

One of the key factors affecting the adoption of SHTs is the existence of communication channels, or the lack thereof. During the discussion of the Diffusion of Innovation (DOI) theory, it was noted that the mechanism by which members of a society are made aware of the existence of technological artifacts is through communication channels, which include word of mouth and mass media forms. Unfortunately, these communication channels can act as a double-edged sword. On the one hand, mass media can increase the general public's awareness of the existence

of a technological artifact, which is supported by the fact that "in recent years, the term 'smart home' has frequently appeared in major media and has become a well-known term" (Li et al., 2021, p. 1). However, mass media can also portray technological artifacts in a bad light, which can negatively contribute to the adoption of the technology.

An example that highlights this idea is in the form of an opinion piece, published by The New York Times, which claims that advanced voice biometric technologies will soon be embedded into smart home devices, like Amazon's Alexa, and will be capable of characterizing a person's age, gender, weight, height, emotional state, and other traits based solely on the user's voice (Turow, 2021). After reading this article, users may feel concerned about the possible collection of voice data from technology companies and may not be so inclined to trust the smart devices or companies, even if the scenario is unlikely to occur. This is consistent with the observation made by Li et al. (2021), where it was found that user mistrust in SHTs and associated companies "were amplified by media reports of security and privacy breaches, and gradually became the barrier to the smart home popularization" (p. 7).

This same argument applies to the exchange of information between two people by word-of-mouth. While members of a society may become familiar with a technology by communicating directly with one-another, negative word-of-mouth can have a negative impact on SHT acceptance by potential users, especially if those users lack awareness regarding the SHT under question (Marikyan et al., 2019, p. 150). Since "potential adopters look to early adopters for advice and information about the innovation" (Rogers, 1983, p. 249) and many early adopters of SHTs provide negative feedback that is critical of the technology, the issue of negative word-of-mouth may be amplified by early adopters.

The Path Forward to Accelerating Smart Home Adoption

While all the previously mentioned barriers are acting in a way that hinders the growth of the diffusion of the smart home, it is possible for the barriers to be dissolved, or atleast partially alleviated in order to accelerate adoption. Going back to the role of the engineer in the SCOT model, it was mentioned that it is important for the engineer to acknowledge the concerns and problems that each user group of a SHT has, and that each user group's values should be negotiated in the process of embedding these values into the technology. If feedback channels are not set up or engineers choose to ignore user feedback, it is clear that there will be a mismatch between users' and producers' perceptions of SHTs, and the problems that users have with SHTs will not be properly resolved. These two factors are the root of the barriers to adoption.

In order to lower the smart home adoption barriers, it is first important that proper communication channels be established so that users of SHTs can voice their concerns and problems associated with the technology directly to the technology producers. It is also necessary for engineers to acknowledge these user concerns and make a change in the technology if it is viable or beneficial for the majority of the relevant social groups. In the case where producers of SHTs are not required to implement changes to their technology or when they have little incentive to do so, it may be necessary for other stakeholders, like government agencies, to get involved. It is interesting to note that many of the researchers that have studied the adoption of the smart home and user perceptions associated with the technology have acted as communication channels. As a consequence, many of these researchers have introduced various high-level solutions to many of the common problems that users have with SHTs (Balta-Ozkan et al., 2013, pp. 368, 369, 372; Li et al., 2021, pp. 10, 11; Lorenzen-Huber et al., 2011, p. 248;

Marikyan et al., 2019, pp. 149, 150). These common problems and solutions are illustrated in Figure 5.

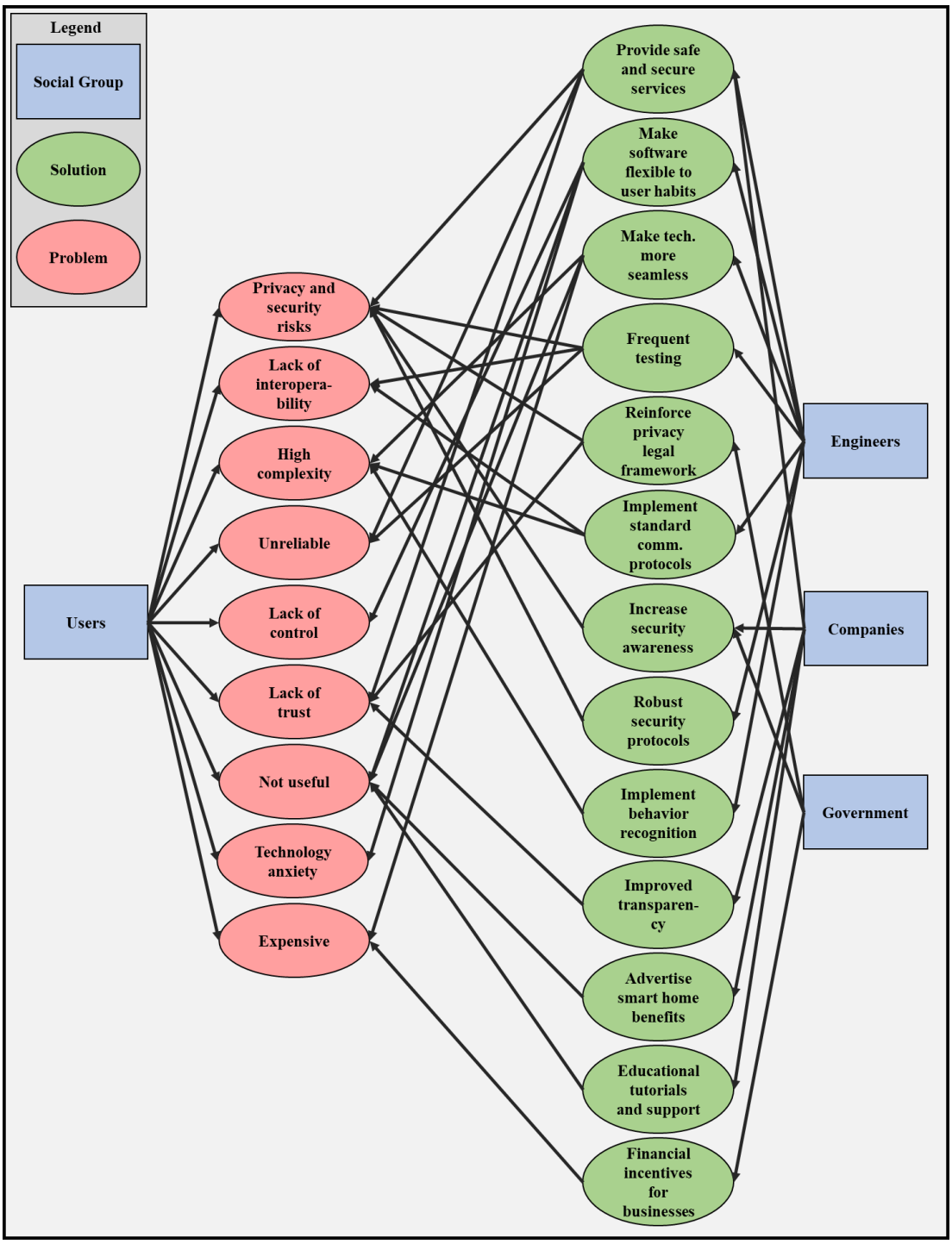

Figure 5: Smart home technology common user problems and solutions. User problems associated with SHTs result from adoption barriers and user perceptions of the technology. (Orioli, 2022e)

The Need for Continued Research in Specific Smart Technologies

In this discussion regarding the adoption of SHTs, the current state and the catalysts of smart home adoption were found using the Diffusion of Innovation (DOI) theory, and the factors hindering the adoption of the smart home were identified using the Social Construction of Technology (SCOT) framework. The current perceptions and problems that different relevant social groups have with SHTs were also discussed for different service types. Finally, several high-level solutions for dissolving the adoption barriers and accelerating the slow adoption rate were proposed.

While the SCOT framework was helpful in mapping out the relationships between SHTs and the different stakeholders, it should be noted that the analysis dealt with the "smart home" as a single technological artifact rather than looking at individual SHTs that make up the entire smart home ecosystem. As was shown through the discussion of the benefits associated with the adoption of the SHTs, the "smart home" is an umbrella term that encompasses all the different sensor-based devices and services that can be incorporated into the home environment. As such, when looking at how to improve the adoption of the "smart home", it is important that the relevant social groups for each specific device and service be recognized since the set of relevant social groups and their interpretive flexibilities associated with each technology may vary greatly. As Chang & Nam (2021) suggest, "the adoption of smart home services should be analyzed based on a detailed understanding of the target users for each service type" (p. 14). Therefore, while the analysis and solutions laid out in this discussion may be useful in combating the slow adoption rate, more research should be performed for specific services and devices to gain a better understanding of the factors hindering the adoption of each individual artifact. This is ultimately the responsibility of the producers of each individual smart home technology.

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