BILKENT UNIVERSITY

GE301 Science Technology and Society – Fall 2021-2022

A CASE STUDY ON KAREL ELECTRONICS SMART HOME TECHNOLOGY THROUGH THE LENS OF RESPONSIBLE INNOVATION

Ata Yavuzyılmaz - 21802466 - EEE

Atakan Topcu - 21803095 - EEE

Başak Ceyhan - 21802990 -EEE

Pelin Ayduran - 21802266 -EEE

Yaren Durgun - 21902664 -CS

Table of Contents

1. Introduction

In this project, smart home technologies were researched and analyzed in the context of STS theory, Responsible Research and Innovation. Karel Electronics was chosen for this case study and interviews were conducted with three engineers who work in the company. The STS theory of Responsible Research and Innovation (RRI), namely, Values Sensitive Design (VSD) was explained in the theory section. The background research was done on the smart home technology itself and the values that can be associated with smart homes. The history of smart home technologies, target applications, user and stakeholder design and the values with emphasis on security, privacy, transparency and sustainability in the context of smart home technologies were researched. The method for finding the articles and conducting the interviews was mentioned in the method section. The information about the three interviewees was also provided in this section. In the findings section, the data gathered from the interviews were presented in the form of paragraphs and tables, categorized by relevant themes. In the analysis and conclusions section, the data presented in the previous section were analyzed in the context of VSD. Using the VSD lens, we analyzed how well the company incorporates certain values in their designs, what kind of strategies they follow to deal with conflicting values, how well they communicate with the users and how well they engage the stakeholders. According to the findings of the studies carried out by Karel Electronics on smart home technologies, through the theoretical lens of Responsible Innovation and the background research, it has been concluded that the company can broaden their current assessments and go further in incorporating values such as privacy, security, transparency, user and stakeholder and sustainability into its designs and solutions.

2. Theory

This project focuses on innovation practices of smart home technologies through the lens of Responsible Research & Innovation (RRI). The approach used in this project is Value Sensitive Design (VSD) referred to by Van de Poel which covers a very important part of RRI [1][2]. VSD is concerned with incorporating various values into the design processes of technology [1][2][3]. According to this approach, identification of values according to stakeholders' and users' interests is quite important and these values such as privacy, transparency, sustainability etc. should be incorporated into design processes [2][3][4].

According to this approach, there are six important lessons for companies to improve their Responsible Innovation activities [3]. These lessons are listed by Van de Poel as follows: (1) Strategize for stakeholder engagement (2) Broaden current assessments (3) Place values center stage (4) Experiment for responsiveness (5) Monitor RRI progress (6) Aim for shared value [3]. The first lesson, strategizing for stakeholder engagement is about listening and involving the stakeholder to the design process. This is very important as this process improves transparency and is also democratic in a way that it has the potential to address the needs and interests of society and various stakeholders [3]. The second lesson, broadening current assessments is another crucial part of Responsible Innovation in which the assessments companies are currently considering are reviewed and expanded [3]. It is often the case that companies are already thinking about values, issues and assessments to a certain extent, RI helps them to go further and broaden their assessments [3]. The third lesson, placing values in center stage, provides the companies to think about several values that are being desired at the same time [3] According to VSD, values should be placed at the center stage in the design process and different values should be contained within a technology simultaneously [1][3]. In this context, the concept of value pluralism is introduced which means there exists values that "cannot be reduced to each other" [4][2]. Due to this plurality, there is a possibility of dilemmas and value tensions within these values if they cannot be realized simultaneously [3][4]. In VSD, this is called "moral overload" as all of the values are required for the technology but some values conflict with others [4]. Thus innovators feel overburdened to design a system that is overloaded with different values. VSD becomes a solution to the problem of moral overload as it helps innovators to understand how to recognize values and value tensions to deal with them as well [3][4]. The fourth lesson, experimenting for responsiveness. The fourth lesson, experimenting for responsiveness is another important part of RI and it is about creating environments for experimentation in order to anticipate possible outcomes of the technology in terms of stakeholder reaction, legal and social impacts [3]. The fifth lesson, monitoring the RRI progress is about creating a supervision mechanism for RRI activities which should be done both from the inside of the company and externally by other parties [3]. The sixth value, aiming for shared value is another crucial aspect in RRI, is that the company only "focuses on its own actions" and leaves it to the society to decide whether the company can provide mutual trust [3].

In the VSD approach, values should be built into systems and they should become requirements for design. If these values are not integrated over interfaces, codes, algorithms, protocols, architectures, infrastructures, etc. problems may arise in the future [4]. The VSD approach further states that requirements of these values should be integrated into the technology when it is being designed, not in the later stages [4]. During the design process, engineers and innovators have the opportunity to come up with creative solutions to conflicting values and they can make a difference [3][4] Also, it is important for engineers to

expand the way they think about technology in terms of incorporating a wide range of relevant values so that they maximize their responsibility.

Smart home technology is an emerging area that can make people's lives easier and more comfortable. However, smart devices that form the basis of this technology, that is, integrated into homes or cities and communicating with each other, raise questions about how they might affect society in terms of privacy, security etc and the environment in terms of sustainability. Due to the nature of technology, the systems and devices are automated and are based on collecting users' data correctly and processing and using this data correctly. The RRI approach mentioned above is closely related to the context created by the smart home technology that the project focuses on. Therefore, using and applying this theory in our project will provide a deeper understanding of our findings. Through the lens of RRI, we investigate what kinds of values are being taken into account, how well does the company implement the strategies of RRI, how are the value tensions dealt with, how well are the stakeholders being listened to and what solutions are being implemented related to certain values in the area of smart home technology.

3. Background Research

3.1. Smart Home Technology

With the boom of industry and technological advancements in the 1960s, people dreamed of techno-utopian homes where the comfort of their home increases and the chores of the home diminishes [5]. Such vision resurfaces each time a new piece of technology is developed. The first attempt at the smart home system was a smart device called ECHO IV in 1966 [6]. Although this device has never been commercially sold, it had functionalities such as computing shopping lists, controlling the home’s temperature, turning appliances on and off, calendar, and air conditioning management [6][7]. It was a simple yet inspiring computer that was able to give a glimpse of the future. With the current advancements in technology, new ways of methods to implement smart home systems have been introduced and during the early 2000s, smart home technology started to gain momentum [6]. Lately, instead of a single wired computer that is responsible for the home, ubiquitous computing has been embraced by the industry [5]. With the concept of ubiquitous computing, internet of things (IoT) technology has been deployed where multiple devices are connected to each other through a defined protocol and collect and share data between each other [8]. With the new emerging IoT technologies for smart homes, the momentum of smart homes reaches a new high. However, with such momentum and popularity, it raises some concern for its effect on the environment and dynamics of society.

3.1.1 Target Applications

Smart home technologies have been used for a variety of applications such as elderly monitoring and home security [5]. For that reason and from Atakan’s and Ata’s experience on smart home technologies, the system can have a variety of sensors and modules [9]. For elderly monitoring, heat sensors, cameras along with the automation of house appliances might be needed while for home security, we might only need vibration sensors, ultrasonic sensors along with a camera. Therefore, the choice of choosing a particular application affects the modules of the technology and in turn, targeted values such as sustainability, privacy, or

both such as using modular and higher lifespan chips compared to high power chips and using intelligent routing protocols that ensure minimal energy route [10].

3.2 User & Stakeholder Design

Smart home technology is a field that affects society dynamics specifically regarding family [11]. For example, smart homes should be adaptive to include dual-income families, the elderly, people with disabilities [9][11]. As the computational power of the houses enhances with the implementation of smart home technologies such as Bluetooth Low Energy (BLE) Mesh networks, personalized monitoring is possible along with enabling elderly or disabled people to operate inside the house with more ease [9]. As an example, door control systems can be realized for such ease of use scenarios. With customizable monitoring, such technologies can be used for determining unexpected incidents such as fall injuries [12]. However, such functionalities might be shadowed by the risk of potential hacking of the data of such users [13]. This leads to potential danger for the elderly and people with disabilities. Furthermore, implementation of the technology can lead to changing dynamics in the house as the control of the house shifts to the most tech-savvy user [13]. Along with the clash of traditional routines, this change in dynamics also creates new identity conflicts for the users of smart home systems since people construct their social identity through the use of products [11]. As the person responsible for the control of the house changes, users' investment in their homes also gets affected which leads to changes in the perceived social identity of the users. For example, control of the house shifts from stay-at-home parent to the technologically literate partner which results in role changes in the home. Moreover, the control that smart homes provide may create some unpleasant social consequences. For example, parents can use smart home systems to spy on each other or their children [14]. The children might feel overprotected, and they might be unable to do anything without their parents' knowledge. The information that is recorded using smart home systems might reveal the person's arrival time to home, which devices are currently used, and maybe some camera footage or audio recordings. This control mechanism restricts the freedom of the smart home inhabitants [14].

Culture can diffuse and shape the use of smart homes in different countries. People have culturally fixed expectations. These differences can lead to different stakeholders of the technology and each has to be targeted accordingly for their preferences. [15][16]. In that sense, culture is what determines society to embrace smart home technology for different purposes.

Smart home technologies do not always address gender inequality, as women have not been added to the design process [17]. According to a survey, only 44% of women understand what a smart home is, while this is 59% for men [18]. Moreover, 59% of men are very interested in new technology, but for women, this is only 39% [18]. Due to the overly male technology industry, smart home technology is a biased technology as well [19]. Women as a social group are not considered enough and this causes gender inequality and in some cases, even domestic violence can occur [17]. Furthermore, due to the biased process of smart home technologies, women are subject to the invasion of privacy and denial of services [19]. The traces of such a process can be seen in digital assistants used in smart homes. Digital assistants such as Alexa use speech recognition which is trained on large datasets of mainly male voices. Thus, it has been observed that digital assistants are 70% more likely to recognize male voices compared to female voices [19]. Furthermore, gender plays a role in setting the conditions in home environments. For example, females are more sensitive to cold

conditions compared to males [16]. Because of each gender's preference in thermal conditions of the house, biased technology could potentially work in favor of males by specifically setting the temperature of the house in accordance with the preference of males.

3.3 Privacy

For smart homes and IoT devices, security is also a significant concern. Due to the fact that IoT systems have heterogeneous network architectures and the devices that are used have low processing power, there are many ways to attack IoT-based smart home systems [20]. Furthermore, since the IoT devices are connected with each other, unsecured devices may expose secure devices [21]. There are many different sensors and devices used to construct a smart home system, and if a device used in the system is vulnerable, the hackers are able to control the whole system [21]. The devices that are more vulnerable to cyber-attacks are mainly the cheaper devices, and most of the companies choose these sensors due to economical reasons [21]. For example, a hacker can gain access from a vulnerable washing machine to unlock the doors throughout the smart home [22]. There have been examples of smart home devices recording private conversations and sending them to random contacts on the user's phone [21]. Thus, it can be concluded that security flaws in smart home systems also raise concerns about the smart home user's privacy. Personal information of the users can be stolen, and even the house properties might be damaged due to these security flaws [23]. The unadvanced security measures allow hackers to control the smart home system with primitive tools and a low level of knowledge and skill [24]. A recent investigation reveals that IoT devices were liable for one-third of the attacks in mobile networks [24]. However, there are several countermeasures that are discussed to prevent these cyberattacks such as mutual authentication and encryption [22].

Smart homes collect various data from the users. There have been examples of smart home devices recording private conversations and sending them to contacts, or baby monitors getting hacked [21]. Furthermore, the sensitive health information of a patient and other potential hacking risks could potentially jeopardize the less digitally literate. The lack of designing systematic privacy can lead to such breaches [25]. To prevent the wrong people from accessing the data of the users, proper security measures such as authorization and encryption should be implemented [26]. Besides the security vulnerabilities, some IoT devices also record the data of the users and they might share the information with third parties [27]. Alexa, the voice-activated home assistant developed by Amazon, stores data such as voice inputs, location, device interaction, and many more [27]. To overcome these problems, the manufacturers should include some privacy by design solutions such as transparency [25]. The manufacturers should specify their privacy policy, and the users should be able to choose which information is being stored [25] [28]. To have a better experience, the user can choose an option so that the manufacturer stores more of their information, but if the user wants to protect their privacy, they might be able to choose a setting that informs the manufacturer not to store private information [28]. These various options may allow the user to feel more comfortable about their data since the manufacturer is transparent about their privacy policies.

Furthermore, societies that value seclusion such as the UK show an aversion to embracing smart home technologies due to potential privacy risks. There can also be problems that hinder society from using this technology due to their tendency to rent a house rather than become an owner, which is the case in the United Arab Emirates (UAE) [15].

Thus, it can be concluded that the culture of a society is also a contributor to the privacy concerns of smart homes.

3.4 Sustainability

The sustainability of smart home technology is crucial. Studies have shown that smart home systems are often associated with sustainability and energy efficiency and this led to receiving increased attention from policy-makers and companies. Smart home companies such as Siemens even predicted that such systems can reduce energy costs by 30% [5]. Some smart water systems also can increase the water efficiency of households [29]. Applications like these may reduce the carbon footprint of households [30]. However, despite the predictions such as these, there are still concerns regarding recycling, waste reduction, energy efficiency, and similar issues. It is important to consider that the saved energy might be spent elsewhere such as smart lights which can be used for ambiance, security, and entertainment reasons. This can lead to more energy usage despite the system's efforts [13][15]. Nonetheless, such problems can be alleviated by gently informing the user of his/her decisions on the environment and gently reducing such consumption patterns [10][31]. This transparent approach can enable this technology to have a truly sustainable future. Thus, through the Responsible Research and Innovation (RRI) process, stakeholders' concerns about the sustainability aspect of the technology can be dispelled. Apart from the energy efficiency of the technology, there is also the problem of waste reduction. Most of the IoT devices are mostly unrecycled. Also, these devices may contain toxic chemicals and are expensive to extract or recycle [21]. Furthermore, the extraction of rare chemicals might be harmful to the environment [32]. Transportation and delivery of the products should also be investigated and should be conducted in an environmentally friendly way. CO2 emission due to automobiles is an important contributor to global warming [33]. It can be concluded that there has to be a thorough investigation of the possible risks of the realization of the technology. Moreover, the companies have to provide service for a product even after it is sold. This includes services, repairs along with the usability of the product even after the emergence of next-generation technology. If a company is bought or closed, they can stop supporting a device that they have sold [21]. This leads to a decrease in the usability of the product. For example, a smart lock user might not be able to fix a bug present in the technology if the smart lock company doesn't provide service for their product [21]. In the end, it can be considered that sustainability is an important dimension of smart homes which needs to be analyzed from different sources and perspectives by the company.

4. Method

The data required for the project was gathered through various written sources and interviews. The written sources were found over the internet in the form of academic articles and news websites. The Google search engine and Google Scholar searching platform were utilized in order to find reliable news websites and academic articles respectively.

In order to directly assess the values that are inscribed to smart homes during the developing process and to examine the developers' approach to responsible innovation and research, a company that has been specializing in smart home technology and devices was contacted. The company, Karel, was chosen because of its proximity to industry giants that have been dominating the smart home industry, and also because of the close relations between the company and the group members Atakan and Ata, who are doing their senior

projects with the company. Two people from Karel were contacted to conclude the interviews. One of the interviewees was a software engineer who is directly working on the software products of the smart home industry, under the position of Embedded Software Engineer in Karel. The other interviewee was an electrical and electronics engineer who had been working for the company for over two decades, occupying positions such as Design Team Leader and Communication Systems Group Manager. This interviewee is currently working as Information and Communication Systems Director in Karel.

The first two interviewees were contacted through their email addresses. The first interviewee helped the establishment of the second interview by providing the communication details of the second interviewee. The third interviewee, an undergraduate student from İhsan Doğramacı Bilkent University who has been working on Karel's smart home project, was found by Atakan and Ata from their project group. All interviews were conducted online over the meeting platform Zoom.

During the interviews, in order to be consistent, the same questions were asked. The questions were about smart home technologies and their applications. The potential security, privacy risks, and social issues that could arise from smart home technologies were discussed. One question also focused on sustainability practices as sustainability is one of the main focuses of the project. Additionally, the stakeholders responsible for the smart home technologies were asked and the future of the smart home technologies was discussed. Transcripts of the interviews were transcribed, then translated into English. The interviews were coded using the QDA Miner Lite software. The coding helped organize the answers of the interviewees under different categories such as risks or values. This practice helped the project report to be more efficiently written.

5. Findings

The findings can be categorized into four subsections, which are technology, user & stakeholder design, privacy and data security, and sustainability. The data is collected from the interviews and the written sources as described in the previous section.

5.1. Smart Home Technology

This section includes the technical aspects that were discussed in the interviews. Efficiency, economy, and target applications will be mentioned respectively.

Technical	Interviewee Comments
Efficiency	...but technology speeds up our lives and reduces time losses. The biggest benefit of technology is time. This is what IoT devices will bring in the future. It is faster for you to take data and process it and reach a conclusion [Embedded Software Engineer].
Economy	...if there is a cheaper alternative, your product will not be sustainable and will expire. Therefore, the profit provided by IoT devices must be valid both in terms of money and time, so that it is sustainable and can be used by everyone [Embedded Software Engineer]…

Risks	...it definitely needs to be done from an encapsulation, security perspective. Otherwise, some attacks can cause worldwide damage [Design Team Leader]… You need to send the data in that product to the center safely before it is found. That data should be healthy without being manipulated by others or environmental conditions [Embedded Software Engineer]… You are trying to obtain data and collect it in the center, but this data may be obtained by your competitors (...) these parties are trying to obtain this data [Embedded Software Engineer]...

Table 1: Technical Findings Table

5.1.1 Efficiency

In the second interview, efficiency in technical aspects is mentioned. The embedded engineer talks about efficiency in terms of time efficiency. According to the embedded engineer, the time losses on data processing and in daily life will be reduced with the help of IoT technology, as the data will be processed in a fast manner [Embedded Software Engineer].

5.1.2 Economy

In the interviews, the economy was mentioned in the context of the price of a product. In the interview with the senior EEE student, the possible competition and the need for a balance between profit and product sustainability were mentioned [EEE Student]. According to this interview, the product should yield a profit while being sustainable in terms of longevity [EEE Student].

5.1.3 Target Applications

The phrase “target application” involves the devices that are being considered as possible products, and the end products that are offered to customers. The interviewees count quite a few devices like sensors, smart meters and valves, and lighting products to have different applications such as patient care, energy efficiency, heating, and cooling systems, and controlling electronic devices at home. In smart home technologies, various products are used to solve different problems and have diverse applications. One quote from the interview with the embedded software engineer explains the capabilities of an IoT device: “It (IoT device) can process and analyze temperature in seconds. IoT will develop because you will not want to turn on the air conditioner when you go home, the television will turn on automatically when you enter the house, you will see how much you have spent on the combi boiler.” [Embedded Software Engineer] According to the engineer, applications of smart home technologies aim to increase efficiency, provide information that leads to mindful consumption, and advocate for sustainability.

5.2 User & Stakeholder Design

Background research and the interviews showcase that many different types of stakeholders are involved in smart home technologies. Per the interviews, the main stakeholders are thought to be customers, target audience, and companies. Customers are the ones who actively use smart home technologies or people who buy smart home devices. The

target audience includes the people for whom the smart home technology is designed and produced. For instance, there are various projects that are being developed for patient care at home, hence caretakers of patients are considered to be a target audience group, according to the second interview [Embedded Software Engineer]. Another group of the target audience that demands attention is the elderly, or rather their caretakers. Embedded engineer at Karel explains that as the population grows older, neurological diseases and other problems that are caused by old age appear more commonly, and therefore, people who are affected by these conditions need care at home. Following this, in the interview with the Design Team Leader, the effect of sensors on efficiently supporting the elders was emphasized, as the elders could be followed using the physical sensors. It was also said that the sensors could help the elders connect with the world and not be lonely [Design Team Leader]. Finally, the last group of stakeholders are companies. Companies are corporations that sell smart home devices or contribute to the progress of smart home technologies. These companies can be rivals or partners, however, they develop the technological system together [Embedded Software Engineer].

It appears that in the future smart home technology will reach more people. The embedded engineer that has been interviewed emphasizes that the technology will become widespread as more people will want to use smart home technologies because of the influence of smart home users [Embedded Software Engineer]. An increase in the popularity of smart home technologies draws attention to future stakeholders. Future stakeholders are considered to be actors or businesses that may get involved in developing technology in the future. When considering stakeholders, it is important to acknowledge future stakeholders and what they might demand from the technology. The embedded software engineer asserts that taking future stakeholders into consideration while designing smart home technologies is an important practice [Embedded Software Engineer].

Below is Table 2 which shows stakeholder groups and some textual material from interviews that explain why the respective groups are considered as stakeholders.

Stakeholders	Interviewee Comments
Customers	This is for daily usage, for consumers in general. It has no specific audience to be exact. It is mainly for homeowners [EEE Student].
	Of course, Karel also has corporate customers … [Design Team Leader]
Target Audience	Therefore, our target group is elderly, but I would say indirectly their guardians. Because the elderly do not use mobile applications or the tracking system, doctors or their children or relatives at work will use these products [Design Team Leader].
Companies	If a product you produce is a better version of a product in the field, or if it will be the same, that product is already used by certain customers in the field and its deficiencies have been revealed. So you have to offer better improvements, better options against these deficiencies [Embedded Software Engineer].

Table 2: User and Stakeholder Design Findings Table

5.2.1 User Experience

As user experience defines how well a product is received by the public, it is a very important aspect for many companies. Especially in a field such as smart home technologies,

it is important for companies to be constantly in contact with users to improve user experience by gathering feedback and modifying the products according to these feedbacks. However, according to a comment from the interview with the embedded software engineer, IoT devices lack a feedback system: “As far as I know, there is no feedback on IoT devices.” [Embedded Software Engineer]. In addition, the incoming replies from the customers might not be beneficial for the company, according to the same interviewee. That is because the customer may not have enough information on the technology, and therefore may not be conscious of the results of their demands. In such cases, the customer's awareness of what they want, how it will be implemented and how it will really benefit them is not sufficient and hence, the chances of their feedback causing harm rather than good is high [Embedded Software Engineer]. The embedded software engineer also expresses the past mistakes of other companies: “Remember the first products of many big companies. These companies came to their customers with a lot of mistakes and a lot of non-user-friendly structures.” He states that these mistakes do not necessarily lead to negative feedback from the users as the users have yet to experience other products that are similar to the product that possesses deficiencies [Embedded Software Engineer]. This situation implies that the nature of user experience is not quite clear until there are competing products on the field that can provide various functionalities by different methods to the users.

5.2.2 Social Values

Social values refer to concepts that carry high importance to society and society principles, which may vary for different ethnic groups or nations. However, values that need to be inscribed to new technologies are usually similar and include concepts such as access, transparency, or the welfare of the general population. There are many social values that should be mentioned in the field of smart home technologies, as the inscription of these values to the technology or the lack thereof will have a direct impact on people’s experience regarding smart home products. However, only two social values were mentioned by the interviewees, namely privacy and the welfare of the people. Privacy, being quite an important and controversial topic, will be discussed in detail in the next section. Here, we will focus mostly on welfare.

The undergraduate student who has been working in Karel’s smart home project stated that increasing the welfare of society was one of their main goals. The interviewee also mentioned that they were trying to achieve this goal by reducing the workload of people and providing automated home maintenance systems. “... People are not supposed to take care of their own homes, it (home maintenance) will be automated.” [EEE Student].

5.3. Privacy and Data Security

Both the Design Team Leader and the senior undergraduate student discussed privacy in their interviews. The first mention of privacy is from the interview with the Design Team Leader, where it was said that all the data in people’s houses will have a connection to privacy [Design Team Leader]. Team leader mentions that the data is being collected from the homes of people and the privacy of this data is important. Another comment from the interview with the EEE senior student combines the data security aspect with the privacy concept, as the interviewee claims that the company is building its systems so that important information cannot be leaked, therefore preserving privacy of data and the privacy of their clients: “We definitely consider the privacy aspect. That is why we are building our system in

a way that there is no information leakage, at least no important information leakage…" [EEE Student].

The topic of data security and its importance were mentioned in all three interviews. Interviewees focused on the security of the data and the integrity of the data in the context of data security. They all mentioned the possibility of attacks and the need to preserve the data against these attacks.

The Design Team Leader states in the interview that the customers are quite concerned about the security of their data: "Especially corporate customers coming from the public sector put a very serious emphasis on data security. For this purpose, we positioned the data center within ourselves…". This highlights the stance of the customers regarding the security of the data and the response of the company. The team leader also emphasizes the importance that the company gives to security by stating that especially for large-scale companies, the customer base expresses serious sensitivity regarding data security and as providers of the technology, the companies respond to the customer's sensitivity [Design Team Leader]. Also, in the interview with the embedded software engineer, he expresses the importance of keeping the data intact and mentions that the data should be preserved against other people and natural factors [Embedded Software Engineer]. This stance is also supported by the director who expresses that storing the data and ensuring data security is very critical in IoT technologies [Design Team Leader].

5.4. Sustainability

In the interviews, sustainability was mentioned in terms of energy efficiency, and some solutions were provided according to the notion of efficiency.

One of the solutions was mentioned in the form of sensors. An example for the sensor-based solution was provided by the Design Team Leader who expresses that devices such as digitalized sensor pads will be integrated into various accessories like heater cores, valves, and on-off buttons of electric appliances. In the same interview, the possibility of sensor integration in future projects was discussed: "...one of the important issues that we focus on is to advance some electronic design activities with a number of futuristic projects in order to integrate sensors into such places, which we frequently use…" [Design Team Leader]

One other solution was discussed in the form of BLE (Bluetooth Low Energy). The undergraduate engineering student discussed BLE, which is a low energy consuming product [EEE Student]. He reported that by using the BLE meshes in smart home technologies, the company could develop new smart home technologies that are energy efficient and therefore sustainable [EEE Student]. The Design Team Leader offered the solution of smart plugs and smart lighting products that would increase energy efficiency, and therefore would help with sustainability. He also stated that they would work on the integration of these devices into smart homes [Design Team Leader].

6. Analysis and Conclusions

6.1. Analysis

From our findings section, we observed that Karel has been successfully implementing IoT applications to smart home technologies by taking into consideration values such as welfare, security, privacy, and sustainability. However, it is possible to say that some of the values that the company considers are in conflict with others. Data security and privacy of the users are found to be two conflicting values in Karel's smart home technology. This situation that Karel is in can be explained by the concept of moral overload introduced in VSD in which both privacy and security are desired values but both cannot be obtained through the current designs of Karel [3][4]. It is observed from the interviews that Karel has been giving more priority to the security of the data in terms of whether the data is being correctly collected and correctly processed than whether the data of the user is not leaked, or the user's privacy is not violated (See section 5.3). It is important to acknowledge that of course, the company pays a lot of attention to privacy as stated in the interviews, Karel is integrating privacy into its platform during the design stages (See section 5.3). However, It is seen that the functionality of the platforms that collect and process the data is of greater importance (See section 5.3). To resolve the value tension between privacy and security, the company can broaden their assessments on how to further deal with privacy-based problems and go further in terms of understanding the conflict between privacy and data security [3]. Moreover, what the company can do more is to come up with creative design solutions to eliminate the value tensions [3]. There are solutions for this issue in the literature. Communicating more clearly to the user about the privacy policy, using technical solutions such as encryption and authentication are the solutions to prevent this problem [25][28].

Also, another important problem regarding privacy that is learned from the interviews is that the company makes sure that "important data" has not been leaked, but does not comment on which data is important or who decides the importance of the data in this context, and whether it is reported back to the user when "non-important" or "important information" is leaked (See section 5.3). It will be a responsible solution for the company to include the stakeholders in this process by listening to the users and their concerns, informing them about the content of the data being used and actively and sincerely communicating with the stakeholders when making a decision about which data is important and which data is not [3]. In this way, Karel will both expand its current assessments on values such as democracy and transparency and engage the stakeholder in the design process [3][28].

Karel gives importance to certain values such as data security and privacy, however, the value of transparency has been ignored as the interviewees have not discussed transparency as a value. In addition, the interviewees have not mentioned any transparency by design solutions, as their solutions focused on the values of sustainability, security, and privacy. Karel can broaden their current values to include transparency as well, by starting conversations on how to integrate transparency to the technology and how they can gain experience on this issue [3]. Although Karel has not been considering transparency as a key value, there have been options stated in the literature that enables the user to have more information on which data of them is being used [28]. This is achieved through specified privacy policies in which users can decide whether the information to be stored or not [25][28] .

It is also important to mention that the current products and the offered solutions mentioned in the interview do not take democracy into account. It seems that the value of democracy has not been inscribed to the current smart home technology and has not been considered as an important value. During the interviews, it is stated that the customer or the user does not have enough expertise to manage smart home technology (See section 5.2.1). Although this type of situation in which the user does not have enough knowledge of the technology, is common, what is expected from the company is to engage the stakeholders and give the necessary training or consultancy to the users in order to integrate them into the technology [3]. This way, user feedback can be considered and the technology can be adjusted accordingly during the design phase. This moment of adjustment to the technology is quite important since earlier the values are integrated and stakeholders are involved, the better as making changes after the design phase is quite difficult and late [3]. However, Karel does not provide any information in the interviews regarding such a training or learning phase for the users. This implies that the company seems to be unwilling to listen to users and their concerns about Karel's current designs. Furthermore, Karel does not provide any insight about how the smart home technology can affect gender, age and family dynamics and what kinds of risks that smart home technology algorithms may pose in this context. As reported in the interviews the users are quite broad for this technology, as stated in the interviews, "can be used by anyone", it is observed that the company sees the users as a whole and does not consider how specific kinds of bias (gender bias, age bias etc.) can be observed due to smart home technology algorithms [EEE Student] (See Table 2 as well). Even though Karel engineers did not report a problem of this kind, it is an important issue discussed in the literature. For example it has been found that smart home systems are more prone to detect male voices [19]. Furthermore, the smart devices, if not coded carefully, can get hacked and thus work unexpectedly and may pose risks to the elderly [13]. Karel's view on the elderly as a user is not direct. They consider elderly's guardians as the main target audience more than the elderly (See Table 2). In terms of VSD, this approach to elderly can be improved by involving the elderly in the design process by listening and addressing their concerns as well as their guardians'[2][3].

As environmental issues and concerns regarding these issues become more mainstream, it is crucial to mention sustainability practices whenever possible. As mentioned in the interviews, Karel spends valuable effort to provide devices that address sustainability issues by their design. In the interviews it is reported that BLE technology is a crucial and innovative solution to reduce energy and power consumption (See section 5.4). Although these devices mostly consist of smart meters and sensors that improve energy efficiency, the company ignores practices such as waste management and recycling. It is important to note that the smart devices and the sensors usually have difficult recycling processes, some of them are not recyclable at all [21]. Furthermore, some sensors may contain waste that is toxic [32]. Due to these environmental problems posed by smart devices, companies should be able to deal with these risks by coming up with creative sustainability-by-design solutions [3][4]. In this context, Karel can further expand their assessment in terms of waste reduction and waste recycling. Thus, despite promoting more sustainable energy use practices, Karel fails to address the whole of the term sustainability. It can be said that the company does not discuss environmental issues when referring to sustainability. The notion of sustainability should also be considered from an ecologic standpoint and the offered solutions should consider the preservation of nature. Apart from this, although energy efficiency has a positive effect in terms of sustainability, it was also observed that the motivations for developing this technology were not purely due to ecological concerns, but at the same time, this requirement was due to economic concerns. As such, motives for developing the said technology might

have an impact on the effectiveness of sustainability practices when developing new technologies, causing the developers to focus more on profit rather than ecological concerns. As a result, this motivation can later cause value tensions and moral dilemmas between economy and sustainability, which is not a desired situation in terms of VSD [3][4]. Overall, regarding sustainability Karel seems to be more successful in integrating it to its designs during the innovation process. However, it is still possible for the company to start considering sustainability in a deeper sense, in terms of preventing environmental impacts.

6.2. Conclusions

In this project, Karel Electronics, one of the leading companies in IoT-based solutions in Turkey, was examined through VSD. The engineers working on Karel's smart home technologies were contacted and interviews were conducted with them. Questions about how the company integrates some emerging values related to smart home platforms into their designs were directed to the interviewees. They were asked how they took steps to innovate responsibly while developing and designing technology. There are risks that can be created by the systems and platforms that the company has developed and designed specifically for smart home technologies. There are risks such as data security breaches, privacy attacks, and high energy consumption, and Karel takes steps to manage these risks. Despite this, it was observed that the company did not bring creative and innovative solutions to all of these problems. One of the responsible innovation shortcomings we identified is that the company prioritizes functionality and efficiency over privacy and user experience. Apart from that, as far as we understand from the company's approach to the privacy issue, Karel does not approach transparency as a solution. As for sustainability, it has been determined that Karel acts responsibly. With the Bluetooth Low Energy technology they use, they have succeeded in establishing a platform that consumes less energy and thus consumes fewer resources. They integrated the value of sustainability in the design process in a responsible and anticipatory manner.

In order to increase innovative solutions in the company, Ata and Atakan’s senior project team which works collaboratively with Karel have considered the previously mentioned values in advance to create a technology that encompasses the values that are essential for the stakeholders. As a solution, the team has decided to use Bluetooth Low Energy (BLE) Mesh technology which needs significantly less energy from the devices in order to cultivate a sustainable environment in terms of both the energy efficiency and the longer lifespan of the product. This in turn leads to sustainability by the design of the product. Also, this technology already has an innate high-security protocol which is called provisioning protocol that makes the network significantly secure. Furthermore, the system has privacy keys that protect the information of the users from any outside attacks by obfuscating the message and making it impossible to track the source address. Thus, it is suitable for Karel’s current values as well as other stakeholders’ values. Also, using a mesh system makes the network dynamic which means the routing of data dynamically changes. Apart from that in order to enforce transparency by design, the team is currently setting the framework for enabling users to know how their data is used in the network through a mobile app, and with an easy-to-use user interface, users will be able to easily interact with the smart home without any prior technical knowledge which will minimize any shift in any house or gender dynamics and increase democracy.

In general, Karel Electronics, considering that it is one of the leading technology companies in Turkey, can go further in broadening values in terms of user experience and

feedback, transparency, and privacy. In our article, we touched on the need for the company to focus more on these values and made suggestions on how the company can move forward in these areas. When looking through the lens of VSD and examining the findings of the project and the background research, it was determined that the company could expand its current assessments especially on privacy, democracy and transparency issues, listen to stakeholders better and go further on stakeholder involvement and user feedback.

7. Credits

The introduction part was written by Pelin and Başak. The Theory section was written by Başak. The sources for the background research were found collectively as a group. The Background Research sections were written by Atakan and Ata. In the first interview, Pelin, Atakan, Ata, and Başak were the interviewers. In the second interview, all team members were present as the interviewers and the third interview was conducted by Ata and Atakan only. First interview was translated and transcribed by Yaren. Second and third interview was translated and transcribed by Başak. Coding of the interviews were done by all of the group members. The Methods section and the Findings section were written by Yaren and Pelin. The tables inside the Findings section were created by Yaren and Pelin. Organization of the findings section is done collectively. The Analysis and Conclusions section was written by Başak, Atakan and Yaren. The Credits section was written by Pelin and Yaren. Formatting of the report is done by Başak and Atakan.

8. References

[1] J. Davis and L. P. Nathan, “Value sensitive design: Applications, adaptations, and critiques,” *Handbook of Ethics, Values, and Technological Design*, pp. 11–40, 2015.

[2] I. van de Poel, “Design for values in engineering,” *Handbook of Ethics, Values, and Technological Design*, pp. 1–20, 2014.

[3] I. van de Poel, L. Asveld, S. Flipse, P. Klaassen, Z. Kwee, M. Maia, E. Mantovani, C. Nathan, A. Porcari, and E. Yaghmaei, “Learning to do responsible innovation in industry: Six lessons,” *Journal of Responsible Innovation*, vol. 7, no. 3, pp. 697–707, 2020.

[4] *The Dutch approach to responsible innovation and value sensitive design*. Youtube, 2014.

[5] Maalsen, S. (2020). Revising the smart home as assemblage. *Housing Studies*, *35*(9), 1534-1549.

[6] D. Hendriks, “The History of Smart Homes,” *IoTEvolution.* 22-Apr-2014. [Online]. Available: https://www.iotevolutionworld.com/m2m/articles/376816-history-smart-homes.htm [Accessed: 06-Dec-2021].

[7] “Echo IV,” *Wikipedia*, 16-Aug-2021. [Online]. Available: https://en.wikipedia.org/wiki/ECHO_IV. [Accessed: 06-Dec-2021].

[8] “What is the internet of things, and how does it work?” *IBM Business Operations Blog*, 28-Aug-2020. [Online]. Available: https://www.ibm.com/blogs/internet-of-things/what-is-the-iot/. [Accessed: 06-Dec-2021].

[9] El-Basioni, B. M. M., Abd El-Kader, S. M., & Eissa, H. S. Independent living for persons with disabilities and elderly people using smart home technology. *International Journal of Application or Innovation in Engineering & Management (IJAIEM)*, vol. 3, no. 4, pp. 11-28. April, 2014.

[10] Blumendorf, M. (2013). Building sustainable smart homes. In Proceedings of the First International Conference on Information and Communication Technologies for Sustainability (ICT4S’2013), pp. 151–158.

[11] S. Davidoff, M.K. Lee, J. Zimmerman, and A. Dey, “Socially-aware requirements for a smart home,” presented at the Proceedings of the International Symposium on Intelligent Environments, pp. 41-44.

[12] Pira, S. (2021). The social issues of smart home: a review of four European cities’ experiences. *European Journal of Futures Research*, *9*(1), 1-15.

[13] B. K. Sovacool, M. Martiskainen, and D. D. Furszyfer Del Rio, “Knowledge, energy sustainability, and vulnerability in the demographics of smart home technology diffusion,” *Energy Policy*, vol. 153, pp. 112196, 2021.

[14] “Healthy Social Dynamics: Smart homes can put stress on family life,” *Candle*. [Online]. Available: https://www.candlesmarthome.com/healthy-social-dynamics. [Accessed: 06-Dec-2021].

[15] D. D. Furszyfer Del Rio, B. K. Sovacool, and S. Griffiths, “Culture, energy and climate sustainability, and Smart Home Technologies: A mixed methods comparison of four countries,” *Energy and Climate Change*, vol. 2, p. 100035, 2021.

[16] J. van Hoof, G. Demiris, and E. J. M. Wouters, *Handbook of Smart Homes, health care and well-being*. Cham: Springer International Publishing, 2020.

[17] L. Nicholls, Y. Strengers and J. Sadowski, “Social impacts and control in the smart home.” *Nature Energy*. vol 5. pp. 1-3. 10.1038/s41560-020-0574-0. 2020.

[18] S. Shelton, “Overcome the smart home gender gap,” *Builder*, 09-Aug-2016. [Online]. Available: https://www.builderonline.com/products/home-technology/overcome-the-smart-home-gender-gap_o. [Accessed: 06-Dec-2021].

[19] Furszyfer Del Rio, Dylan & Sovacool, Benjamin & Martiskainen, Mari. (2021). Controllable, frightening, or fun? Exploring the gendered dynamics of smart home technology preferences in the United Kingdom. Energy Research & Social Science. 77. 102105. 10.1016/j.erss.2021.102105.

[20] Geneiatakis, D., Kounelis, I., Neisse, R., Nai-Fovino, I., Steri, G., & Baldini, G. (2017, May). Security and privacy issues for an IoT-based smart home. In *2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (pp. 1292-1297). IEEE.

[21] Virt-Eu, “Ethics beyond data: How does IoT challenge our perspective on data ethics?,” *Medium*, 21-May-2019. [Online]. Available: https://medium.com/@VIRT_EU/ethics-beyond-data-how-does-iot-challenge-our-perspective-on-data-ethics-df6952745adc. [Accessed: 14-Oct-2021].

[22] “Smart home: Threats and countermeasures,” *Rambus*, 05-Mar-2020. [Online]. Available: https://www.rambus.com/iot/smart-home/. [Accessed: 06-Dec-2021].

[23] M. Reddigari, “The 10 biggest security risks in today's Smart Home,” *Bob Vila*, 07-Oct-2019. [Online]. Available:

https://www.bobvila.com/slideshow/the-10-biggest-security-risks-in-today-s-smart-home-53081. [Accessed: 06-Dec-2021].

[24] T. Riley, "The Cybersecurity 202: Smart home devices with known security flaws are still on the market, researchers say," *The Washington Post*, 04-Feb-2021. [Online]. Available: https://www.washingtonpost.com/politics/2021/02/04/cybersecurity-202-smart-home-devices-with-known-security-flaws-are-still-market-researchers-say/. [Accessed: 06-Dec-2021].

[25] C. Perera, C. McCormick, A. K. Bandara, B. A. Price, and B. Nuseibeh, "Privacy-by-design framework for assessing internet of things applications and platforms," *Proceedings of the 6th International Conference on the Internet of Things*, 2016.

[26] A. Chakravorty, T. Wlodarczyk, and C. Rong, "Privacy-Preserving Data Analytics for Smart Homes." *Proceedings of IEEE CS Security and Privacy Workshops*, SPW 2013. pp. 23-27. 10.1109/SPW.2013.22. 2013.

[27] T. Anscombe, "IoT and Privacy by Design in the Smart Home," ESET, Bratislava, Slovak Republic, 2018 [Online]. Available: https://www.eset.com/us/business/resources/white-papers/iot-and-privacy-by-design-in-the-smart-home/

[28] A. Cavoukian and K. Kursawe, "Implementing privacy by design: The smart meter case," *IEEE International Conference on Smart Grid Engineering (SGE'12)*, 2012.

[29] C. Watts, "Smart Home Technology for a sustainable lifestyle," *Control4*, 15-Jan-2021. [Online]. Available: https://www.control4.com/blog/607/smart-home-technology-for-a-sustainable-lifestyle/. [Accessed: 06-Dec-2021].

[30] C. Links, "How smart homes can deliver sustainability as a service," *Microwaves & RF*, 03-Mar-2017. [Online]. Available: https://www.mwrf.com/technologies/systems/article/21848145/how-smart-homes-can-deliver-sustainability-as-a-service. [Accessed: 06-Dec-2021].

[31] M. LaMonica, "Will smart home technology systems make consumers more energy efficient?. " *The Guardian.* 22-Jan-2014. [Online]. Available: https://www.theguardian.com/sustainable-business/smart-home-technology-energy-nest-automation. [Accessed: 06-Dec-2021].

[32] T. Perry, "Why Are Smart Homes 'Bad'? 19 Disadvantages To Consider," *Smart Home Point*, 11-Feb-2020. [Online]. Available: https://www.smarthomepoint.com/disadvantages/. [Accessed: 06-Dec-2021].

[33] F. Noh, "Sustainability Begins at (the Smart) Home," *Jabil*. [Online]. Available: https://www.jabil.com/blog/smart-home-sustainability.html. [Accessed: 06-Dec-2021].

9. Appendix

Interview 1 with Design Team Leader

1. **Please tell us about smart home technologies that Karel is developing. What are the latest developments in smart home technology?**

   The most critical issue in smart home technologies is to create a platform. The creation of this platform is not simple enough to be monopolized by a single company. Why am I saying this? Bosch, Samsung, these companies have tried before and they have seen that it will not be possible without an ecosystem. Therefore, moves are being made to create a platform at work in Turkey, where Arçelik is one of the most important players. Karel is in a position to theoretically talk about some basic points in the R&D layer in order to develop this ecosystem with them. We've been talking for the past year and a half. After creating a smart home platform, what I mean by platform is that the devices must be able to talk to each other, for this there must be a common protocol, and then they must be able to send and receive data to each other. This is actually an infrastructural situation. Of course, you have to feed it with something like a market base and put the product plus the software related to them. What kind of things are we going to head towards here, here we are going to work towards the integration of points that are frequently used at home, such as smart plugs and lighting products, into such a platform. One of our important research topics is positioning inside the house or building, this is of critical importance. In the coming period, we will be moving forward to productize our research here. Another important issue is that the old age population will be the growing problem of the world, forgetfulness or some neurological diseases are also coming, and this results in people needing care at home. One of the most efficient methods of this care is to support people with sensors. We will also be taking action in this direction. Of course, when we consider this whole, one of the most critical points is data security. In other words, for IoT devices- unfortunately, the IoT has not been fully in Turkey yet. We are gradually seeing examples of these abroad as well. In other words, infrastructures where generations communicate directly with each other. But it definitely needs to be done from an encapsulation, security perspective. Otherwise, some attacks can cause worldwide damage. For this reason, the important issue is data security and how to share data related to it, in which we will be involved. Finally, one of the important issues that we focus on is to advance some electronic design activities with a number of futuristic projects in order to integrate sensors into such places, which we frequently use on these wet floors, such as sinks, toilets, bathrooms.

2. **Question about applications and users. For example: What are the main applications for this technology (if not covered in the answer: Who are the main users?).**
   - **Who is the targeted audience? (i.e, Elders, Males, Females, etc.)**

- **What are the targeted applications? (i.e, Tracking, Security, Sustainability, etc.)**

Our research draws the conclusion that we need to focus on two main axes. One is aged care, and the second is energy efficiency. We have directed our work towards these two main axes. Therefore, our target group is the elderly, but I would say indirectly their guardians. Because the elderly do not use mobile applications or the tracking system, doctors or their children or relatives at work will use these products. So there is a small ecosystem. It will also be more comprehensive on the efficiency side, energy efficiency. There, what we look at in terms of social interaction - actually, this comes to us from requirements - firstly, following the elderly with physical sensors, and secondly, providing peers or people they can contact with in the world where they are lonely is the priority. In order to relieve that loneliness, there is a call machine that they can communicate with when they touch with their hands, and live human voices will be able to talk to them. Again, it is among the topics discussed in terms of social content. And the thing is, storing the data properly is very critical in these IoT studies.

3. **What are the risks associated with smart home technologies?**
    - **security: Do you consider security to be a main concern?**
    - **privacy: Is privacy one of your concerns?**
    - **sustainability (recycling, energy efficiency etc.)**
    - **addressing social issues (gender inequality, family dynamics etc.)**
4. **What adjustments have been made (or will be made) to smart home technologies in response to user/stakeholder concerns?**

Now, since our positioning as a company is SMEs or large-scale companies, serious sensitivity comes before us in terms of data security. Of course, Karel also has corporate customers. Especially corporate customers coming from the public sector put a very serious emphasis on data security. For this purpose, we positioned the data center within ourselves, so the data stays in a closed loop with us. There is no outside going anywhere, and we are aware that, I say this often, data is actually the oil of the coming period. It will be precious. Especially the data generated from IoT devices will have an important place among them. When you produce it by touching people, it becomes even more valuable. Because you can make sense of the data that seems meaningless today by establishing relationships with each other tomorrow. Therefore, the needs that come to us are especially about the security of data from the public level. It is important to keep them local, not to open them, and to consult them when they are opened.

5. **Could you elaborate on ways that Karel addresses sustainability through the technological designs and organisational practices?**

Now the key point for sustainability is process. If the process areas are properly defined and the infrastructures related to the process areas are used properly, then sustainability can be discussed in the company. The most important of these is CMMI, which is also applied around the world. Karel has CMMI level 3 certification and it

continues to be updated, so these process steps are applied as ordered. Of course, while applying the process steps, one of the important points for sustainability is configuration management, that is, the continuation of your work under proper version control. The second is the change management system. In other words, the work you do is subject to change under the record. Here's what it brings: you wrote a code, three days later someone comes, it will be maintained because it has a history and he puts history on it. All of these are sustainable when they are controlled by defined processes. But of course, what is needed in addition, in today's conditions, the financial power of companies is also required. Why, because if the company that exists today does not exist tomorrow, it becomes extremely dangerous in terms of sustainability. Karel is a company that has invested heavily in terms of both its financing power and the implementation of this process. It continues to update these investments, so this is not specific to just one project, but sustainability is important for us across all projects.

6. **What is the future for smart home technologies? How do smart home technologies fit into the future societies and home dynamics?**

   Now the future is fiction, different generations are also joining the business life. It was Z then it would be Alpha. The future fiction will move towards a plane that is more accustomed to using it with a rental model, rather than buying and using things, especially with these generational changes. This will also be reflected in household goods, and this generation that I am talking about was born connected to the world in a way, growing connected, that is, they were always in data exchange with the ecosystem. They will carry this expectation to household goods as well. Therefore, it is expected that household goods or any part of the house must have had a share of this digitalization. With this share, certain verticals will come to the fore. One of these verticals will be energy efficiency. Here, you can already see that energy is limited in the upcoming period. For energy efficiency, there will be digitalized sensor pads at many points, from these heater cores and valves to the on-off buttons of electric light bulbs. In addition, we have already talked about the elderly. Efficient heating and cooling systems will be very, very important. And, as I mentioned at the beginning, another important issue in this new plane will be security. Because all the data in your home will actually be data about your privacy. And with a little more processing of this data, more optimal devices will be designed. If you say what comes next, the devices at home producing bitcoins, we will probably see this in the near future. With these bitcoins, the creation of hot wallets, where you can do at least small shopping at home, may also be applications that we can see in the near future.

<u>Interview 2 with Embedded Software Engineer</u>

1. **Please tell us about smart home technologies that Karel is developing. What are the latest developments in smart home technology?**

We have many projects that we do over smart home systems and IoT. There are projects developed for patient care at home. For example, we have started conversations about what it is, where a person in the house is located, and what activity he does, that is, how information such as falling situations are obtained through sensors, but we have not developed a product for this yet. But we follow what other companies are doing in the market. Products are developed especially within the scope of smartwatches. There are also projects on a larger scale, for example, the number of people working in factory environments, and how they are followed up. These enable smart home systems to be located on larger scales and research and development for it. We follow all this. There are innovative ideas like these, but there is no project we have realized yet.

2. **Question about applications and users. For example: What are the main applications for this technology (if not covered in the answer: Who are the main users?).**
    - **Who is the targeted audience? (i.e, Elders, Males, Females, etc.)**
    - **What are the targeted applications? (i.e, Tracking, Security, Sustainability, etc)**

    If you think of Karel as a whole, the marketing side of the company is located in Istanbul, the R&D side is in Bilkent, and the production side is located in the Ostim Organized Industrial Zone (OSB). Since we have our field of use in OSB, we enable them to be developed in the factory. Because we have an environment ready, many companies in the market need it. Let me put it this way, we already use IoT for a lot of smart devices to communicate with each other. For this, you can collect the data of a smart device equipped with a sensor that concerns the curious part in any production line with IoT communication, and get this data if you want to observe and analyze what you want. We are mostly able to obtain data that will positively affect the production or workflow in large-scale areas.

3. **What are the risks associated with smart home technologies?**

    if the interviewee does not address the topics below, it might be a good idea to bring them up:

    - **security: Do you consider security to be a main concern?**
    - **privacy: Is privacy one of your concerns?**
    - **sustainability (recycling, energy efficiency etc.)**
    - **addressing social issues (gender inequality, family dynamics etc.)**

    When you say Internet, security comes first. It is now an environment where everything is shared, and every right or wrong information is spread. Therefore, there is the security of the data, and there is the security that others obtain the information you obtain. Let's first look at it this way. You will develop a product. You need to send the data in that product to the center safely before it is found. That data should be healthy without being manipulated by others or environmental conditions. This is primarily data security. Then think about it personally. You are trying to obtain data and collect it in the center, but this data may be your competitors or not necessarily

competitors, it may also be someone inside, these parties are trying to obtain this data. There are also leaks here. Communications like IoT's MQTT are evolving, but the security aspects are independent of them. Think of them as small-scale devices that transmit their information. Therefore, you have to communicate that data securely in that environment. That's why the priority is to get the right data long before security and to create a security layer on top of it. First, you need to get the data right. That data must also be secure.

4. **Could you elaborate on ways that Karel addresses sustainability through the technological designs and organisational practices?**

As a company that has been producing, developing products, and putting them on the market for years, there must always be an effort to obtain a sustainable product. In other words, if you produce something today, if it becomes unusable after two days, then you will not be doing long-term work. We have to consider that every product we intend to release or will release is sustainable in the long run, both sufficient and successful. We sell our telephone exchanges nationwide. For example, I have been working in this company for fourteen years. The sale of them, their positioning in the field, their development, and technological additions to each of them, in fourteen years from before, ensure that these products are sustainable. Therefore, when you produce a product, it also requires it to be adaptable to today's conditions. We consider these.

5. **What adjustments have been made (or will be made) to smart home technologies in response to user/stakeholder concerns?**

I can't say much based on IoT. As far as I know, there is no feedback on devices on IoT. I can say that. While we are developing another product, we do not take it to the field, but we know the expectation of the field, so we develop the product accordingly. But there is a difference here. This is developing a product according to the demands of the field. In other words, the customer requests from us and we make this device. During this time, you only do what you want. We do not subject it to field conditions, and what happens to the customer when he actively uses the device in the field is only up to your test team. Therefore, when you take a product to the field, you have to improve it and correct its mistakes. In the feedback part, the customer may not be completely conscious sometimes. Sometimes he is not aware of what he wants and how it will really benefit him, and he can also harm. What I mean by damage is that it costs time, so it takes longer to do a job, but this time it feels like it. For example, he wants to press five keys to do a job, and you do this by pressing five keys. When the product itself arrives, it gives feedback that it would be better if I did it with two keys instead of five. In this case, we have to make a change. The interrelationship here emerges when you start selling the product. Remember that the first products of many big companies come to their customers with a lot of mistakes and a lot of non-user-friendly structures. But these deficiencies do not arise because they say it should be like this on him. Companies work on those products for months and years

and offer them to the customer, but the customer does not accept them. This is the R&D process. The innovation process is different, it's a bigger process. An example of this is the iPhone. While everyone is using a push-button phone, the emergence of the iPhone is a huge change, an innovative change. There is no demand or request from the customer while developing that product because the customer does not have such a world. When you present your product as innovative, you are telling what the customer will use and how they will use it. Then your feedback becomes even more different. The hard part of innovation is here because you are developing a new product and this product has a new usage area, the customer does not know how to use it.

If a product you produce is a better version of a product in the field or if it will be the same, that product is already used by certain customers in the field and its deficiencies have been revealed. So you have to offer better improvements, better options against them. This is the customer's expectation and feedback. But things change when you do something brand new. For example, you are going to present a product to the field, but there is already a lot of field from that product. The new features will add value to it, that is, it will be profitable and preferable. But if you do the same thing, you will not meet the expectation. Therefore, remaking some products in the field is not innovative, but it also requires an R&D process to improve it. That feedback happens when you go to the customer and ask, and it is the product you sell yourself or the product sold by another company. You study them, you read the comments. Of course, these works are done by the marketing and sales units. They know the heartbeat of the field, and they see what it has evolved into. For example, there is a generation gap between the people working in the company and the top management of the company. The people in management grew up without the internet, and many young people working in the firm grew up with the internet. Even this makes an incredible difference in terms of expectations and users. In other words, when the management takes over a product, the expectation from the product becomes the environment in which it develops. For young people, the situation is different. If the product does not have a Facebook, Twitter integration, they may not find this product successful. Of course, I'm talking about mobile phones. There is a customer that you can get feedback from and you have the opportunity to get feedback from this customer. But there is also a portfolio of customers who may come to the field later. Therefore, it is necessary to determine a target audience so that you can ask them about the criteria. If you do not have a target audience, you will not be thinking about the customers who will use it in the future while developing a product. We talked about sustainability before, and we can come back to that here. A future customer should also use this product in the future, if the device is not sustainable, we cannot talk about it. Apart from that, we use tools such as surveys and contests to get feedback, just like many other companies. Our marketing department does these activities.

6. **What is the future for smart home technologies? How do smart home technologies fit into the future societies and home dynamics?**

Let's classify users as over 40 years old, over 30 years old, over 20 years old, and over 10 years old. Like the X, Y, Z generations. With every 10 years of age, technology addiction is increasing. In the past generations, it was possible to live without technology at all, but now we cannot live without technology. However, it can be lived, but technology speeds up our lives and reduces time losses. The biggest benefit of technology is time. This is what IoT devices will bring in the future. It is faster for you to take data and process it and reach a conclusion. What could it be otherwise? For example, if we wanted to measure the temperature of a room, how would we measure it? We used to assign a man, he would hold a thermometer all day and at the end of the day, he would tell you how the temperature changed throughout the day. But the IoT device already does it in seconds. It can process and analyze temperature in seconds. IoT will develop because you will not want to turn on the air conditioner when you go home, the television will turn on automatically when you enter the house, you will see how much you have spent on the combi boiler. Currently, many companies are working on IoT devices that allow us to be aware of how many of the products in the cabinet are healthy and what deficiencies there are at home when you go to the market. IoT devices will do all of this, and this technology will expand even more. But everyone can answer the question of whether we need them differently. This will change over time, in the future, as one uses this technology, the other will want to use it, and in this way, it will become widespread. This is how the market will manipulate it. It will be used as we see the time gain of IoT in terms of time. Everyone resists change at first. This is inertia. You apply force to make something stationary move, and you apply force to stop something that is moving. The people who will apply this power are the users of this technology because IoT is a very large area, these are the devices that communicate on the internet. Why it communicates, for what purpose it communicates, is such a vast subject that when you reduce it to home, you say personal user. These devices will make improvements in your life. It needs improvement. If it doesn't improve, if there is a cheaper alternative, your product will not be sustainable and will expire. Therefore, the profit provided by IoT devices must be valid both in terms of money and time, so that it is sustainable and can be used by everyone. To give an example of mobile phones, it has so many benefits that you can ignore its price. It is difficult to buy a phone in the upper segments in our country, but everyone buys it because everyone wants to benefit from that profit. If you can provide this gain to people in IoT devices, then it will be usable.

Interview 3 with Senior EEE Student

1. **Please tell us about smart home technologies that Karel is developing. What are the latest developments in smart home technology?**

After Bluetooth 4.1, as far as I remember, there is this new technology called Bluetooth Smart, which is also known as Bluetooth Low Energy (BLE), and by using BLE, we realize that by using BLE meshes in smart home technologies, we can

develop more sustainable and efficient smart home systems. This is why we started developing such a system in the first place as Karel.

2. **Question about applications and users. For example: What are the main applications for this technology (if not covered in the answer: Who are the main users?).**
    - **Who is the targeted audience? (i.e, Elders, Males, Females, etc.)**
    - **What are the targeted applications? (i.e, Tracking, Security, Sustainability, etc)**

   This is for daily usage, for consumers in general. It has no specific audience to be exact. It is mainly for homeowners. We can say homeowners, it is not age dependent when we look at the demographics

3. **What are the risks associated with smart home technologies?**

   if the interviewee does not address the topics below, it might be a good idea to bring them up:

    - **security: Do you consider security to be a main concern?**
    - **privacy: Is privacy one of your concerns?**
    - **sustainability (recycling, energy efficiency etc.)**
    - **addressing social issues (gender inequality, family dynamics etc.)**

   We definitely consider privacy. That is why we are building our system in a way that there is no information leakage, at least no important information leakage. Our main concern is reducing energy consumption and increasing people's welfare. By reducing the workload of the people, because when we are building a smart home system, people are not supposed to take care of their own homes, it will be automated. So as things are automated you will have more time and more focus to spend on other daily things.

   As far as I know, there are no serious concerns that people should be worried about. However, one of the problems may be privacy because today, information is worth a lot. If you manage to steal someone's information from the metadata, you can learn so much about those people using Machine Learning algorithms. Because of that our main concern is making a safe and private system so that there is no information leakage. At this moment we are not dealing with security, we are more concerned with people's welfare and how comfortable they feel in their own houses. But if we decide to work more on the project, we can add more security aspects to the project as well, but it is not our prior concern.

4. **Could you elaborate on ways that Karel addresses sustainability through the technological designs and organisational practices?**

   Sustainability is a serious concern. When it comes to engineering there are two important aspects that engineers should be concerned about. One of them is the power

consumption especially for electrical engineers. The other one is ethical considerations and the functionality maybe. Functionality is more of a fundamental objective because without functionality you cannot sell the product in any way. As a downside of this we see that in many of the engineering products, the efficiency is most of the time not considered properly and because of that high energy consumption causes the world to have many environmental problems. This should be an engineer's consideration when they are developing a product in any field. So, I think that sustainability is one of the most important ethical concerns.
Smart home technologies are being developed all over the world and it is a really common practice. However, we are developing it from the beginning due to sustainability issues. BLE as its name explains is a low energy consuming product and because of that when you are switching to a smart home system, there are two upsides of this. One of them is BLE and due to the automation of the system you are consuming much less energy and that is important when you look at the big picture. As a world trend, if we start to use less energy in more of the technologies, maybe we can use renewable and sustainable energy sources like solar and hydropower instead of using fossil fuels etc.

5. **What adjustments have been made (or will be made) to smart home technologies in response to user/stakeholder concerns?**

   As we mentioned before, the target audience is very wide for this technology. Because of that, our fellow colleague who is working on the front-end, is working on it in such a way that it is applicable by anyone. It is so simple that anybody can use this technology with no knowledge of how to use smartphones like elder people or very young children or adults. As this project is not age dependent, we would like to make such an interface so that people will easily use it and will easily adapt to this system.

6. **What is the future for smart home technologies? How do smart home technologies fit into the future societies and home dynamics?**

   I think that the future smart home technologies will be in such a way that people will stop considering what is going on in their houses. If something is measurable, it will be added to the system. Right now what we are considering is mainly most common objects like temperature controlling using an AC maybe or home positioning, finding your location in the house.