Integration of sensors in the smart homes of tomorrow – possibilities and limitations

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MASTER THESIS

Integration of sensors in the smart home of tomorrow - possibilities and limitations

Exploring the implementation of sensor technology in the smart home

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Abstract

It is estimated that in 2020 there will be more than 20 billion connected devices around the world. Hardware keeps getting smaller and microprocessors and communications modules can be found in all manner of products. On the software side, voice assistants are getting more intelligent by the day, with smart speakers being promoted as a natural part of people's future homes. However, for these products to really become intelligent, they need to be aware of their surroundings. This is solved by implementing sensors.

Bringing sensors inside people's homes might seem trivial, but how do people react to bringing this kind of technology inside their homes? Why should they have it and what issues might exist in incorporating sensor technology in household items?

By performing qualitative user studies comprised of interviews and observations, insights about how sensors should be implemented were gathered. Interviewees were also asked about some of their everyday problems and needs, which was used to provide examples of what household needs could be solved through sensor implementation. In combination with expert consultation and literature studies regarding technological limitations, this gave an understanding regarding how and why sensors will be a natural part in the smart home of tomorrow.

Apart from examples of sensor implementation in product concepts, key findings regarding subjects such as personal privacy, big data handling and product life-cycles are presented and guidelines for how these issues can be handled are proposed.

Keywords: Internet of Things, Smart Home, Sensors, Human-Machine-Interaction, Smart Devices, IKEA TRÅDFRI, IKEA Home Smart

Sammanfattning

Uppskattningsvis kommer det år 2020 att finnas fler än 20 miljarder uppkopplade produkter runt om i världen. Hårdvarukomponenter blir allt mindre och mikroprocessorer och kommunikationsmoduler kan hittas i alla möjliga produkter. Inom mjukvaruutvecklingen blir röstassistenter mer intelligenta för var dag som går och smarta högtalare presenteras som en naturlig del av människors framtida smarta hem. För att dessa produkter verkligen ska bli intelligenta så måste de vara medvetna om sin omgivning, något som sensorer kan lösa.

Att introducera sensorer i människors hem kan ses som en trivial sak, men hur reagerar folk på den här typen av teknologi i sina hem? Vad ska de ha den till och vilka problem kan uppstå när man inkorporerar sensorteknologi i hushållsprodukter?

Genom kvalitativa användarundersökningar, bestående av intervjuer och observationer, samlades insikter kring hur sensorer bör implementeras. Intervjuobjekten frågades även ut om problem och behov i vardagen, vilket användes för att exemplifiera vilka vardagsbehov som kan lösas genom sensorimplementering. I kombination med expertkonsultationer och litteraturstudier kring teknologiska begränsningar gav det en förståelse för hur och varför sensorer kommer vara en naturlig del av framtidens smarta hem.

Utöver exempel för sensorimplementering i produktkoncept presenteras även huvudinsikter kring ämnen som personlig integritet, hantering av big data och produktlivscykler samt riktlinjer för hur dessa problem kan hanteras.

Nyckelord: Sakernas internet, Smarta hem, Sensorer, Människa-Maskin-Interaktion, Smarta enheter, IKEA TRÅDFRI, IKEA Home Smart

Acknowledgments

During this project, we have had the help of many different people in tasks both great and small. These people are too many to list individually but we would like to acknowledge some of the people who have helped us the most during these 20 weeks of work.

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We also want to thank Per-Erik Andersson, our supervisor at Lunds Tekniska Högskola, for his support in the project.

Thank you to everyone who participated in our user survey through interviews and observations - your insights were essential for this project.

Lund, June 2018

Erik Karud and Jesper Lindberg

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1 Introduction

In this chapter the areas to be examined in this project are introduced. Key definitions as well as the background of the project, the problem definition and project delimitations are presented. Furthermore, a brief description of the provider of the task, IKEA, and the research questions which the thesis is based on are introduced.

1.1 Definitions

As this thesis will revolve around certain key terms, it is important that these are clearly defined as to how they are used in this report. This section presents these key definitions.

1.1.1 Sensors

According to Merriam-Webster (2018), a sensor can be defined as "a device that responds to a physical stimulus (such as heat, light, sound, pressure, magnetism, or a particular motion) and transmits a resulting impulse (as for measurement or operating a control)". Fraden (2010) states regarding this definition that it is broad and "covers almost everything from a human eye to a trigger in a pistol" (p.1). This thesis will instead follow the definition proposed by Fraden (2010) and presented as:

A sensor is a device that receives a stimulus and responds with an electrical signal.

In this definition, a stimulus is described as "the quantity, property or condition that is received and converted into an electrical signal" (p.2). Furthermore, this definition allows the differentiation of a sensor from that of a transducer, the latter being a converter of any type of energy into another.

1.1.2 Smart home

There is no fixed definition of what a *smart home* is today, instead several different versions can be found claiming to define a smart home. One definition is presented by Gram-Hanssen and Darby (2018) as:

A smart home is one in which a communications network links sensors, appliances, controls and other devices to allow for remote monitoring and control by occupants and others, in order to provide frequent and regular services to occupants and to the electricity system.

For the scope of this thesis, this definition works well to define certain key elements which will be essential to the project such as the linking of devices and remote control and monitoring. However, the final statement saying "[...] in order to provide frequent and regular services to occupants and to the electricity system." was deemed non-essential for this project. Therefore, a shortened version of the definition by Gram-Hanssen and Darby (2018) is presented as the definition this report follows:

A smart home is one in which a communications network links sensors, appliances, controls and other devices to allow for remote monitoring and control by occupants and others.

1.1.3 Smart devices

In the report by PwC (2018) *smart devices* are defined as:

We use the term to refer to everyday objects and devices that connect to the internet and to each other; not computers, smartphones, or tablets. Smart devices often connect to apps on mobile devices, allowing users to control them remotely. [...].

Here, a key observation is that smart devices do not include computers, smartphones or tablets as these are instead referred to as mobile devices. This definition also correlates well to that of the smart home as both definitions emphasizes the connection between different smart devices and the possibility for remote control.

However, for this thesis a small change is proposed in the definition to allow for a wider interpretation of smart devices: An internet connection should not be a requirement for a smart device as one can argue that a smart home can be created using smart devices which only communicate locally and to each other. Thus, a slightly different definition is proposed for the sake of this project:

We use the term to refer to everyday objects and devices that connect to the internet ***and/or*** *to each other; not computers, smartphones, or tablets. Smart devices often connect to apps on mobile devices, allowing users to control them remotely.*

A smart device is often connected to mobile devices, enabling remote controlling and more in-depth control of the functionality of the device. Certain smart devices,

such as smart speakers (e.g. Amazon Echo, Google Home or Apple HomePod) allows interaction through voice control and do not rely completely on mobile apps to enable functionality.

1.2 Background

1.2.1 The Smart Home

One may argue that a part of human nature is to always look for ways to simplify and streamline tasks which are considered dull and difficult. Nowhere is this more true than in our homes. This became more apparent than ever in the 1900s as machines started to become available which took care of laundry (washing machine), dishes (dishwasher), cleaning (vacuum cleaner), etc. As these machines now have become household items, their status as revolutionizing is ever diminishing.

The next step in the home streamlining evolution is the introduction of the smart home, first presented as a concept by American Association of House Builders in 1984 (Harper, 2003). Throughout the last decades, the term Smart Home has become more and more well-known. In a recent study performed by PwC in the US, 81 % of the respondents were familiar with the concept of a smart home device and one in four US internet users currently own a smart home device, see Figure 1.1 (PwC, 2017).

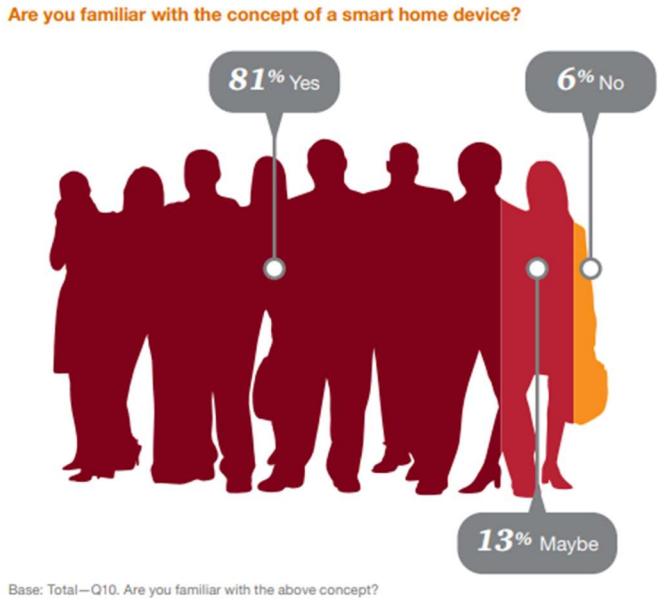


Figure 1.1 Familiarity of the smart home according to PwC (2017)

Research company Gartner predicts that 8.4 billion connected things will be in use in 2017 and that this number will reach 20.4 billion by 2020. Furthermore, the amount of installed consumer connected things will reach almost 13 billion by 2020 and thus account for roughly 63 % of the total market as opposed to the industrial use of connected devices. It is also estimated that the hardware spending of connected things among consumers will reach almost $1,5 trillion in 2020. (Gartner, 2017)

According to the study by PwC, price is the primary purchase barrier for smart devices as 42 % of the respondents provided this answer. 17 % stated that privacy and security of data was their purchase barrier. However, the respondents who currently own smart home devices are very satisfied with their devices and the corresponding mobile app with over 90 % claiming to be either very satisfied or somewhat satisfied according to the study by PwC. The study also highlights that 74 % of respondents who currently own a smart home device use their devices more frequently because it connects to their mobile devices.

During the last decade, an array of different smart devices have become available to consumers. With the rise of the smartphone as a tool available to practically everyone, the smart home devices can fully start to show their potential, providing its users with intuitive and simple controls which simplifies the user's everyday life.

1.2.2 Examples of smart devices

To give the reader insight into some of the popular product types on the smart home market, this section presents examples of these products.

IKEA TRÅDFRI

IKEA TRÅDFRI is a series of smart lighting products, consisting of smart light sources, remote controls, a motion sensor and the gateway which enables smartphone control of the light sources. Depending on the setup chosen, it allows its user to dim the light and either choose between three alternatives of white light or up to 20 different colors/shades of light. With the gateway setup, it is also possible to program your lights with wake up mode, vacation mode and timers (IKEA, 2018b). See Figure 1.2 for examples of TRÅDFRI products.

Nest Thermostat E

The Nest Thermostat E is a connected thermostat which allows you to control your heating from anywhere in the world through your smartphone, tablet or laptop. In addition, it allows for scheduling of temperature adjustments as well as an away-from-home setting which automatically lowers the temperature when nobody is at home (Nest, 2018a). Figure 1.3 shows a Nest Thermostat E.

Figure 1.2 IKEA TRÅDRFRI products (IKEA, 2018c)

Figure 1.3 Nest Thermostat E (Nest, 2018b)

Amazon Echo

Amazon's smart speaker Echo allows its users to instantly connect to Amazon's voice assistant Alexa through voice interaction. By saying Alexa, the smart speaker starts to listen for commands and the user can now ask Alexa to play music, control other smart devices in the smart home, get information about news, weather and more (Amazon.com, 2018). Figure 1.4 shows Amazon's smart speaker Echo.

Ring

Ring is a video doorbell that offers its users instant alerts on their smartphone, tablet or PC when a visitor rings the doorbell. Through the corresponding app, the user is then able to see, hear and speak to guests directly. The video doorbell comes with infrared night vision, weather-resistant design and does not require professional help to be installed (Ring, 2018). Figure 1.5 shows the video doorbell by Ring.

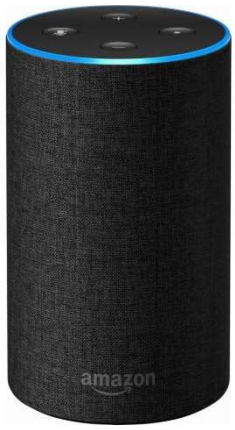


Figure 1.4 Amazon Echo (Amazon, 2018b)

Figure 1.5 Video doorbell by Ring (Ring, 2018)

1.2.3 Sensors

All of the human senses are to a certain extent able to be simulated by the sensor technology available today. Capacitive and pressure sensors for touch, microphones or vibration sensors for sound, cameras or IR-sensors for vision, etc. There are also sensors which can detect things that humans cannot, such as ultrasound or pH values. Translating the readings of these sensors allow us to better understand our environment and can allow us to avoid hazards or make better choices regarding our health and safety.

Many people associate sensors with technology of a high degree, but many sensors around us have become so ingrained in our society that we do not give them a second thought, even though they could be seen as science fiction just a few decades earlier. These sensors allow doors to open automatically, lights, taps and hand dryers to turn on and makes it possible to unlock our phones by just holding a finger against it. In addition to fingerprint readers, modern smartphones usually include sensors like gyroscopes, accelerometers, cameras, ambient light sensors and barometers. Even though most people do not realize it, sensors make their lives easier every day.

1.2.3.1 Sensor examples

There are many different sensors types available on the market today. Below follows a short description of a few common ones with the topics taken from Handbook of Modern Sensors by J. Fraden (2010).

1.2.3.1.1 Temperature sensors

Temperature sensors measure the temperature in their surrounding media and come in several different subtypes, such as thermistors and thermocouples. They are used in all manner of products such as air-conditioning systems and ovens where knowing the temperature is crucial for the product function.

1.2.3.1.2 Occupancy and motion sensors

The sensors of this category are used to detect the presence of an object or any movement that occurs in the sensor's detection field. There are several ways of detecting if an object is in the sensor's detection field and the optimal sensor type to use is dependent on what type of object that needs to be detected.

One of the most common sensors used in this type of application is the passive infrared (PIR) motion detector. These sensors detect the infrared radiation emanated from humans (and all other objects with a temperature over 0 K) and translates it into an electrical signal.

1.2.3.1.3 Position, displacement and proximity sensors

These type of sensors are used to determine the distance to an object from a set reference and are the most common type of sensor devices according to Fraden (2010). Depending on the reference, it is possible to detect whether things have moved from their set position or if the level of a substance has changed. There are many ways of detecting position and displacement, such as potentiometric, capacitive, inductive, magnetic and optical sensors, each with their own advantages and disadvantages.

If the output signal is triggered upon reaching a set distance, instead of giving a linear response as is common, you get a proximity sensor. This is among other things used in smartphones by implementing a light-sensitive sensor which detects when you put your phone against your ear to lock the screen. This prevents you from issuing commands by pressing your cheek against the screen.

1.2.3.1.4 Velocity and Acceleration

Measuring the velocity or acceleration of objects can be used in several clever ways, such as the screen rotation function of your smartphone or the triggering of airbags in a car crash. By combining several accelerometers together, it is possible to create a system which can determine an object's orientation in space by using gravitational pull as a reference.

1.2.3.1.5 Force, strain and tactile sensors

By using sensors which can register force or strain, it is possible to create product solutions that know where and with which amount of force an object is being manipulated. This could be used for diagnostic measurements, e.g. deciding the robustness of furniture by measuring the deformation caused by a certain weight upon it. It can also be used to allow robots to grip with a moderate amount of force as to not damage the object being handled, allowing more delicate tasks to be better automated.

There are several types of tactile sensors, the simplest being mechanical buttons like those found on a keyboard but capacitive touch sensors is something which is becoming ubiquitous as touch screens are all around us. Since these sensors do not require direct contact, they can be protected by other materials such as plastic screens, allowing for robust systems.

1.2.3.1.6 Pressure and acoustic sensors

Measuring the pressure from the surrounding environment, either absolute or relative to atmospheric pressure, can tell us many things. It is used to determine altitude and water depth, and can also be used to predict weather patterns and to calculate flow. In a home environment, it could be used to determine when doors or windows are opened or when appliances that use water are currently active.

Acoustic sensors are just pressure sensors which focus on detecting the intermittent patterns of sound waves, in contrast with pressure sensors which usually measure constant pressure levels or slow changes in pressure. Through clever programming, these sensors can be used to determine the presence of people in your home or even if someone is knocking on your door.

1.2.3.1.7 Humidity and moisture sensors

The amount of water vapor that exists in our surrounding air affects many things in our homes, such as the expansion of wooden furniture (Svenskt Trä, 2018) and the comfort level for humans and animals (Fraden, 2010). Humidity sensors are already in use in climate control systems in cars (Volvo, 2018) and buildings (Autodesk, 2018).

Soil moisture sensors can be quite simple in their construction with one common method being to measure the conductivity between two probes put in the soil. This gives a good approximation of the water content in the soil since the water is the main contributor to the electrical conductivity in soil (Fraden, 2015). This can be used to monitor farming grounds for more resource efficient production.

1.2.3.1.8 Light sensors

Light sensors measure electromagnetic radiation in spectra from UV to far infrared and convert the radiation into electrical signals which can be processed, taking advantage of either quantum or thermal responses of certain materials.

These sensors are used in systems such as control systems for automated awnings (Rollease Acmeda, 2018) as well as in digital cameras (illumin, 2018).

1.2.3.2 Biometric sensors

Biometrics is "the measurement and analysis of unique physical or behavioral characteristics (such as fingerprint or voice patterns) especially as a means of verifying personal identity" (Merriam-Webster, 2018).

The ability to quickly and with a high degree of certainty distinguish an individual enables many system functions that make people's lives more efficient, such as going through security checks. One biometric sensor that is becoming more ubiquitous is the previously mentioned fingerprint sensor. Most new smartphones have the ability to be unlocked through this technology and new technologies even makes it possible to incorporate the sensor in the screen (Synaptics, 2018).

Facial recognition has become widespread during the last decade, most recently as Apple integrated the feature as an unlocking method of their latest smartphone; the iPhone X released in 2017 (West, 2017). Apple uses a flood illuminator to shine infrared light on the users face followed by projecting 30 000 dots on the face of the user, creating a depth map which can be read by an infrared camera.

Apple states that the chance of its facial recognition technology mistaking a person is 1 in 1 000 000 (deAgonia, 2017). According to IHS Markit (2017), the cost of the hardware for the facial recognition technology in the iPhone X is $ 16.70.

Another biometric way to identify people is through their eyes. A major advantage about using the eye for biometrics is that it is an internal part of the body which is more protected than a fingerprint which might be hard to read if the user have worn or damaged fingerprints from manual labor or lesser injuries.

There are two main ways of doing this; retinal scanning and iris recognition. Both the retina and the iris remains virtually unchanged during people's lives which allows for long lasting databases. The retinal scan works by illuminating the blood vessels in the back of the eye with infrared light. The complexity of their structure makes the blood vessels of an individual distinct from others and therefore a good identifier. An iris scanner takes a high-resolution photo of the iris with the goal of capturing its structure and translates it to code. It is then possible to match the code against the database to confirm the identity of the user. (Heimdal Security, 2018)

1.2.3.3 Peripheral technology for sensor nodes

In addition to the sensor itself, there is need for other components depending on where the sensor is installed and what its purpose is.

The resulting signal from the sensor needs to be processed to be turned into a useful metric. For smart products, a microprocessor is the logical choice because of its size, cost and relative simplicity. The microprocessor can use the sensor reading to directly control a device or transmit the signal to other devices or hubs.

To allow the device to communicate with other devices, it needs to have some sort of communications module. There exists several popular communication protocols for smart devices, such as Zigbee, Z-wave and Bluetooth Low Energy (BLE). They are all striving to minimise the energy used to send and receive information. Several of these types of communication protocols are structured in mesh networks, allowing each node in the network to act as a relay for nodes that are out of range of the initial sending node or hub unit. (The Ambient, 2018)

To power these components there needs to be a power source as well. If the sensor is part of a larger appliance, such as a fridge or a television, the power can be supplied from the power source of the appliance. For non-electronic units and mobile units, some kind of battery solution needs to exist to power the sensor and its accompanying components.

1.2.3.4 Future sensor technology

With the evolution of computing and electronics, it is possible to make smaller sensor solutions with better data processing capabilities and higher accuracy. Sensor prices are dropping as well, see Figure 1.6 below, which allows them to become even more ubiquitous in our lives (BI, 2014).

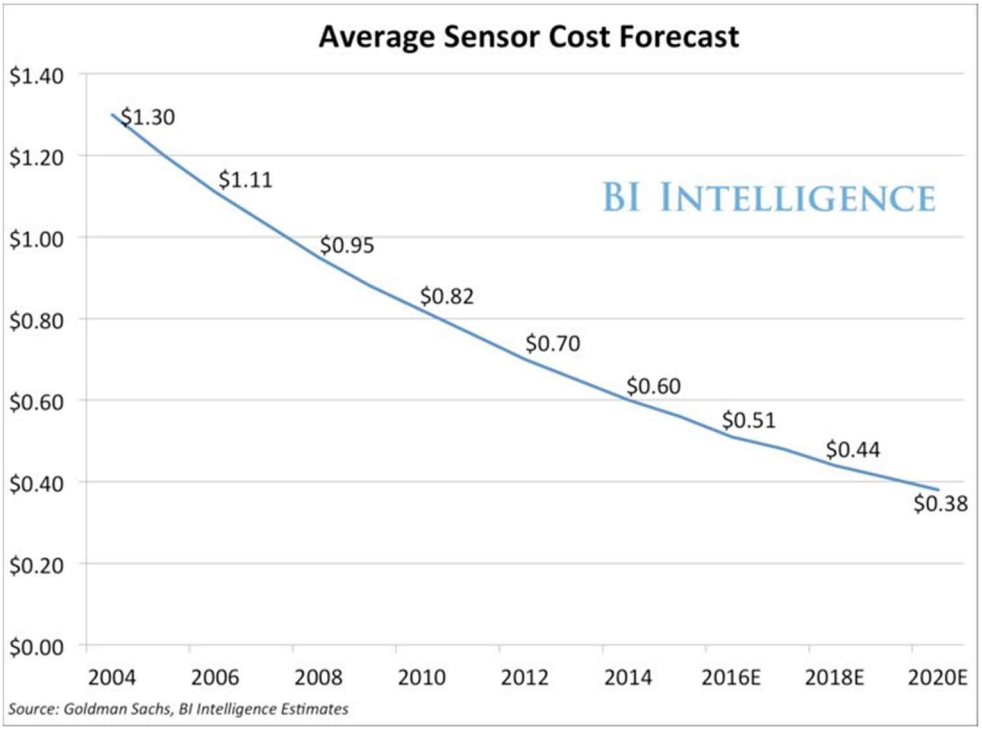


Figure 1.6 Average Sensor Cost Forecast (BI, 2014)

Further development of sensors and associated technology will create new ways of implementing it in our everyday lives. For example, sensor modules are usually powered through fixed electrical installations or battery solutions but in the future there might not be a need for either. Improvements in energy harvesting technology can allow sensors to be completely powered by ambient energy in their surroundings. Piezoelectric elements can harvest energy from vibrations, thermoelectric system take advantage of temperature differences and it is even possible to power systems through ambient electromagnetic emissions. For example, textile materials have been created with interwoven antennas for capturing energy from radio frequencies, an energy solution which could find uses in wearable tech and furniture (IEEE, 2015).

Batteries are still the most effective way for powering wireless sensor nodes, with a small 3V lithium cell with a capacity of 300 mAh being able to power a typical low-power node (100 µW average power draw) for 1 year (Priya et. Inman, 2008). In certain applications where batteries are not feasible, energy harvesting might be a

solution to power sensor nodes. Pacemakers are an example of where energy harvesting could be of great value, as it would mean no invasive surgery is needed to replace the battery. It is also an option in solutions which need to be properly sealed to function, such as underwater electronics. Being able to weld parts together or molding them with electronics inside, instead of using mechanical joints or adhesives, allows for better capsuling of components.

The size of sensors is another important part of development, especially for the mobile and wearable tech industries. Researchers at Berkeley University have developed so-called "neural dust", sensors, 3x1x0,8 mm in size. One possible use for the sensors is the ability to monitor in vitro muscle activity (Berkeley, 2016). Bosch Sensortec are providing micro sensors for the industry today and are selling accelerometers smaller than 4 mm^3 for use in smartphones and wearable tech (Bosch Sensortec, 2018).

1.4 Delimitations

The scope of the project has put several limitations on what was possible to include. Three key areas were observed as the main subjects of delimitations: Geographical, technical and economical.

1.4.1 Geographical

Implementation of technology in homes around the world will meet different challenges depending on local circumstances. For example, the ubiquitousness of high-speed internet might be a factor for installing connected products or the prevalence of another technology, such as climate control, might be another.

The thesis will be biased towards western living conditions in general and to those in Sweden in particular. However, because of IKEA's global presence it was deemed necessary to consider international differences to some extent.

It was possible to get input from IKEA employees who have lived outside of Sweden in several different countries. Even though this will not give a complete picture of technological integration in those countries, it will allow for a more nuanced perspective.

1.4.2 Technical

The thesis focuses on implementing current sensor technology and will not attempt to improve or innovate in the field of sensors. It provides examples of how the sensor technology written about in publications as being on the verge of commercialisation could be used.

IKEA has chosen to use the communication protocol Zigbee and when proposing possible implementation examples, they will be modeled around this communication protocol. The scope of the project did not allow for in depth research of communication protocols and it means that concepts will adhere to IKEA's current product series and their limitations.

1.4.3 Economical

Economic analyses regarding acquirement and production prices will not be made in detail. There will however be attempts at following the IKEA design principles which include 'a low price'. This will affect the discussion regarding possible implementation.

1.5 Project management

At the start of the project, a preliminary time plan was created for the project in the form of a Gantt chart. Since the project was exploratory in nature, it was expected that many changes to the chart would be made but it was a good way of ensuring that all necessary parts of the project were incorporated.

The project ran over 20 weeks during the spring semester of 2018. Work on the project was done at IKEA of Sweden in Älmhult and LTH in Lund with time evenly spent between both locations.

The proposed time plan and the actual time plan are presented in Appendix A.1 and A.2. There is a difference in the planned and actual project sections. This is due to the exploratory nature of the process and the way it developed during the project. For example, information that was initially planned to be acquired by the project team could be provided by IKEA instead, leaving that step unnecessary.

1.6 IKEA & IKEA Home Smart

Since its founding in 1943, IKEA has grown from a small mail-order company to the world leader in home furnishing (Statista, 2017). IKEA is an ever-expanding company, in both product ranges as well as physical presence around the world, but their vision stays the same - to create a better everyday life for the many people; a vision which guides all new development. By offering the combination of *Form*, *Function*, *Quality* and *Sustainability*, all at a *Low Price*, IKEA aims to allow everyone to afford good home furnishing (Inter IKEA Systems B.V, 2018). This is their vision of Democratic Design.

In the aforementioned aspects, *Form* is about making aesthetically pleasing products that make people feel good about their homes. Designing for *Function* is to not just make each individual product work but how they make things work better at home. In addition to making products that are durable, creating *Quality* products is to ensure that people's homes stand the wear of everyday life. The aspect of *Sustainability* means to not only have sustainable ways of producing products but to facilitate people to live more sustainable at home. Offering products at a *Low Price* allows everyone to make things better in their lives.

In addition to these design principles, five areas of interest to IKEA will have an extra focus in the process of identifying user cases. These are *Atmosphere, Convenience, Safety, Health & Sustainability.*

The project has been made in collaboration with IKEA of Sweden (IoS), a subsidiary to Inter IKEA Holding B.V. IoS are responsible for product development for IKEA

but not for producing any of the products or their sale. Manufacturing and sales are the responsibility of other subsidiaries of IKEA. (Inter IKEA Group, 2018)

In 2015, IKEA launched their IKEA Home Smart range with wireless charging products. This was followed by their smart lighting range, TRÅDFRI (Inter IKEA Group, 2017). It consists of a series of smart light sources, remote controls, a motion sensor and the gateway which enables smartphone control of the light sources.

The TRÅDFRI range uses the Zigbee communications protocol to enable their products to communicate with each other, a protocol used by many other products on the smart home market, such as Philips Hue and the Amazon Echo Plus (Philips, 2018; Amazon, 2018a).

IKEA has chosen to gather their smart devices under the IKEA Home Smart label as a way to illustrate that their primary focus always lies on the home. This also enables them to incorporate other products in this range which does not typically fall under the Smart Home label, e.g. wireless charging. IKEA intends to proceed in launching new products in the IKEA Home Smart range but they do not see themselves as a company leading the technological development, focusing instead on innovative ways of implementing existing technology. (R. Töreman, 2018)

1.7 Problem description

The objective of this thesis is to evaluate the possibilities and limitations of implementing sensors into the smart home of tomorrow. It should correlate to the current IKEA smart home products while maintaining the vision of IKEA - to create a better everyday life for the many people. The scope of the project is initially wide to but will subsequently narrow to focus on the customer needs and based on these needs implementation examples and key findings will be presented. The project will be initiated with research into user needs, technology solutions (both current and upcoming) and expert evaluations. Thereafter, using these needs, user cases and user insights are presented and based on these implementation examples and key findings are presented.

In this project, the aim has been to explore the possibilities of implementing sensors in the homes of the many people, not the early adopters with the financial capabilities of custom tailored solutions. This mindset will have a significant impact on the shape of the project.

1.8 Research questions

This report will attempt to answer the following questions:

I. Which needs can be satisfied by implementing sensors in the smart home?

II. How can current sensor technology be implemented in the smart home?

III. What are the possibilities of upcoming sensor technology?

IV. What are the limitations of implementing sensors in the smart home?

2 Method

In this chapter, the overall method applied to the project is presented. It is divided into two parts; presenting the general methodology for the project and how the method was modified to better suit the scope of the project.

2.1 Double Diamond

The Double Diamond design process was developed by the Design Council in 2005 and consists of 4 phases; Discover, Define, Develop and Deliver (Design Council, 2005). The name is derived from a visualisation of the cycle the process takes the user through, see Figure 2.1.

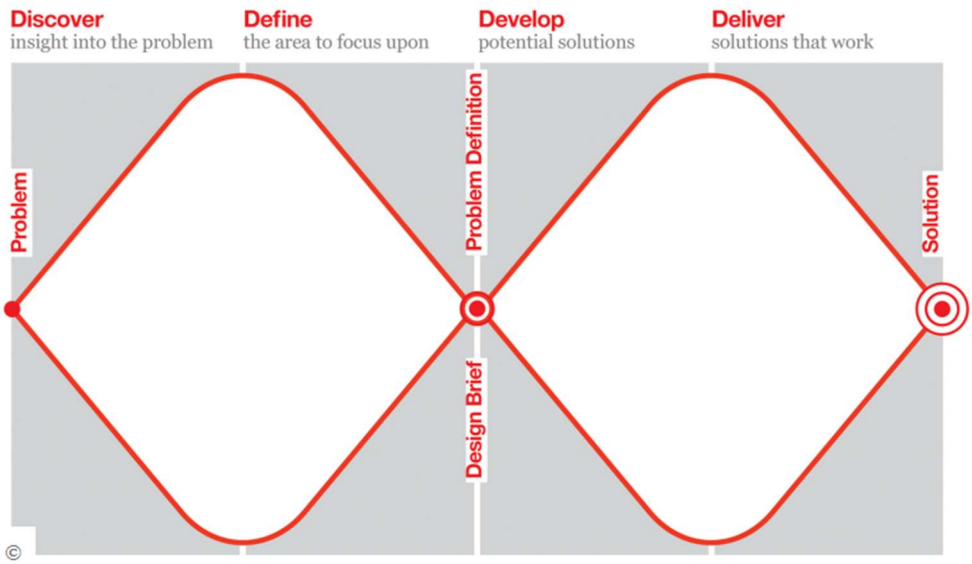


Figure 2.1 Illustration of the Double Diamond process (Design Council, 2005)

The Discover and Develop phases are so called “divergent thinking” phases whereas the Define and Deliver phases are so called “convergent thinking” phases. In the divergent phases, the aim is to create quantitative work and in the convergent phases, the goal is to screen the quantitative work to decide what is relevant and worth focusing on. The Discover phase initiates the process with tasks such as data collection and literature research before using that information to brainstorm ideas and decide opportunity areas in the Define phase. In the Develop phase, the ideation process takes place until reaching the Deliver phase in which the results are concretised and presented.

In Table 2.1, examples of the performed tasks in the phases of the Double Diamond method is presented.

Table 2.1 Examples of performed steps in the Double Diamond methodology

Discover	***Define***	***Develop***	***Deliver***
Literature studies	Clustering	Brainstorming	Presentation images
User interviews		Filtering sessions	Presentation prototype
Expert consultations		Ideation	
User observations			
Sensor research			

2.2 Our application

While the Double Diamond method served as a general structure for the project layout, certain aspects and parts of the project needed to be further specified in their methodology and approach.

Entering the Develop-phase of the project, it was essential to have a methodology in place in order to have a clear understanding of the desired outcome. In consultation with supervisor Rebecca Töreman of IKEA, the following methodology was proposed: In Figure 2.2 below, the approach to the project is presented but the number of sub steps in the method is merely an example. Using the data collected in the Discover-phase of the Double Diamond method, the Define-phase is used to generate a number of user cases which then are used as a base for creating several product concepts. Some of these product concepts may be evaluated as possible within the frames of the project to be further developed, denoted as 'refined concept' in Figure 2.2 below. However, as the project is exploratory in its nature, the resulting concepts may vary in their degree of completion.

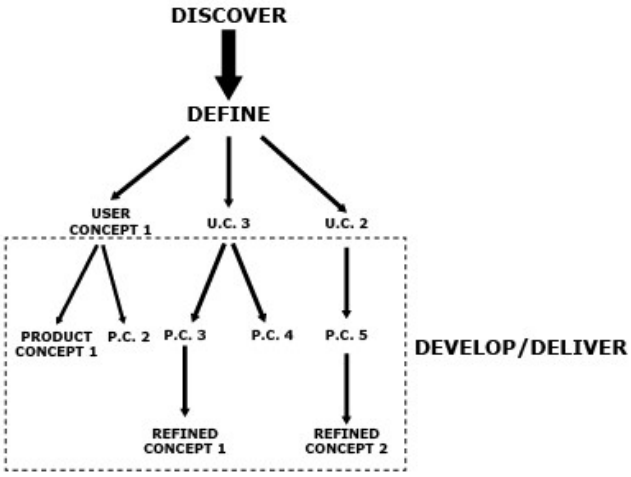


Figure 2.2 Illustration of the applied version of the Double Diamond methodology

3 Research

As the project is done in collaboration with IKEA, it was deemed important to maintain a strong focus on the user needs and as such, user interviews were used as the primary source of data collection. This method was combined with observations, expert consultation and literature review focused on sensor technology.

3.1 User interviews

To gather data and information from relevant users, semi-structured interviews were held in combination with observations. By having the interviews semi-structured, a more open interview environment is achieved and a friendly atmosphere can be created which facilitates a 'natural' flow of ideas and opinions (Hardon, Hodkin & Fresle, 2004). When constructing the interview questions, the proposed methodology of Arvola (2014) is applied, attempting to create questions which were open and trying to get the interviewees to explain and describe by using wording such as "Can you describe a moment when…" while continuously following up with 'why-questions' whenever appropriate in order to gain further insights. A conscious decision was also made not to mention the sensor focus of the project to the interviewees as to not affect their answers and opinions.

The interview went through two rounds of pilot testing to ensure that the interviewees could understand the questions and that they were written in such a way that relevant information could be extracted from the answers given. It also gave an indication of how long the test would take.

A set of household constellations were generated which was deemed representative for customer segments interesting to IKEA. When selecting interview candidates, these household constellations were used as reference in order to cover as many of IKEA's customer segments as possible. The household constellations are presented in Figure 3.1.

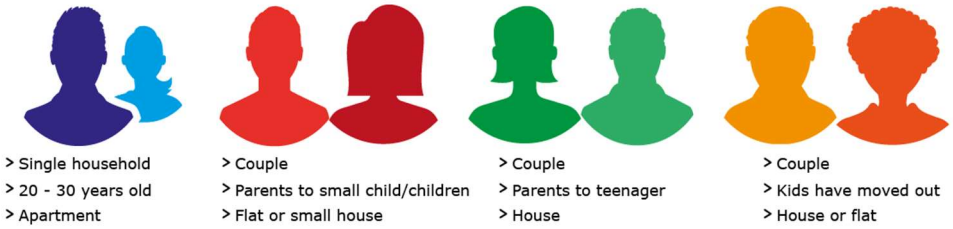


Figure 3.1 Visualisation of interesting customer segments

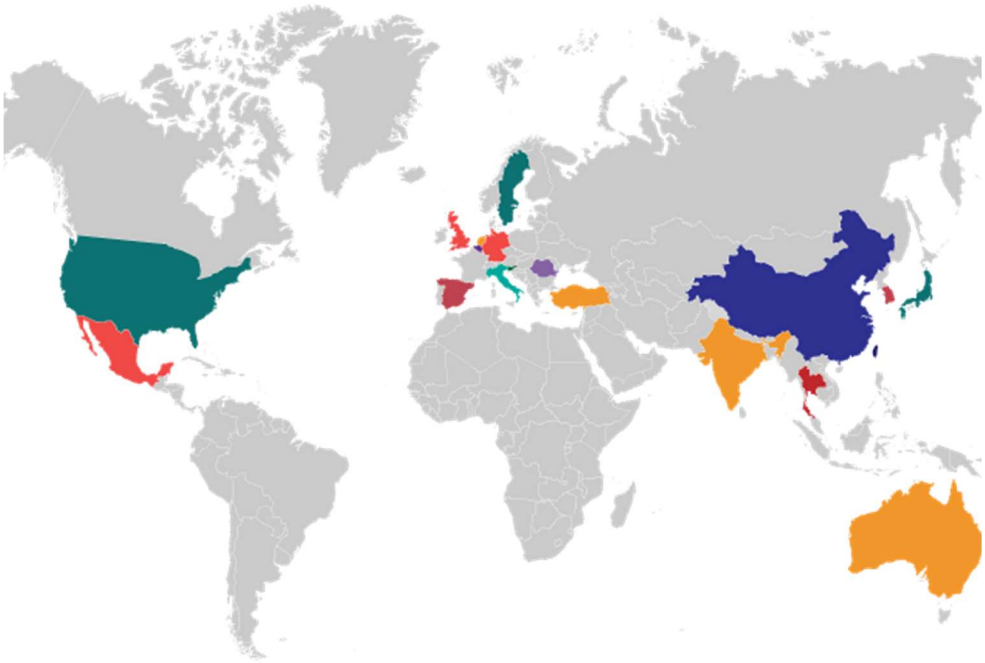
As IKEA is present in many countries around the globe, interviewing people with a background of living in a country besides Sweden was also deemed important.

A total of 20 interviews were held with 23 people - 10 women and 13 men. (Three interviews were held with couples). See Table 3.1 for a compilation of the interview subjects. Each interview lasted for approximately 1 hour.

Five interviews were held in the homes of the interviewees in order to combine the interviews with a natural observational environment. 15 interviews were held at IKEA of Sweden in Älmhult with IKEA employees. 14 of the interviewees provided insights into living in a different country, the countries represented can be seen in Figure 3.2.

Table 3.1 List of interviewees

ID	*Age*	*Living conditions*	*Living situation*	*Size of home*	*Ages of children?*
A	31 & 34	House	Couple with 2 children	127 m^2	4 & 1
B	30 & 34	Apartment	Couple with 1 child	70 m^2	1,5
C	26	Apartment	Single household	38 m^2	-
D	26	Apartment	Single household	50 m^2	-
E	60 & 62	Apartment	Couple, children moved out	100 m^2	-
F	40	House	With wife and 2 children	280 m^2	6,8
G	38	Apartment	With partner, part-time custody of 3 children	100 m^2	4,6,8
H	40	House	With husband and 2 children	200 m^2	8,12
I	31	House	With wife and 4 children	142 m^2	0,6,8,12
J	40	House	With husband and 3 children	167 m^2	3,11,14
K	53	House	With husband and 1 child	170 m^2	20
L	26	Apartment	With girlfriend	45 m^2	-
M	46	Apartment	With 3 children	95 m^2	9,12,15
N	30	Apartment	With friend	100 m^2	-
O	38	House	With wife and 1 child	117 m^2	2
P	36	House	With husband and 2 children	135 m^2	8,13
Q	29	Apartment	With girlfriend	65 m^2	-
R	50	House	With partner and 2 children	150 m^2	9, 11
S	52	House	With wife and 2 children	180 m^2	17,19
T	35	Apartment	Lives alone	55 m^2	-



Australia	**England**	**Thailand**	**Japan**	**Mexico**	**India**	**Shanghai**	**Spain**
Belgium	**Germany**	**The Netherlands**	**China**	**Romania**	**Italy**	**Slovenia**	**Taiwan**
USA	**Turkey**	**South Korea**	**Sweden**				

Figure 3.2 Map and list of countries represented countries in the user interviews

A reservation should be made as a significant amount of the interviewees was working at the IKEA Home Smart or Lighting departments, thus their use of technology may not fully be representative of the population as a whole. One should be aware that several of the interviewees have a more developed relationship to technology, due to the nature of their work, than the average person in their respective age and living condition.

The interviews consisted of three parts with the first two always carried out and the third performed depending on if the interviewees had any experience of living in a different country. The complete interview guide can be seen in Appendix B.2.

The first part consisted of questions regarding their thoughts on technology, particularly in their home. The second part consisted of more room-specific questions, allowing and encouraging the interviewees to explain more in detail how they interacted in certain rooms. During the interviews with households consisting of more than one person, it was encouraged to answer both as a household and as individuals.

The goal of the first two parts of the interview was to find openings for user cases and understand people's attitude towards new technology in general but especially their view on smart devices. Getting these answers would ensure that further development is based on real world situations. Knowing how people feel about this type of technology will enable the design of the product and its presentation to make the customer feel comfortable in knowing how to use the product. The goal of the third part of the interviews was to gain insight into global living conditions and how they differed from Swedish living condition.

3.2 Observations

As a part of the home interviews, in which the interviewees were asked questions regarding their actions in certain rooms, they were also asked to simulate their actions in two rooms.

First, the interviewees (one of them when it was a couple) was asked to "bake" a sponge cake according to a provided recipe. It was explained that they were not required to actually bake the cake (however, one participant actually did bake the cake) but merely simulate their actions as if they were to actually bake the cake. The participants were encouraged to use the *think-aloud* technique (Rubin and Chisnell, 2008) where they comment their actions as they are performed. By selecting sponge cake, it was possible to ensure that the participants interacted with interesting items in the kitchen such as the refrigerator, the oven, the stove and the cupboards.

Observations as a complement to interviews is encouraged by Arvola (2014) as you miss important nuances when only asking how people how they do things. As Arvola states:

Just because people say they do things a certain way, does not mean that is the way they actually do it. (p.50)

3.3 Expert consultations and presentations

To obtain information about specific points of interest and the smart home topics, experts were consulted and relevant presentations were attended.

In order to achieve a deeper understanding of the technological aspect of the project, especially sensor technology, an interview was held with Gunnar Lindstedt, senior lecturer in Industrial Electrical Engineering and Automation at Lunds Tekniska Högskola.

To get an insight into overall customer needs, interviews were held with Stanley Nielsen of the Bedroom/Bathroom section at IKEA and Anna Charlotte Jansson Noremark of the Living Room section at IKEA. An interview was also held with Nilofar Javadinejad at the lighting department of the IKEA Malmö store in order to gain valuable insights into the questions and inquiries they received from customers regarding the TRÅDFRI range.

January 31st, the project team attended an event titled *Innovation Summit on Nano sensors & Power electronics - enablers for the future electrical society* which was organised by Material Business Center, Mobile Heights and NanoLund. The reason for the attendance was to gain insights into the future visions of sensor technology

as predicted and envisioned by the industry. Material Business Center is operated by Innovation Skåne.

April 24th, Stacey Higginbotham of the podcast Internet of Things held a presentation at IKEA which the project team attended. The presentation included her thoughts as a reviewer of smart devices on the smart home and the challenges she foresaw for the implementation of smart home technology.

3.4 Literature review

For the scope of this project, the literature review was used to gain further insight to the subject and corresponding topics. Much of the literature review was performed online, through searching based on keywords such as *smart home, smart device* and *sensors.*

Material from scholarly sources was favoured while complemented with grey literature as academic journals, industry studies and news reports.

3.5 Market research

The current smart device and smart home market was used as a reference when evaluating sensor implementation examples generated throughout the project. The objective was to get an indication of the implementation horizon of the generated concepts.

4 Analysis

The research yielded information which needed to be structured and condensed to be usable further on in the process. This was done through discussions and clustering of data from the studies done in the previous chapter. The results from the analysis was divided between two categories: User insights and User cases.

4.1 Method

In order to process the data collected from the research, a methodology was proposed which would categorise and cluster answers for further development. Having the data clustered enabled the exploration of possible user cases and insights prior to entering the ideation phase. The differentiation between user insights and user cases is in the projected outcome - a user insight presents information regarding general usability and usage whereas the user cases are connected to a more direct user need. The generated user cases acts as groundwork for the ideation phase with the user insights acting as guidance in the following developing phase.

4.2 Clustering

As a method for categorising the answers from the user interviews, a variation on the *Bundle ideas*-method was used. The bundling of ideas is used to take strong individual concepts to solutions of substance. By putting the best parts of ideas together, the goal is to create concepts that are more complex. (IDEO, 2015)

This method was used for the process of clustering answers from the user interviewees into representative statements. Each new answer analysed was discussed whether it matched one of the current statements or if a new statement was required. If a pre-existing statement matched the present answer, that statement would be awarded one point. This resulted in a grading system where certain statements had high scores (equal to many interviewees expressing opinions matching this statement) and certain statements with low scores. The scores were however mainly used for guidance and not as screening material as statements could be deemed important despite only a few interviewees providing answers matching

the statement. Furthermore, some statements received low scores as they correlated to answers provided spontaneously by some of the interviewees.

In these cases, an assessment was made whether the statement would have received a higher score if the other interviewees had been asked to concur or not with the statement.

This is exemplified by the statement:

> *I wish my energy consumption was lower when I am not at home.*

Only 9 out of 20 interviewees actually gave answers correlating to this statement but all of the interviewees are, according to the project team, believed to have concurred with the statement had they been asked about it directly.

The full list of statements created through clustering is presented in Appendix C.

4.3 User insights

4.3.1 Presenting the user insights

This chapter covers the insights and findings based on the conducted research presented in the previous chapter. The presented insights are extracted through the use of clustering and in relation to the research questions.

Based on the clustering of interview answers, the user insights could be created and are presented in this chapter with the insight first presented followed by a description and a quote from the interviews which highlights the insight.

4.3.2 Interpreted user insights

I like to be in control of availability - both when it comes to when and for whom.

From the data collection, it became apparent that users like to feel that they are in control of availability. Users want to be able to decide themselves who in their household has access to what and when and the products that offers these possibilities are among those most appreciated by users.

> Interviewee F on the impact of Apple TV in their home: *It has changed the way you are watching TV. From watching predefined shows to choosing yourself. Especially for the kids.*

It is desirable to have products which gather several different functions.

Several of the interviewees expressed their preference of products which enabled easy control of several functions from the same device, such as on-demand TV solutions or music systems.

This correlates well to the study by PwC (2017) in which 42 % of respondents asked for a universal app which controls all technology when asked what they desired in a smart home.

> Interviewee D on why they like their streaming device Google Chromecast: *It works really well as all Play-services are connected to it.*
>
> Interviewee D regarding the trend of smart devices: *Everything sort of have to change in order for it to be attractive. I do not want more devices that require pairing and all that.*

I get frustrated when products does not fulfil my expectations.

Users tend to get frustrated when a product expresses certain functionality yet does not deliver this satisfactory. It is of utmost importance to create products which tries its best to meet the expectations of the customers and that its functions are in line with the user's needs.

> Interviewee I on expectations on devices: *I bought a "Smart TV" and had certain expectations when it said Smart TV on the box. It should be easy connectivity. Now it drops the Wi-Fi. It did not live up to the expectations. I bought a Chromecast instead since the functions did not work properly.*

I want new products to be easy to install and that the installation process is quick.

It may seem obvious but it cannot be stressed enough - an installation process that follows the logical steps expected by the user and allows for an intuitive interaction is highly desired. Several user expressed their frustration towards technology which did not meet this as the installation process failed despite the user feeling like they followed the proposed steps.

> Interviewee F on the frustration of installation processes: *When you have done something and your settings are reset and you have to do it again. When you feel like you have done everything right and it still does not work.*

I use my smartphone a lot when I am at home but I do not need to carry it with me everywhere.

This statement is based on several interviewees claiming to have their phone close by all the time when they are at home but, upon further inquiry, it turned out they were quite content having it located at the same place all the time while at home. Some interviewees did however claim to always keep their phone with them, even while at home. Overall, the importance of the smartphone during our life at home cannot be underestimated but for some, it is not by their side constantly which is a factor to consider when developing products for the smart home.

> Interviewee O regarding smartphone usage at home: *If I put it on a charging spot away then it feels a bit awkward. We are quite conscious about it in our home - we do not put them in a kitchen. We limit our interaction with our phones consciously.*

If technology is used which the user is familiar with, the functionality is expected to be more robust and trustworthy than if newer (and more unfamiliar technology) is used.

Several of the interviewees listed malfunctioning Bluetooth or Wi-Fi as their main frustration when it comes to technology. When asked for the reason, their answers were that they simply expected this to work when they wanted it to. This leads to the insight that when using technology and communication solutions which are familiar to the public, a higher level of expectancy concerning robustness is present whereas newer and more unfamiliar communication solutions could be exempt from these expectations.

> Interviewee D2 on Bluetooth technology in the car: *It is just supposed to work. It has happened that it has malfunctioned and as I am not too handy, I just want it to work.*

I do not always hear notifications on my smartphone when I am heading somewhere outside my home.

A large majority of the interviewees concluded that they from time to time missed notifications on their phone when they were leaving home despite having their smartphone on them. As it was common among the interviewees to have their phone on silent, it is understandable that when the phone is placed in a jacket pocket or a bag, it is hard to notice a notification. This should be taken into account when developing concepts where getting the attention of the user is of utmost importance, for example if it is a product which concerns home safety.

> Interviewee A1 on when missing notifications: *If I have it in my bag I may not notice notifications but I check it regularly in case I missed something.*
>
> Interviewee A2 on differentiating notifications: *Had it been an emergency, they would have called.*

I find it annoying when there are too many notifications on my phone which calls for my attention. I want it to be up to me to decide when I want to look at my phone.

It became apparent that the amount of notifications that the interviewees received today on their phones was overwhelming to many and that several actively either turned off all notifications except texts and phone calls or turned off notifications for each new app they installed. This goes to show that having concepts where communication with the user is through their phones could be subject to the same type of filtering as other apps. As mentioned in the insight above, this is also of utmost importance when it, for example, concerns home safety.

> Interviewee O on notifications: *I remove notifications and sound to limit the amount of triggers. I try to be aware of notifications and how they affect me.*

It is important that my children are comfortable with technology but I limit their screen time as I am worried too much time in front of a screen may affect their development.

Interviewees with children were unanimous in their opinion that their children were very comfortable with technology and that they were quick to learn. Furthermore, the children had next to no obstacles in interacting with technological devices which goes to show that when designing technological concepts, it is not necessarily required to make it "child-friendly" when it comes to interaction. However, several of the interviewees expressed a concern at the amount of time their children spent in front of different screens and limited this through different methods. As more functions besides entertainment are now available through mobile devices, it is clear that the limitations on screen time may also affect children's interaction with devices offering control of smart devices.

> Interviewee M on children and technology: *They have grown up with it so they just think it's fun. Sometimes it becomes too much and then we will limit it a bit. Their phones are outside their rooms, charging, during the night. But I understand that they are a different generation and that they have a different relationship with technology.*

I find smart devices to be exciting but I need to see the benefit and need for them for it to be interesting to me.

75 % of the interviewees claimed to be excited by the idea of smart devices, indicating that the product segment generates interest in consumers. However, it also became evident from the interviews that smart devices require strong and convincing use cases to pass the threshold from general interest to an ambition to buy. The same conclusion is presented in the report by PwC (2017), stating that demonstrating a clear value proposition to the customers is essential. As PwC (2017) states in their report:

> Unless the product meets a specific need, solves a problem, or smooths over a major inconvenience, consumers cannot justify the purchase— especially for the big-ticket items like a smart refrigerator. This means the potential loss of opportunity to experiment with smart home devices, and a larger need to demonstrate legitimate value. (p.11)

> Interviewee F on the trend of smart devices: *I think it is amazing but we are at a stage where more companies need to know why they do things - I cannot really see the benefits of Siemens connected features in their refrigerator. We are in a phase where we are connecting things without really knowing why.*

I do not want a new app for each new smart device that I purchase.

With the same rate as smart devices are entering the market, the amount of apps required to control the devices increases. Several of the interviewees stated a desire to have systems which gathered control of different functions, also expressing the lack of complete ecosystems as an obstacle for them to purchase smart devices. Hence, a conclusion is that in order for smart devices and smart homes to be further developed and accepted among the public, allowing for seamless control of functionality of different smart devices is desirable and advantageous.

> Interviewee C on the idea of a smart home: *If everything works seamlessly and without being hacked, it would have been really nice. Now, there are too many different systems and devices. If everything was connected, that would have been nice.*

My level of comfort depends on what device is monitoring me and what purpose said device has. If I benefit from the device, I might be willing to compromise on my personal integrity.

The introduction of smart speakers in homes raised the question of having indirect surveilling devices which could monitor activities. Several interviewees expressed a discomfort at having devices in their homes which could record their activities, even when presented with the concept of a fully local system where they would have full control of the recorded information. Some interviewees however stated that their comfortableness depended on the benefit of the device monitoring - if they felt that the benefit was satisfactory, they would tend to ignore the monitoring. Furthermore, the comfortableness depended on the type of monitoring - while cameras and sound tended to trigger the most uncomfortableness, movement tracking was generally more accepted.

In conclusion, there still exists a general notion amongst the public where people are hesitant at taking monitoring devices into their homes. However, depending on the type of monitoring and if the benefit is great enough, people are more inclined to accept devices which monitor them.

> Interviewee T on the idea of having products at home which can monitor actions: *I am not quite sure what I think about it, I have to give it some thought. Motion sensors feels a bit better than for example waving in a camera. Camera feels a bit worse.*

> Interviewee O on monitoring devices: *I think here as well as the convenience is the good thing, the surveilling is the bad thing. I saw a camera which based on IR tracked what people were doing - nice idea to detect falls e.g. but who is looking at the data and how is it stored? It is almost an ethical question. The convenience is using the data for other things you have not even thought about but it can be used against you as well.*

When doing my dishes by hand, I usually do it under running water even though I know I am wasting water. However, as I only do it occasionally, I am okay with it.

A majority of the interviewees were aware of their water wastage when doing dishes by hand under running water but justified it by claiming it was only a small amount of dishes done by hand. This justification expresses a certain behaviour - when the positive effects of a task is believed to be negligible in comparison to the required action, the task is less likely to occur. In order to encourage the opposite behaviour (performing the task even if the positive effects are small), presenting the user with feedback showing the result of their actions is a potential method.

> Interviewee A1 on wasting water when doing dishes: *It is such a small amounts of dishes that we do by hand so it feels all right.*

I am conscious about leaving my home in a state with which I am comfortable.

A majority of the interviewees explained that when leaving their homes, they were mindful of leaving it in a state with which they were comfortable. For most, that mainly meant turning off lights but some also checked if appliances were off and if doors were locked. Feeling as if you have left your home in a "turned off-state" also meant they could expect the same state to greet them when they got home. Offering solutions which allows the user to feel confident about leaving their home in a state they are comfortable with is important and expected. Extending the solutions to allow for remote monitoring (making sure things actually were turned off) should mainly notify the user only if something is turned on which should be turned off when the user is not home.

> Interviewee M on routines when leaving home: *Turn off all the lights. Walk around my home, making sure all the lights are off and that the shades are up. Making sure all appliances are off and when I leave, check that the door is locked.*

I can see the benefit of being able to remote control devices in my home.

When asked about remote controlling devices in their homes, a majority of the interviewees were positive about the idea but needed to be presented with strong user cases to be convinced. Being able to remotely start a conventional coffee maker which still requires the addition of coffee beans and water was not convincing enough, especially as the addition of remote control most likely would generate a higher price tag. This further clarifies the statement that creating strong, convincing and logical user cases are essential when creating smart devices, especially when these smart devices have a non-smart counterpart which the users will use as a comparison.

> Quote from interviewee T on desirable device at to be remote controlled: *Watering my flowers and lighting. Possibly heating, but then again maybe not… No, it feels too complicated.*

4.4 User cases

This section covers the interpreted user cases that could be extracted from the literature studies and the clustering made from the results of the user surveys. It details how we arrived at the different user cases and proceeds to list all of the user cases interpreted.

4.4.1 Creating user cases

From the clustering of answers provided in the user interviews, interpretations of the statements were made in order to create user cases. The purpose of the user cases is to create statements which explains the goals of a user (Töreman, 2018). Having a statement which explains the current problem and the desired goal creates a general requirement specification which can be used throughout the ideation process. As a concept is presented, the user cases can be used to verify that the concept fulfils the needs expressed.

An example of the interpretation process of user cases is the creation of the user case:

> *I wish I could make sure I locked the door/turned off the coffee maker/blew out the candles as I am uncomfortable when I am not sure.*

This was created based on the statements

- You are careful to leave your home in a state with which you are comfortable.
- You are careful to turn off the lights when leaving your home.
- I worry about forgetting to do something important when I have left my home.
- I wish I could get informed if something happens in my home when I am away.
- I can see the benefit of being able to remote control things in my home.

These statements all correlate to notions of safety and control when users are not at home and expresses a desire to be able to make sure potential hazardous situations are avoided. Creating the user case thus had to incorporate these notions and express the desired goal of the user - to be able to remotely check and control devices which could be the source of hazardous situations.

4.4.2 List of interpreted user cases

- *I wish handling the laundry was a more automated task (e.g. sorting, dosage). Then I would have more time for my family/recreational activities.*

- *I wish the dishwashing was more automated to allow me more time with my family/recreational activities*

- *I wish the important devices/appliances at home (e.g. fridge, freezer, washing machine) always work. If they do not work, then life does not work.*

- *I wish I could keep an eye on my children while I am busy with household tasks (e.g. cooking, cleaning.)*

- *I wish I could let people inside my house when I am not there, but I am worried about how I keep my home safe at the same time.*

- *I keep the tap running when I am doing the dishes for convenience sake but at the same time, I would like to waste less water.*

- *I want to use technological tools in the kitchen but they are too complicated and/or tedious to use/clean/etc.*

- *I tend to do other things while preparing my food but I risk forgetting about it so that it burns/boils over.*

- *I feel bad when wasting water.*

- *I feel bad when wasting electricity.*

- *It is important that my children can be together with me in the kitchen, but there are many hazards for them there.*

- *I want to get reminders sometimes, but beeping sounds are annoying.*

- *I wish I could make sure I locked the door/turned off the coffee maker/blew out the candles as I am uncomfortable when I am not sure.*

- *I appreciate having plants at home but it can be difficult taking care of them.*
- *I want a clean and tidy home but cleaning is a boring chore.*
- *It is easier to save electricity when I see it presented in an intuitive way.*
- *I wish some things just happened when I have my hands full.*
- *We cannot have fragile things in places where our small children can reach them because they might play with those things and break them.*
- *It is difficult to keep track of fresh produce so that it will not spoil before being used.*

5 Ideation

With the user cases as the groundwork, the ideation process to explore sensor implementation possibilities was initiated. The ideation process consisted of brainstorming sessions to create a plethora of concepts followed by a filtering process where the concepts were evaluated against set criteria.

5.1 Brainstorming

As stated by Arvola (2014), the goal of brainstorming sessions is to create many different ideas in a short time. During a session, no ideas should be criticised and crazy ideas are encouraged. It is important to get people to share their ideas so other people can add their thoughts or be inspired to find new openings for the matter at hand.

5.1.1 Brainstorming from user cases

For each user case presented in the previous chapter, an individual brainstorming session of 5 minutes was held. This amount of time was seen as appropriate for the scope of the subject. If at the end of these 5 minutes the participants felt that there were more openings to be found, the session was extended until it was deemed that continuing would be fruitless. The ideas created during the brainstorming were mostly single-sentence ones, just enough to understand how it was meant to solve the problem. Further development of the concepts were done if needed to evaluate the concept in the filtering process. Figure 5.1 shows some of the results from the brainstorming session.

5.1.2 Brainstorming from sensors

As an additional method for exploring possible sensor implementation in a smart home, a list of sensors was used for a brainstorming session. The goal was to complement the user-focused brainstorming with a technological focus using current sensor technology as a base.

A list of interesting measurable quantities was created based on available sensor technology today and where each quantity underwent a brainstorming session of 3 minutes. As for the brainstorming session based on the user cases, if at the end of the 3 minute session more openings were expected to be found, the session was extended until the subject was believed to be exhausted.

From these brainstorming sessions, a total of 226 concepts for sensor implementation examples were created. Due to the amount of concepts and the simplicity of their presentation, these will not be presented in the report.

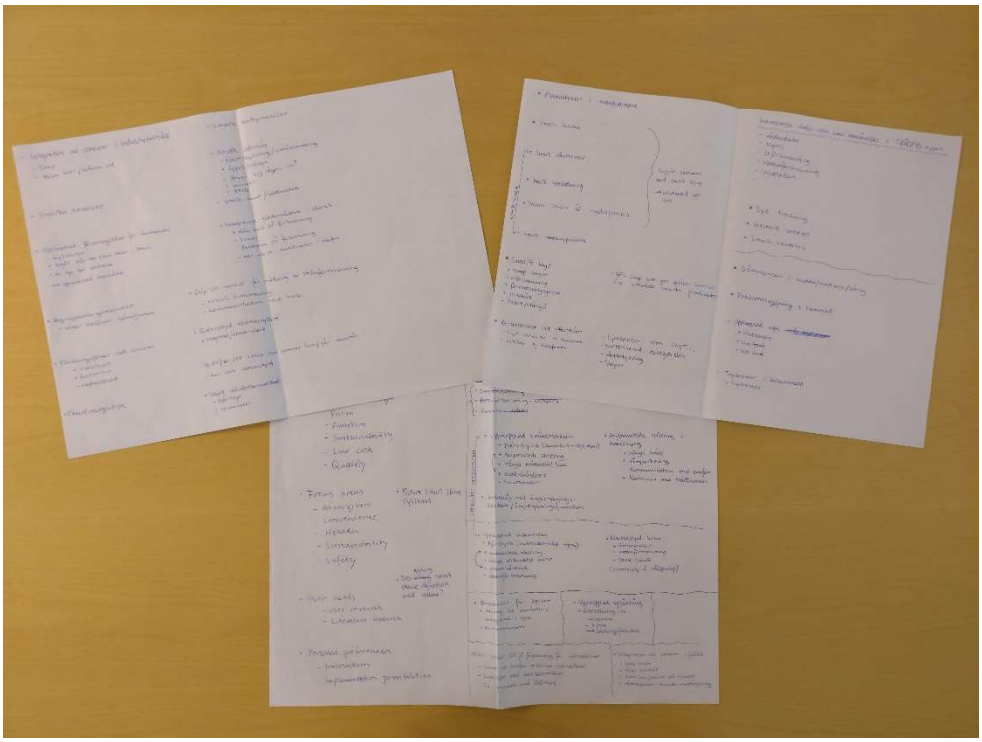


Figure 5.1 Some of the results from the brainstorming sessions

5.2 Filtering

After the brainstorming sessions were completed, the concepts were put through two separate filtering sessions but evaluated against the same criteria. The first filtering session was to reject concepts which clearly would not fit the criteria and to not waste time further developing these concepts before proceeding with the second filtering session. To pass through the first filtering session, the concept had to fit *some* categories and not be obviously in conflict with any of them. To pass

through the second filtering session, the concept had fit *most* criteria and not be obviously in conflict with any of them.

Between the first and second filtering session, where there were 41 remaining concepts remaining (see Appendix D), the concepts were further developed to get a clearer understanding of how it could be implemented. This allowed for a more thorough examination concerning the filtering criteria.

The criteria were decided with the help of the project supervisor at IKEA, Rebecca Töreman, and each concept was then evaluated against the criteria by the project team through in-depth discussions.

The concepts were evaluated against the following criteria:

- Does the idea correlate to the research?
    - Is it properly correlated to a user need and does it adhere to the presented user insights?
    - Does it correlate to the data from the literature studies?

- Does the idea fit with areas of interest for IKEA?
    - Does it contribute to a better atmosphere at home?
    - Does it make the user's life more convenient?
    - Does it facilitate living more sustainable?
    - Does it help in making our homes safer?
    - Does it help us live healthier lives?

- Is it probable that the idea can be implemented according to IKEA's principles of Democratic Design?
    - Form - can it be made aesthetically pleasing?
    - Function - is the function making life at home better?
    - Quality - is it possible to make both the form and function be long lasting?
    - Sustainability - can it be produced in a sustainable way and/or help us live more sustainably?
    - Low price - could it be produced at a relatively low cost?

- Can it be considered a part of a future smart home system?
    - Does it make sense to have this product in a home filled with other smart products?
    - Could it be seen as a step towards the totality of a smart home, e.g. a sensor that improves a voice assistant's functionality?

- Will the addition of the smart functionality, according to the definition, add value to the product?
    - Will the ability to communicate with other products add to either products functionality?
    - Will the ability to control/monitor the product through a mobile device add to the functionality of the product?
    - Will the increased price be balanced by the added functionality?

- Is the idea innovative?

- Does the idea have a global perspective?
    - Would the product be able to be implemented globally?

- How close in time would it be able to be implemented? (I.e. is the tech available now or is it speculated that it is ready for a commercial market in 5 years?)

The Democratic Design principles were not deemed as important as the other criteria since they are more dependent on the later steps in the product development process and the ideas presented in this report will stop at the concept level where it primarily is the function that is important.

Several of these criteria are subjective and as such, the preferences of the project team will have an impact on the concepts chosen.

After both the filtering sessions were completed, 11 concepts remained. These implementation examples are presented in the following chapter.

6 Results

In this chapter, the sensor implementation examples generated through the ideation process and passing the filtering in the previous chapter are presented more in depth. The depth with which these concepts are presented will vary as some concepts will be described more in detail and some concepts will be presented more generally.

6.1 Examples of sensor implementation in the smart home

When providing implementation examples of sensors in a smart home, this report will approach it from two different perspectives; implementation possible today and implementation possible tomorrow. As many of the presented sensors are commercially available today, the implementation and integration of their functions in the proposed solutions could be done today. However, some of the proposed implementation examples requires the sensor technology to be further commercialised and more widespread in order for it to be a plausible technology for IKEA to use in its products.

Referring to the proposed application of the Double Diamond method, among the following examples the smart plant pot is considered a refined concept whereas the others are to be viewed as product concepts. See Figure 2.2 for reference.

The smart plant pot was further developed than the other examples as it was considered an adequate example to show more in detail the application of sensors in a smart device as well as the implementation of user insights presented in the previous chapter.

6.1.1 Smart plant managing

During the interviews performed for the project, one data point which was unanimous amongst the interviewees was the importance of plants in homes. However, a majority of the interviewees also claimed that they found taking care of their plants as tedious and a chore which they did not appreciate. Nearly half of the interviewees (9/20) also found it difficult to take care of their plants.

Based on this, presenting a product concept which allows for easier maintenance of plants is well founded. From a future smart home perspective, the addition of devices which allows for remote monitoring and control of plant managing is desirable and can be implemented without any major technological difficulties as the technology to allow for plant monitoring already exists and is proven to work.

From an IKEA perspective, the addition of smart plant managing was deemed logical as the company already has an established range of plants and corresponding accessories, making smart plant managing a possible development of this range.

Based on the aforementioned, three concepts are presented: Smart plant Pot, Smart plant monitor and smart hydroponics.

6.1.1.1 Smart plant pot

An implementation example which correlates well to both the data collection and from an IKEA perspective is a smart plant pot which allows for remote monitoring and communication with other smart devices. The smart plant pot will be monitored through implementation of the sensor data in the TRÅDRI-app to allow for seamless control of all the users TRÅDFRI products.

The communication between devices, which signifies a smart home per proposed definition, can be achieved by communication between the smart plant pot and a motorised and smart blind. The communication sent could be the ambient light sensor in the smart plant pot indicating it is receiving too much light, communicating this to a motorised blind, which in turn is lowered, and thus limiting the amount of light the plant is receiving.

The concept can be described as integrating several sensors in a conventional pot and combining these with a PCB and microcontroller to allow for smart home integration.

The concept includes the following components:

- Sensors for measuring soil moisture, soil fertility, temperature and ambient light.
- PCB with Zigbee communications module
- Battery holder for one CR2032 battery
- LED-lights connected to PCB which display overall status of the four factors monitored by respective sensor
- Housing components

6.1.1.1.1 Sensors

Soil moisture

A soil moisture sensor using probes as described in chapter 1.2.3.1, *Sensor examples* is used to monitor the amount of water held between soil particles. The soil moisture is presented as a percentage.

Soil fertility

Soil fertility can be measured through electrical conductivity in the soil which returns values of salts and fertilisers in the soil. Electrodes are inserted into the soil to get proper contact with said soil. Soil electrical conductivity is measured in mS/cm with the SI-unit for electrical conductivity being S/m (Siemens per meter).

Temperature

A thermistor probe as described in chapter 1.2.3.1, *Sensor examples* is a type of resistor whose electrical resistance varies with temperature and can output an electrical signal, is inserted into the soil to measure the temperature.

Ambient light

The amount of light a plant requires varies from plant to plant but is usually this information is presented to the consumer upon purchase. Using a light sensor as described in chapter 1.2.3.1, *Sensor examples*, the output signal from the sensor varies corresponding to the incoming light and can be measured in the SI-unit of luminosity, lux.

6.1.1.1.2 PCB with Zigbee

The heart of the smart plant pot will be a printed circuit board (PCB) which includes the necessary components to allow processing of the signals from the sensors and communicating these to the Zigbee-module which in turn allows for integration of the smart plant pot to the TRÅDFRI ecosystem.

6.1.1.1.3 Battery

To allow unhindered placement, the smart plant pot would be battery powered. According to Larsson & Samuelsson (2018), using a single CR2032 battery would offer a reasonable battery life expectancy of about 1 year although it depends on the frequency of measuring.

6.1.1.1.4 LED lights

From the user interviews, it became apparent that although the smartphone is central to many households it is not always within reach for users as they can leave it on a table, a countertop or a dresser when they are at home. This indicates that interaction with smart devices should not be strictly limited to smartphones but instead some interaction should also be offered directly with the smart device itself.

For the concept of a smart plant pot, this is solved by using four separate RGB LEDs where each LED corresponds to one of the four quantities measured by the integrated sensors. As a measured quantity falls out of the predefined range, the LED lights up indicating an action is required. If the LED shines with a white light, the level is too high and requires decreasing and if the LED shines with a red light, the level is too low and requires increasing.

By integrating the possibility for the user to monitor the status of their plants directly at the pot itself, the smart plant pot will also work as a separate product from the TRÅDFRI ecosystem should the user not want to purchase the TRÅDFRI Gateway to access monitoring through their smartphone. However, to experience the full potential of the smart plant pot and its functions the TRÅDFRI Gateway is required.

6.1.1.1.5 User interface design

A key data point from the user interviews was that many users feel like they are receiving too many notifications from their smartphones, causing many to turn off app notifications altogether and others to limiting app notifications. Regarding the status of the user's plants, this information is deemed non-essential and therefore a function is proposed where the user only receives information from their smart plant pot if their smartphone is connected to the same Wi-Fi as the TRÅDFRI ecosystem is connected. This is also considered reasonable, as the user will only be able to act on the information provided from the smart plant pot if they are present at the same place as the smart pot itself, meaning any notifications when the user is elsewhere are generally unnecessary.

A function proposed in the app is the utilisation of QR-codes as identification of plants and thus limiting required steps taken by the user to get their smart plant pot to function. The idea is that on the plants IKEA sell, adding a QR-code which stores information about the desired levels of moisture, fertilisation, light and temperature of the plant. As the QR-code then is read when setting up the smart plant pot, the user does not have to manually search for the plant but simply scan the code and the data is automatically registered. This is a function based in the user insight that users want an easy and quick installation process without hassle - by simply scanning a QR code, several steps during the 'installation process' of adding a plant is eliminated.

6.1.1.1.6 Future possibilities

Remote watering of the plants was a functionality requested by users and is a technology which could be implemented in a not too distant future. However, it was deemed that integrating the necessary parts required to allow this functionality would make the concept too complex at this instance. It is though a highly plausible development of the proposed concept and can in a future be offered both as a complementary product to the smart plant pot and could be integrated in the smart plant pot itself.

Figure 6.1 - Figure 6.5 shows an example of how the smart plant pot could be designed and constructed.

In Figure 6.6 - Figure 6.11, an example of how the user interface design could look and how a possible user scenario would be when a user purchases a plant to place in the smart plant pot.

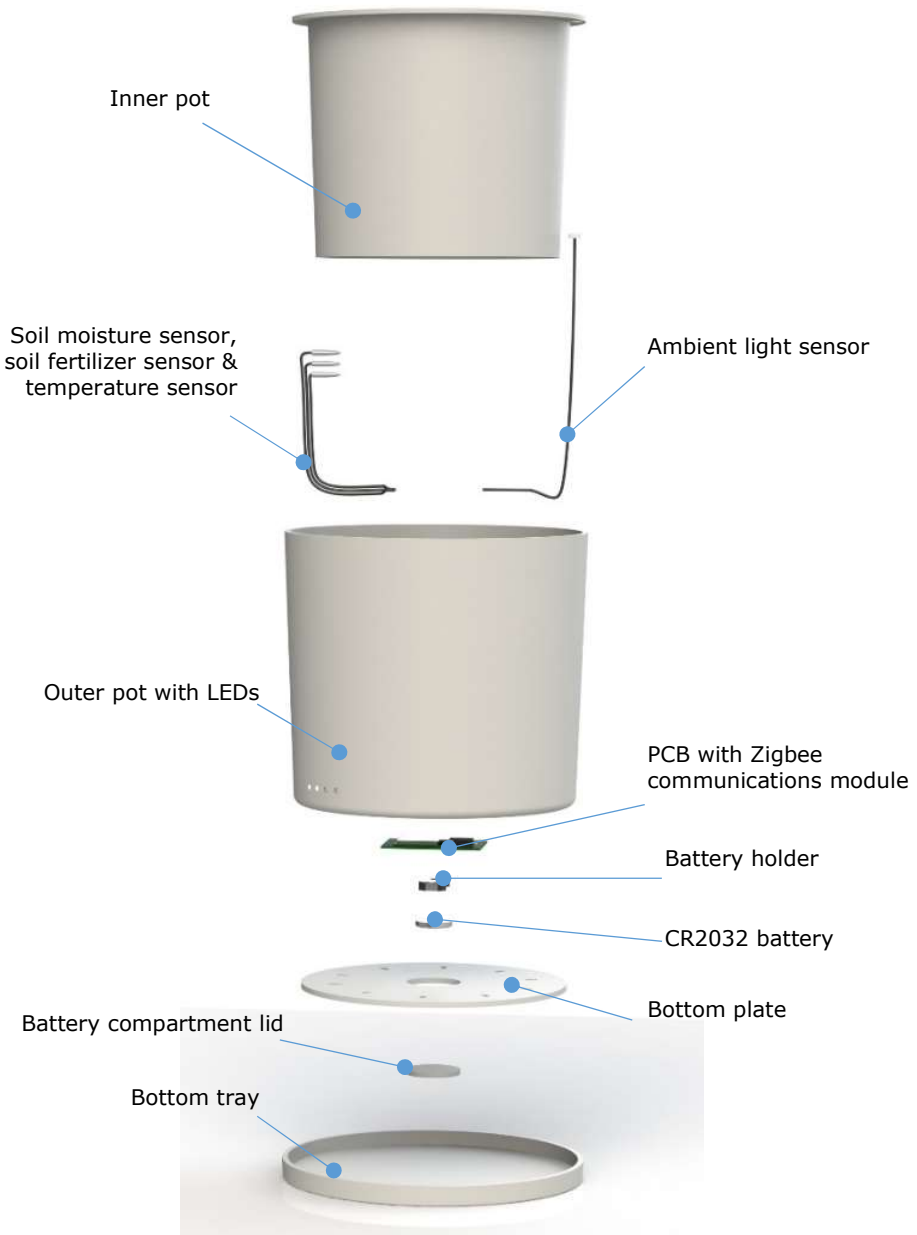


Figure 6.1 Exploded view of the smart plant pot

Figure 6.2 Cross section of the pot with internal component positioning

Figure 6.3 Cross section

Figure 6.4 Example of usage scenario

Figure 6.5 The LED lights indicating status

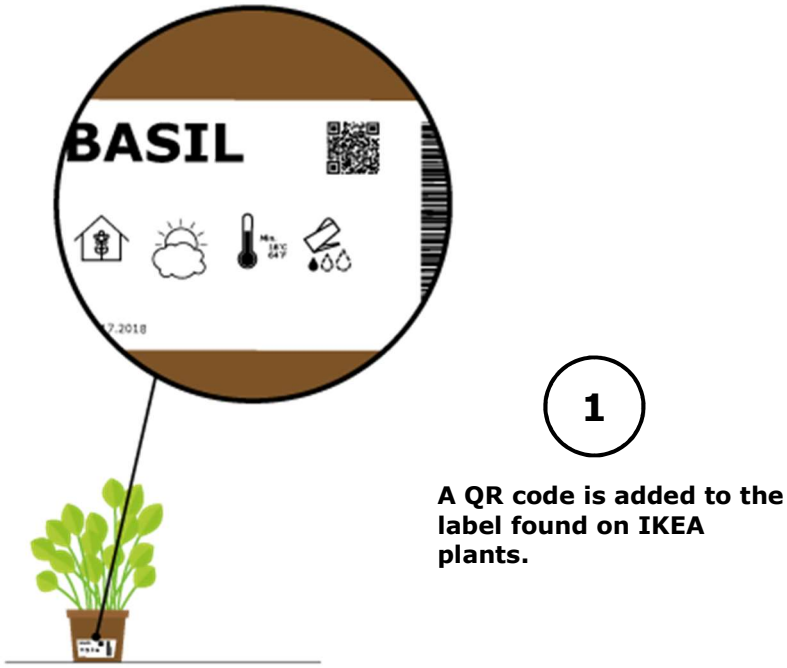


Figure 6.6 QR-code on label

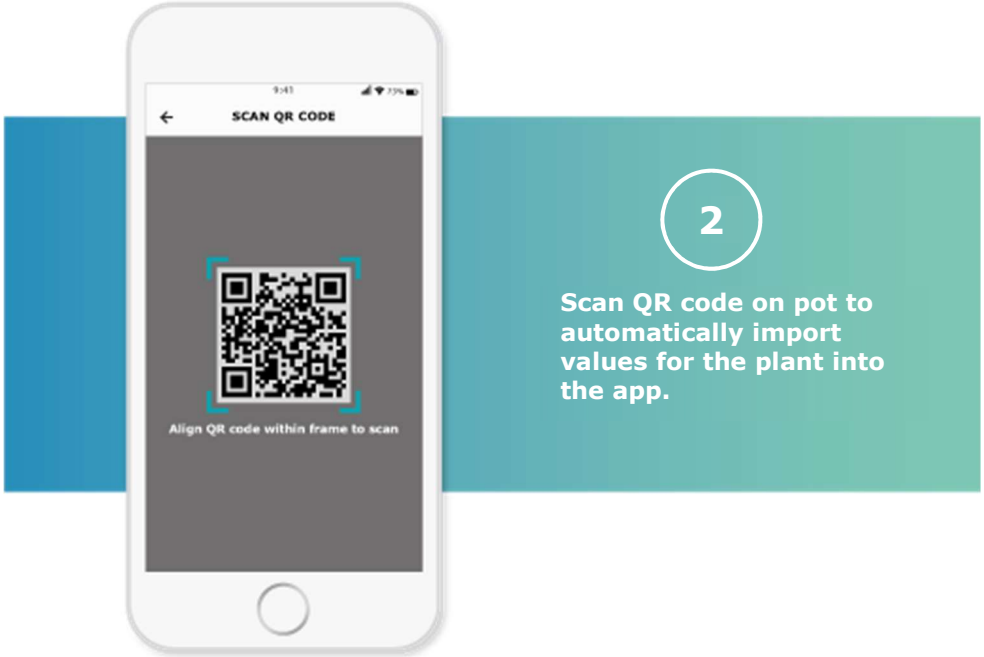


Figure 6.7 QR-scanner in the TRÅDFR-app.

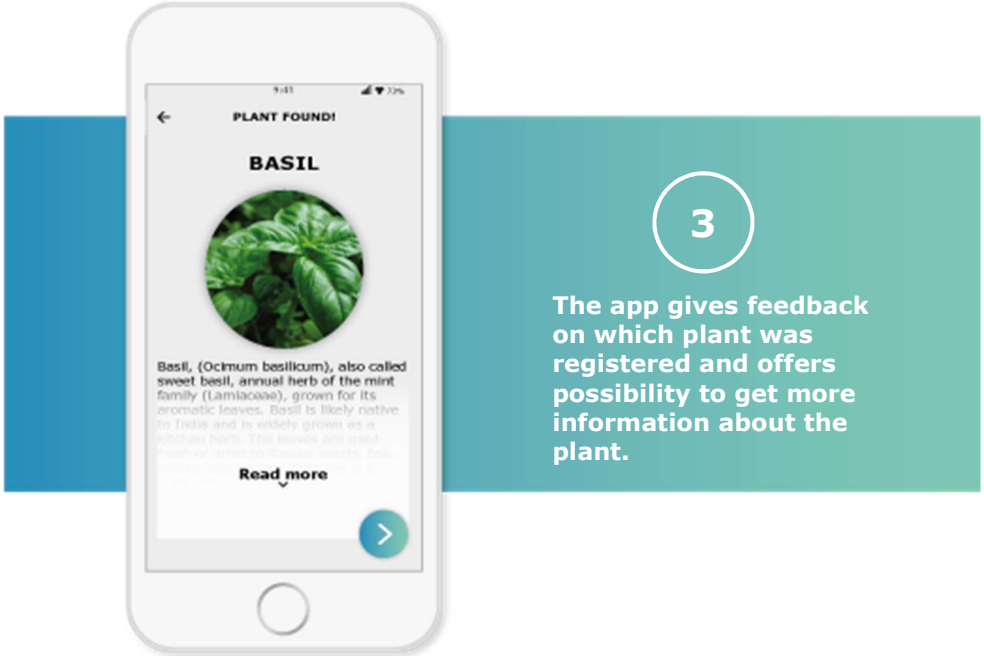


Figure 6.8 Information about registered plant.

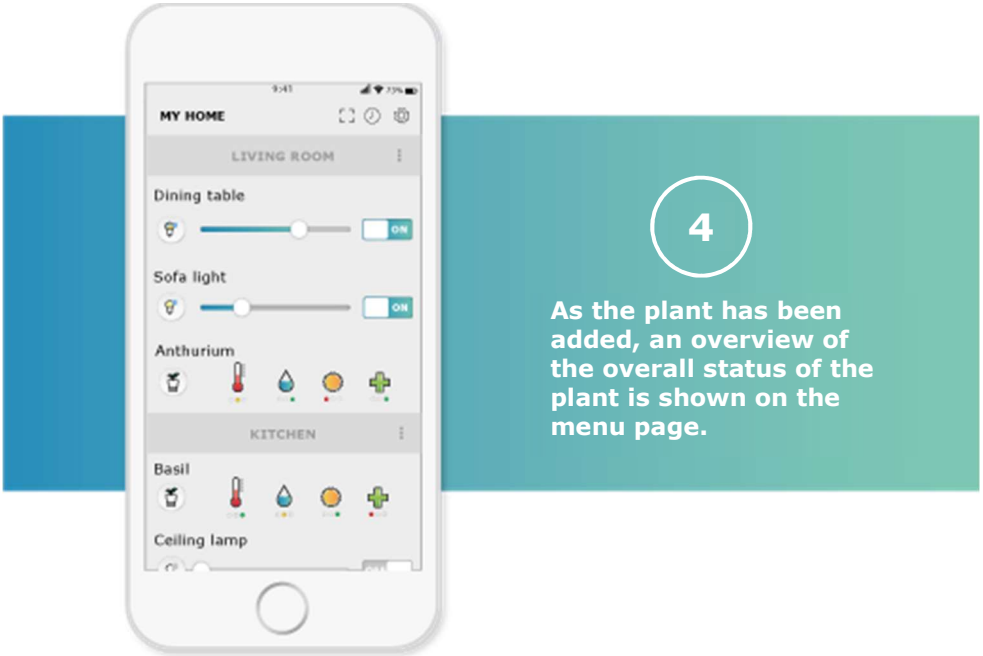


Figure 6.9 Overview of plant status.

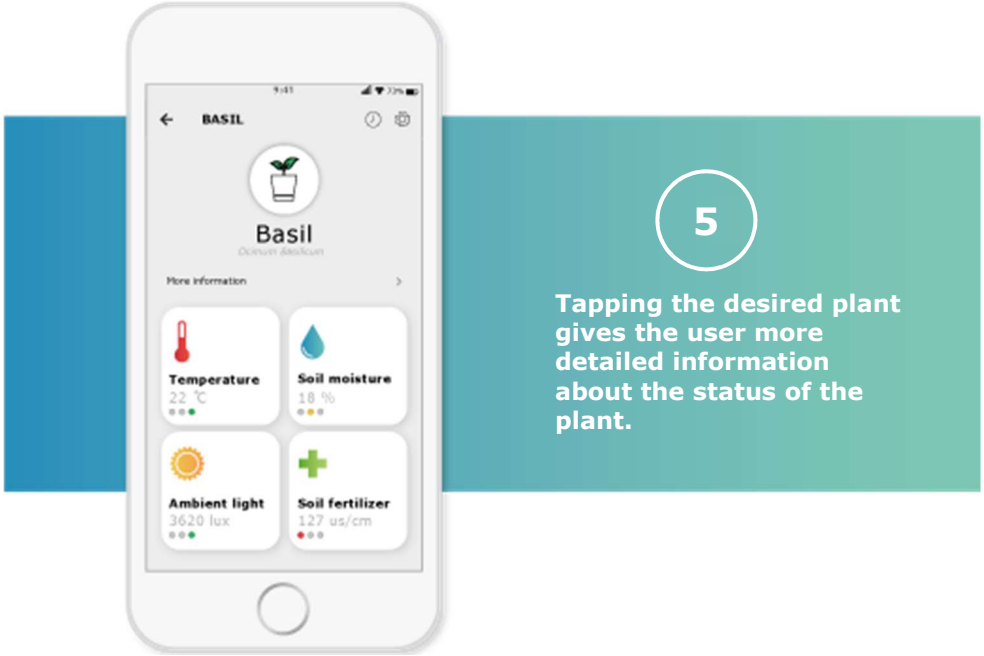


Figure 6.10 Detailed information about plant status.

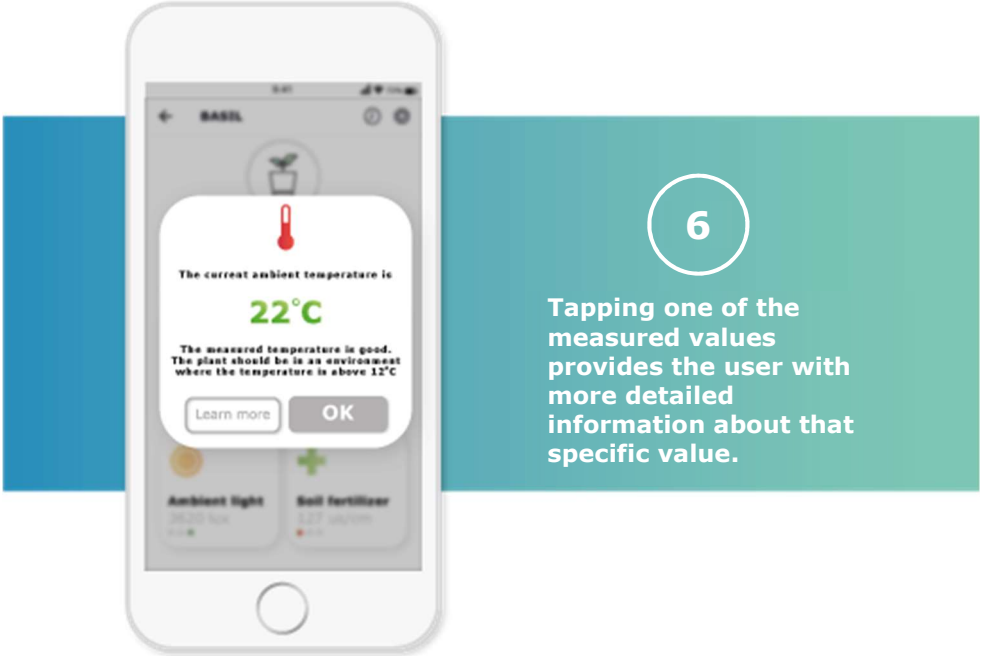


Figure 6.11 Detailed information about measured values.

6.1.1.2 Smart plant monitor

The idea of a stand-alone sensor which monitors the status of the user's plants is based in the same user cases and data collection as the smart plant pot aforementioned. Although the integration of sensors into a product as the plant pot is advantageous from a consumer perspective (the technology becomes less apparent), offering a stand-alone sensor which offers the same information as the integrated version is desirable in this case. Having a highly portable sensor allows the user to themselves decide where the monitoring should take place and does not limit the user to an IKEA pot but rather maximises the available places where the sensor could be used.

The proposed concept uses the same technology as the Smart Plant Pot and provides the user with the same type of information; soil moisture, soil fertilisation, ambient temperature and ambient light. Figure 6.12 and Figure 6.13 shows a sketch of the initial idea and an example of how a finished product could look.

An added functionality is however presented in the stand-alone version as it should be IP67-classified, meaning it can be used outdoors. However, the user should be made aware of the distance limitations the Zigbee communication standard presents as the sensor cannot be placed too far from the TRÅDFRI Gateway. Should the user however purchase several sensors, the mesh technology present in Zigbee means that the sensors can use other sensors as nodes to pass information greater distances, meaning the functional range of the sensor usage increases.

The same interaction is presented with the stand-alone sensor as with the smart plant pot, meaning four RGB LEDs will be present which indicates the status of their respective monitored value. The user interface design for the stand-alone sensor would be the same as for the smart plant pot with the same information displayed to the user. Figure 6.14 shows a construction example of the smart plant monitor.

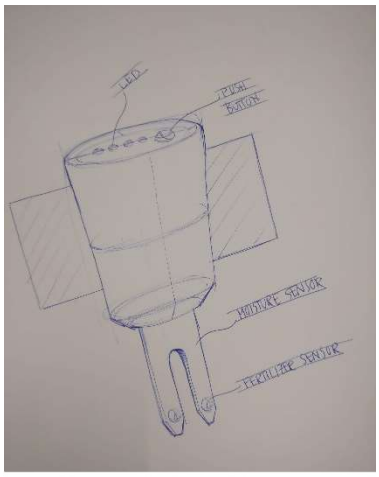


Figure 6.12 First idea sketch

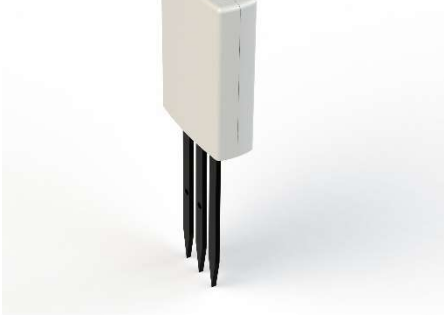


Figure 6.13 Example design

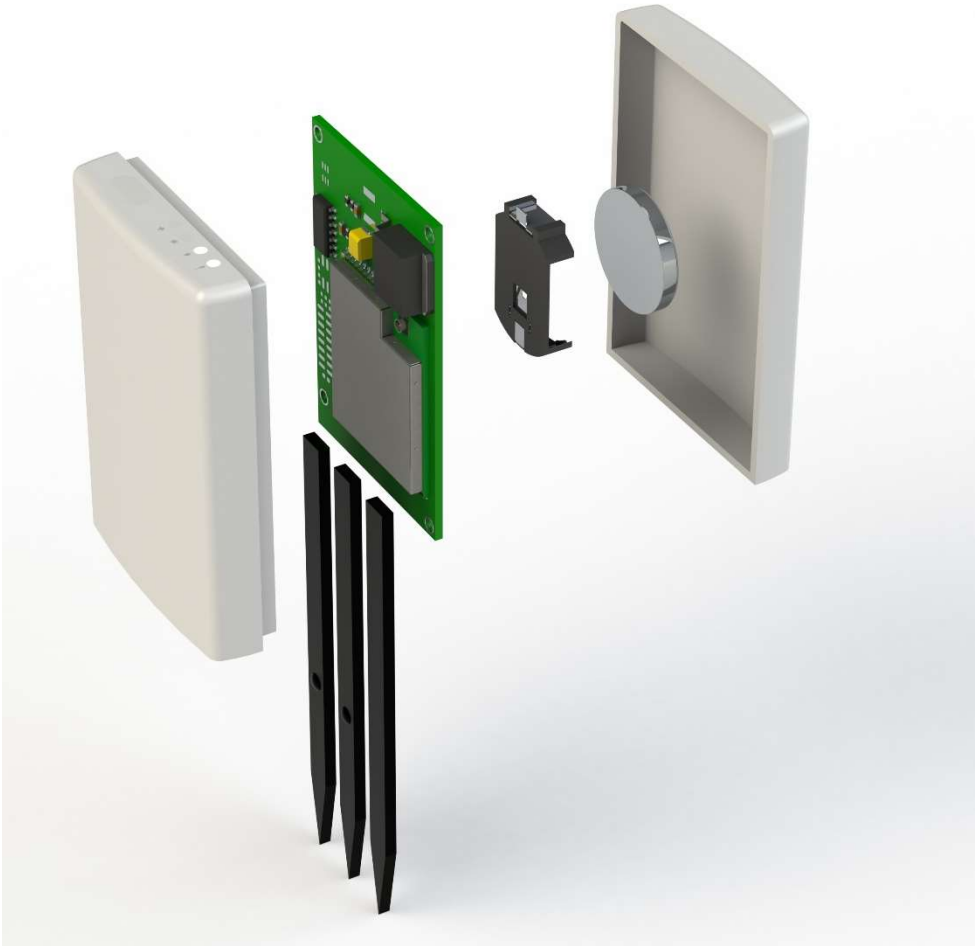


Figure 6.14 Exploded view of the Smart plant monitor.

6.1.1.3 Smart hydroponics monitoring

Today, IKEA offers a range of hydroponic products which are used for growing plants in water instead of in soil (IKEA, 2018c). IKEA's range of hydroponic products include cultivation units, seeds, cultivations lights and more. As the process of hydroponic cultivation requires certain levels of water, light and fertiliser to optimise the growing process, the integration of sensors in the cultivation unit could help this optimisation.

Using the same types of sensors presented in the smart plant managing section, the user could be provided with relevant information regarding the status of the plants as well as get reminders if values are reaching critical levels.

6.1.2 Smart oven

This product concept is based on the extended development of current IKEA oven KULINARISK which offers the user extended functionality in terms of automation and predefined cooking programs, see Figure 6.15. The user can use the oven to prove doughs, sterilise vessels, dry food or use an array of cooking programs for different meals.

IKEA KULINARISK

- Turbo grill allows you to grill, brown and cook larger dishes and meat all the way through.
- Top and bottom heating is ideal for cooking dishes with a crispy finish and for slow cooking of casseroles.
- You can use bottom heating at the end of cooking to get a crispy bottom on such foods as pies, quiches and pizza.
- You can easily choose the best grill function to cook thin cuts of meat and vegetables or to brown gratins and steaks.

Figure 6.15 IKEA KULINARISK oven with examples of offered functions (IKEA, 2018d)

The proposed concept utilises the functionality of KULINARISK as a base and through the addition of various sensors and a connectivity module, make it a smart oven.

KULINARISK today offers a function where the user can program the oven specifically to certain food (such as roasted chicken) and use the built in weight program in which the user sets the weight of the meal being cooked and the oven adjusts the cooking time accordingly. In the proposed concept, the weighing of the food is done automatically through the implementation of pressure sensors. Through this implementation of sensors the process of cooking becomes further automated.

The concept would also feature a camera in the oven which overlooks the inside, allowing the user to remotely monitor the cooking progress and thus not having to remain constantly in the kitchen during the cooking process. From our user interviews, it became apparent that it was common to leave the kitchen while cooking though many went back and forth to the kitchen to check on the progress. Furthermore, burning food was the most common mistake happening in the kitchen according to the interviewees. By offering a live feed of the cooking progress directly in the user's smartphone they can confidently leave the kitchen and even their home.

Being able to remotely control the oven is a desirable function for some according to our user interviews. It is a functionality that would allow for a more efficient cooking process as the user can preheat the oven from their smartphone. In the presented concept, the addition of remote control would make the base oven KULINARISK primed for a role in the smart home as it would allow other devices to control the oven, e.g. should a smart smoke alarm detect a fire, it could turn off the oven. The technology needed for this implementation is available today but the work needed to implement each sensor differs in complexity.

6.1.3 Range Hood with integrated sensors and connectivity

As stated in the previous section, a majority of the interviewees claimed to frequently leave the kitchen when cooking. Combining this with the fact that users, according to our study, are keen on leaving their home in a condition they are confident is safe means that allowing for monitoring of potentially hazardous situations would be beneficial.

Through the integration of different sensors in a range hood, which are available on the market today, as well as a communication module, remote monitoring of certain key factors could be achieved. In this sensor implementation example, three different sensors are proposed to be integrated in a range hood.

6.1.3.1 Flame sensor

A flame sensor detects the presence of fire or flames. This can be done in different ways, e.g. a near IR array flame sensor which confirms the presence of flames by reading near IR radiation (Petro-online.com, 2014). By integrating a flame sensor in a range hood which monitors the cooking area of the oven, hazardous situations involving flames could be avoided. Should the user have the aforementioned smart oven, the range hood could communicate to the oven when a flame is detected, causing the oven or cooktop to shut off. Although a problem may occur when the user has a gas cooktop (as in this case the flame is always present), the flame sensor could still function as a safety feature, notifying the user if a flame is detected when the user leaves their home.

6.1.3.2 Gas detector

Gas detectors measure the concentration of certain gases in air and are employed to prevent toxic exposure and fires. A common detector of combustible gases is a catalytic sensor which reacts to resistive change due to oxidation which in turn can trigger a signal. (Thomasnet.com, n.d.) As several of the interviewees with international living experience states that cooking with gas is still common globally, the integration of a gas detector in a range hood is beneficial. The gas detector would alert the user if a predefined threshold of gas concentration is surpassed and could possibly communicate with a smart gas cooktop to force shut off.

6.1.3.3 Proximity sensor

As stated previously, the user interviews showed that it was common to leave the kitchen while cooking. By integrating a proximity sensor in the range hood, it would be possible for the range hood to keep track of when a user is present at the cooking station or away. This information in combination with the information from the two previously mentioned sensors would allow for a safety system which would alert the users should they leave the cooking station for an extended period of time and a high concentration of gas or a flame is detected.

6.1.4 Smart washing appliances

An implementation example of sensors in a smart home from a washing perspective is to integrate various sensors in dishwashers and washing machines to simplify the process of washing clothes or dishes. A first implementation step proposed is the addition of a sensor to keep track of remaining amount of laundry detergent or detergent tabs for dishwasher. By adding a compartment which houses laundry detergent or detergent tabs and distribute this automatically while keeping track of remaining amount would simplify the process for the user. With a communication module integrated, the information of detergent levels could be provided to the user through notifications, allowing the user to keep track and purchase new detergent when required. An extended functionality, should the user utilise an online shopping service, would be an automatic ordering of new detergent when low amounts are detected by the integrated sensors.

To keep track of amounts, using a load cell would measure amounts in weight allowing for an easy monitoring of remaining volumes for the user. For monitoring remaining dishwasher tabs, an ultrasonic sensor could be used as it measures distances, allowing for an easy tracking of remaining tabs based on distance.

In line with IKEA's sustainability goals, a further development using sensor technology is the integration of sensors to monitor water quality as a step in a circulatory water management system. By utilising filter technology and sensors such as pH-sensors, turbidity sensors and dissolved oxygen sensors the water quality can be determined (Floridakeys.noaa.gov, 2011). If the water quality is deemed sufficient, the water can be reused in the washing process.

From the user interviews, it became evident that lowered energy consumption through smart devices was desirable. By adding remote control of washing appliances and offering a service which monitors the electricity price, users could run their appliances during times when prices are low. The technology needed for these types of implementation already exists but might need some development to reach a price level suitable for the many people.

6.1.5 Flame detector in smoke alarms

Smoke detectors are present in homes around the globe and is a device where smart alternatives are present today, e.g. Nest offers a smart smoke alarm which can alert the user's smartphone when it detects smoke. A proposed extended feature to include in smart smoke alarms is flame detectors. From the user interviews, it became apparent that situations containing fire (e.g. candles or gas stoves) could be a source of worry when the user left their homes. Worth noting is that, as stated in the user insights in chapter 4, users often miss notifications when leaving their home which indicates that an alternative method for getting the users attention if they leave their home in a possibly hazardous state would be required.

Incorporating flame detectors in a smoke alarm would allow for the tracking of flames and could notify users if they left home while a flame was detected. The addition of flame detection to smoke alarms is also seen as a natural progression of implemented functions given the original purpose of the smoke alarm. No sources of this type of implementation of flame sensors have been found but it would seem plausible that this type of implementation is possible in the near future with some development work being made. A possible user scenario involving the smart smoke alarm is shown in Figure 6.16.

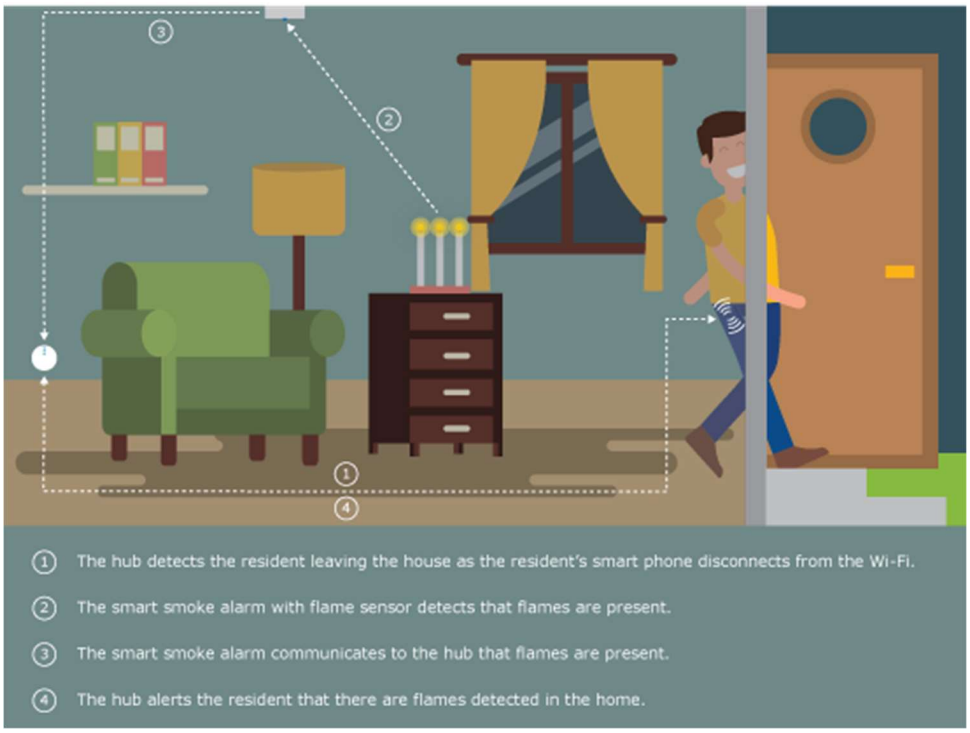


Figure 6.16 Scenario involving the smart smoke detector with flame sensor

6.1.6 Smart delivery box

E-commerce continues to grow around the world and the past three years has seen an increase from 7,4 % to 10,2 % in retail e-commerce sales as a percent of global retail sales. (Statista, 2018a)

As the amount of goods purchased online will continue to increase according to Statista (2018), the need for a developed delivery service is required. By offering consumers a smart delivery box which allows remote control of access and feedback when a package has been delivered, the need to be at home to receive the delivery is eliminated. If a cooling system was incorporated, it could be used to receive groceries when the residents are not home.

From a sensory perspective, a smart delivery box could include a QR-scanner as the package would be scanned upon delivery to notify the resident that a package has been delivered. A load cell could also be present to verify that a package truly was placed in the box. By integrating a code lock to gain access to the delivery box, the user can hand out temporary codes to delivery personnel and thus feel confident that their delivery will not be stolen. By incorporating a cooling compartment, users would be able to receive deliveries of groceries as well, thus eliminating the need to be home during delivery. The proposed technology is widely present today and this type of solution would be able to be implemented without further development.

Implementing a smart delivery box in a house versus an apartment would be different - for a house resident, a single box per house could be placed as desired whereas in an apartment building, a joint multi-compartment solution would be proposed. Figure 6.17 shows a current solution for public places where deliveries can be picked up whenever desirable by the client and a similar solution could be developed for apartment buildings.

Figure 6.17 Amazon Locker where deliveries can be picked up whenever desirable.

6.1.7 Smart radiator thermostat

When asked what they would like to happen in their homes when they are not present, 45 % of the user interviewees stated that they wished their energy consumption would be lower when they were away. From the user interviews it became evident that many households has a relatively static energy consumption whether the residents are home or not, especially when it comes to heating.

Domestic boilers and radiators are seeing a high installation rate in Europe and North America and combined occupy for nearly a third of the heating equipment market by volume in these regions (Businesswire.com, 2017). Based on this research, offering a radiator thermostat valve which allows for remote controlling and as a part of a smart home would be beneficial both for IKEA and for its consumers.

Apart from a motor to control the temperature in the radiator, the thermostatic valve would include a temperature sensor and a humidity sensor, all of which exists on the market today. The information from the sensors would be communicated to the user, allowing for remote monitoring and controlling. Through integrated controls in the TRÅDFRI-app, the user would be able to set specific programs to lower energy consumption as pleased - e.g. during the night, when at work or at holiday. Figure 6.18 shows an example of how the user interface could look for a smart radiator thermostat valve.

Figure 6.18 Example of user interface design for smart radiator thermostat valve

6.1.8 Smart Mirror

As mirrors are common in many homes and offers a natural interaction with its users, using this product as a source of information display is logical. From an IKEA perspective, as mirrors are a part of their current product range, developing this product segment towards the smart home is a logical next step.

A smart mirror would feature information displayed at a certain location on the mirror, customised to the person in front of the mirror at the time. The information could feature calendar entries, weather information, notes, etc. In Figure 6.19, an example of a smart mirror is shown.

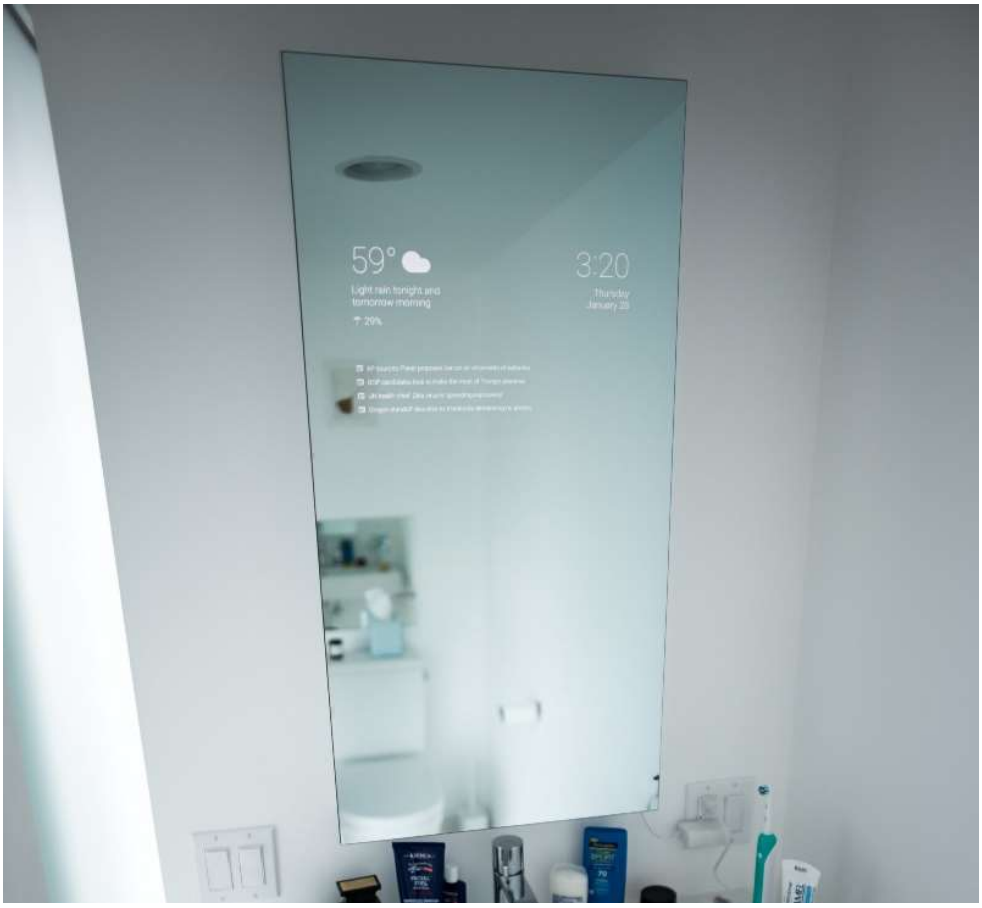


Figure 6.19 How a Smart mirror can look. (Medium.com, 2016)

In order to customise the information displayed to each person, presence detection and identifying individuals are features required. For implementation today, this could be achieved through a smartphone Bluetooth pairing where the RSSI (Received Signal Strength Indicator) can be used to estimate the distance between the mirror and the smartphone based on the received signal strength (Jung, Kang and Bae, 2013). Combining this technology with a proximity sensor for presence detection would allow the mirror to activate when the proximity sensor received an input signal and the identification of the user to be performed by identifying the smartphone closest through RSSI. However, as stated in the user insights in chapter 4, the use of familiar technology such as Bluetooth brings expectations of a robust and trustworthy system.

Another possible solution is Facial Recognition Technology (FRT) for identifying individual users. Integrating the facial recognition hardware and software emerging in smartphones today in a mirror would allow for quick identification of the person in front of the mirror and therefore make individualised information displayed. The information could be retrieved from the user's smartphone or other smart devices present in the household. In Figure 6.20, an example of how a smart mirror could be constructed is shown.

Both of these technologies are available today and have been shown to work. However, the facial recognition technology is still in its early days and is expensive to incorporate. Further development will reduce pricing, making it more available to the general public.

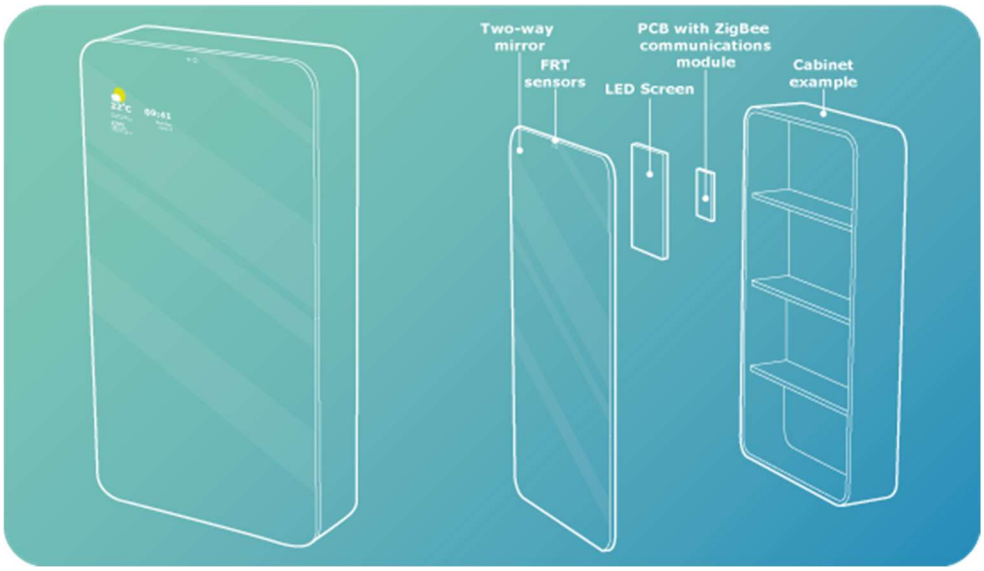


Figure 6.20 How a smart mirror can be constructed and designed.

6.1.9 Sleep Tracking

A possible implementation example of sensors in a smart home that suits IKEA's current range of products well is to use sensors for sleep tracking. As IKEA today offers a wide variety of products related to sleep (beds, duvets, mattresses, pillows, etc.), using this range as base for implementation of smart functionality is advantageous.

Sleep trackers available today uses various sensors to track heart rate, sleep quality, breathing, snoring and more. However, from our user interviews, it became apparent that users need clear user cases to see the benefit of smart devices and merely getting data of your sleeping pattern without clear indications on how to use the data is not enough. It was however concluded that analysing sleep data is not a task for IKEA but a partnership with a suitable company could be a way forward in which IKEA provides the technology for sleep tracking and the partnering company would handle the analysis of the sleep data.

A possible implementation strategy of sensors would be to utilise ballistocardiography, a technique which monitors the movements of the body imparted by the ballistic forces associated with cardiac contraction and ejection of blood (Meshb.nlm.nih.gov, 2018). This method is readily available for sleep quality monitoring with commercial sensors using the technique available for purchase today.

Integrating sleep tracking in an IKEA smart home would mean that the integrated sensors could communicate the current sleep status of the user to the rest of the home. For example, gradually turning on bedroom lights and increasing the temperature in the house when the sensors detects a light sleep during the 30 min prior to a set alarm to allow for a more pleasant awakening. Figure 6.21 illustrates possible interaction between the integrated sleep tracker and other smart devices.

According to the report *Digital and disrupted: All change for healthcare* (Roland Berger, 2016), the global digital health market will increase by an estimated 75 % between 2017 and 2020. In a future scenario, the sleeping data gathered by the integrated sensors could be used by digital health providers to better monitor the overall health of the users and help them live healthier lives.

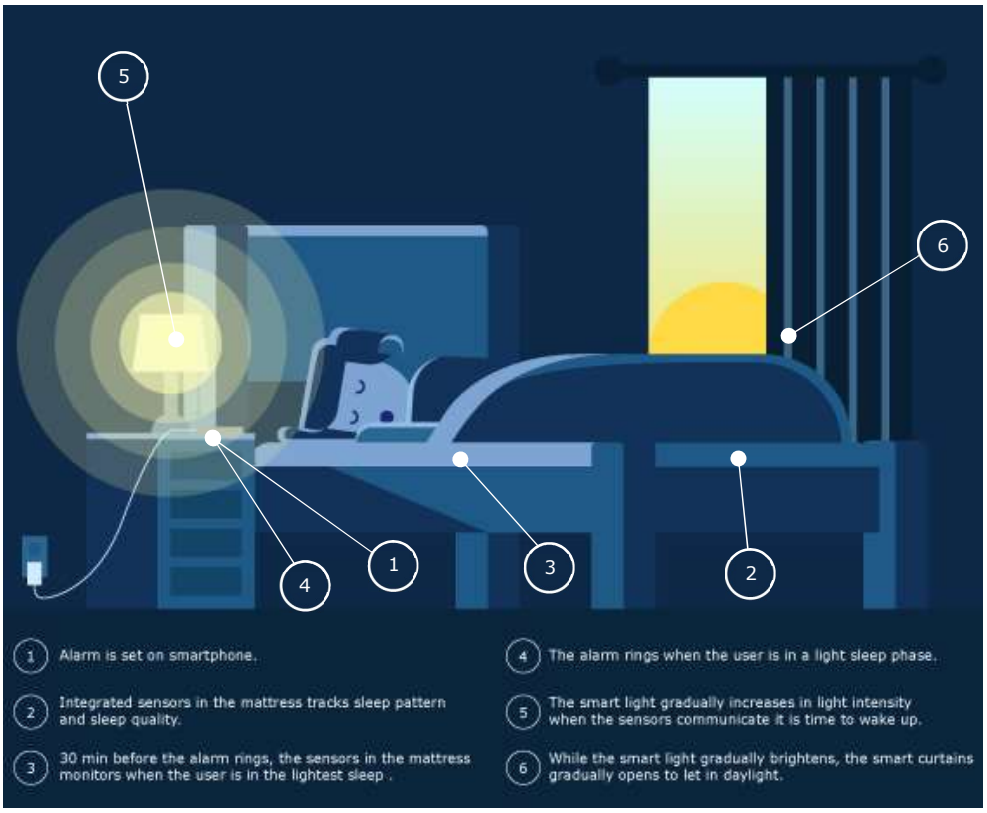


Figure 6.21 Possible scenario using an integrated sleep tracker

6.2 Key insights

The discussion section of the report will be the main result of the thesis and will be divided into two categories, discussion of the subject at hand and of the methods used. Each category will be divided into several subcategories to more clearly present the topics deemed important enough to bring forth in the report.

6.2.1 Personal privacy

To be able to find refuge from one's surroundings inside one's home is something a lot of us take for granted and if people feel the need to shield themselves further from the gaze of others they close the curtains or plant a hedge. However, ever since the webcam started to enter the general populace homes, there exists a possible window into our most private spaces. Today, webcams are a standard component of most laptops and smart speakers are becoming more widespread, even if they are still mostly seen with the early adopters. Add to this the information a potential hacker could gain by knowing, for example, when your smart coffee maker is started or your fridge has not been opened for two days. It is not hard for people to imagine all manner of terrible situations that could arise from a hacked appliance in their homes.

More than a fifth of respondents in GfK's study about the potential for people to acquire smart devices state that they have concerns regarding personal privacy when asked about what barriers influence their willingness to purchase smart products (GfK, 2015). This is data that validates the user surveys wherein several people stated their distrust towards products with the ability to monitor them in their homes, such as cameras and smart speakers. Some interviewees even stated that they were suspicious towards these products even if they were just connected to a local area network. This shows that it is not only necessary to have safe products, convincing the user that it is safe is just as important.

One way of making people feel more confident about when their products are active is to give them some form of feedback. Take for example the Amazon Echo smart speaker. Whenever the speaker is actively listening for commands, it gives an audio cue and then lights up until it has finished listening. This gives the user a clear indicator of when what they are saying is sent for processing. Another example would be the small LED that is present on many cameras with video recording functions, a glowing red light means that you are now being recorded. If for some reason your devices have been compromised, you are at least conscious of it and can take appropriate counter-measures. This is of course reliant on the fact that the feedback mechanism is hard-wired and not able to be disabled by the intruder.

It still does not solve the issue with the “always listening” part of the smart speaker and smartphone assistants which is necessary to catch the activation command, e.g. “Hey Google” or “Alexa.” How can one be sure that the company collects no other data when the speaker is in stand-by mode? For now, the only solution is to place your trust in the company responsible for the product.

The trust for companies is a factor that will have an increasing importance as smart products and subsequent data gathering enters peoples’ homes. Ensuring that the company is seen as trustworthy and will respect its customers might possibly have a major impact on sales.

6.2.2 Safety - smart locks, smoke detectors, etc.

Just as with the issue of products invading on your personal privacy, using products meant to keep you safe are just as dependent on the user’s trust to be let inside people’s homes. Because the stakes are much higher, people’s demands on the product increase as well. If your smart light bulb is compromised, you will probably just be mildly annoyed by it turning on and off but if someone is able to open your front door - then everything you own and your own personal safety might be at hazard.

When asked in the survey if they would trust a smart lock today, half of the respondents said that they would not. One interviewee said about smart locks “It is super-convenient, but there HAS to be a risk.” Even if the interviewee might not have had an understanding of the exact way the system could be compromised, he was convinced that, in some way, it was possible to hack.

With smart smoke detectors, this issue may not be as significant as they retain their original function with the added functionality of connectivity. This means that the trust people put in smoke detectors might transferred to the smart smoke detector since that base function stays the same and the smart functionality is added on top of the base product.

Several people stated that they need to completely trust a safety product to be willing to use it in their homes. The key word here being the word ‘trust’.

6.2.3 Integrated sensors vs. stand-alone sensors

Most sensors that are bought by the general population come as integrated parts in electronic products such as smartphones, TVs or ovens but stand-alone sensors are still mostly a product used by the industry to create custom-fit solutions for process monitoring. Some sensors that could be classified as stand-alone sensors are commonplace in people's homes, mainly thermometers and motion sensors. These products usually come as a package deal with a motion sensor connected to a lighting solution or a thermometer connected to a weather station monitor, all in a package with communication and programming pre-set. This allows for easy plug 'n' play use of the products with only minor installation work needed. Some people buy stand-alone sensors to create their own custom-fit smart home systems but these are in the minority. It is simply too complicated and time consuming for most people to do this kind of set-up by themselves, even if the product comes as a package with communication module and energy source already implemented.

With the smart home starting to become a well-known phenomenon (GfK, p.23), there might be a rising interest in more stand-alone sensors for people's homes. It still depends on these sensors being easy-to-install products but being able to retrofit non-connected products or increase the functionality of connected products through a sensor-kit will allow those with less money to spare to take advantage of the improvements smart devices are able to bring into our lives.

It will still be easier for people to adopt the use of sensors through other products. As seen in the user studies, they just want things to work and the easiest solution for this is to not have them do any extra installation procedures other than plugging their device into an outlet.

6.2.4 Sensors as part of the AI-controlled home

Through their smart speakers, companies like Google, Amazon and Apple are all pushing for the voice assistant to become a natural occurrence in homes all around the world. The voice assistants are able to do things like controlling your lights, set timers and reminders, place orders and through condition based systems, often referred to as 'scenes', able to control groups of devices such as lighting & sound to quickly change the environment to suit an activity or a certain mood. The technology is still in its infancy but is quickly evolving and it can be seen as a first step of having your home controlled by an artificial intelligence (AI).

To really make your home smarter, an AI needs to be able to properly assess the status of you, your family and of the home itself. It needs to see, feel and hear what is going on to be able to respond accordingly and this is where sensors enter the picture. As the equivalent to the human senses, sensors can register most of the things humans are able to perceive from our surroundings.

They have the added benefit of being able to register physical phenomena beyond our capabilities, such as light and sound outside of the spectra perceivable by our eyes and ears.

Stand-alone sensors might be a new business area for companies to explore if they want to compete in the smart home sector, but there will probably be data which can be acquired through other smart products. You might have connected radiator thermostats which read the ambient temperature or you might have light sensors connected to the motorised awnings. Preferably, these would be able to transmit their readings to the AI to be used as input for controlling other devices. Products with these capabilities might have a market edge over similar products if they are equal in other aspects.

Ambient light & temperature can be used for controlling lamps, curtains & thermostats, sensors on doors & windows can remind you to close & lock when leaving home or going to bed and tracking & recognition of individuals inside the home opens the possibility for personalised settings being automated. Connect this system to your personal calendar, weather information and other online services and you could potentially have an AI capable of assisting you in most aspects of your life.

6.2.5 Energy harvesting

One of the main drawbacks of adding smart capabilities to products is that you often increase or even create an energy demand. Many products, such as IKEA's TRÅDFRI remotes, rely on batteries to solve this issue. With an expected battery life-time of 2 years and an easily changed CR2032 battery (IKEA, 2018), this is only a minor inconvenience for the user but it would of course have been an improvement if no battery was needed, both for convenience sake but maybe more importantly from a sustainability point of view.

A solution to this is the previously mentioned concept of using ambient sources of potential energy to power products, so called energy harvesting. One of the ways of harvesting ambient energy is to convert vibrations into current. There are several experiments with the goal of using the movement of people as an energy source, one example being floor tiles which generates energy when stepped on. (Huffington Post, 2016)

It is however important to design these systems to not hinder the "user" by exhausting them or hinder their movements. Having a system that will make daily tasks more difficult is simply not attractive in a customer's point of view as evidenced by the user survey. (Priya et. Inman, 2008, p. 431)

6.2.6 Biometrics & presence detection

Using biometrics instead of identifiers such as digital keycards significantly reduces the risk of unauthorised people getting access with an identifier belonging to someone else. It also removes the need to remember to bring physical object identifiers or remembering a PIN, errors humans are prone to make.

In a more private setting being able to accurately identify members of a household can allow for custom-tailored solutions regarding lighting, heating, air-conditioning and more, to have an automatic response in regard to which individuals occupy which area of the home.

However, biometric information is something very personal and many people feel an aversion about sharing this information. In a study conducted in Great Britain in 2016, 61 % of the respondents said that they favoured passwords over biometric authentication. 42 % stated that they did not want companies to store and use their biometric data. (Biometric Technology Today, 2016)

In study conducted in Sweden among smartphone users, 38 % of all smartphone users said that they had access to a fingerprint reader in their smartphone. A majority of these 38 % said that they used their fingerprint reader to unlock their phone. (Deloitte, 2016)

Fingerprint readers are becoming a standard feature with 67 % of smartphones shipping in 2018 having the feature. (Statista, 2018b)

This means that the amount of users having the ability to use a means of biometric identification will steadily increase as people upgrade to a new phone, creating possibilities for innovation that takes advantage of this fact.

Using biometrics allows people to live a more convenient life in exchange for sharing very personal data. As such, the user balances the benefits given against their trust for the company responsible for the product or service. This means that a company's customer approval rating might severely affect the use of their products if biometric information is a requirement to use it.

6.2.7 Data collection & Big data

With the advent of products connected to the internet, the possibility for companies to gather large amounts of user data is a fact. User data is a valuable commodity, as evidenced by companies like Facebook which provide their services for free but still thrive because of how they market the data provided by their users.

For IKEA, data gathering could allow for more optimised design of their products, leading to increased customer value and increased margins on sales.

It could also facilitate improvements in software design, such as duty cycle improvements for products with intermittent active patterns as well as more user-friendly mobile applications.

In Deloitte's *Global Mobile Consumer Survey 2016 - Swedish cut (2016),* 31 % of mobile phone owners stated that they never share personal information in any form. Since data is shared as soon as you start your phone, accessing a browser or using any social media, this shows that a significant part of people are completely unaware of the fact that they are sharing a lot of information with many different companies every day. A fact evidenced by the following quote in the same study: "only 27 per cent of the respondents claimed to have shared their names with at least one organisation online, despite 68 per cent of the respondents having stated that they have used Facebook."

As seen in the *User insights* chapter, the acceptance of being monitored is highly correlated with the benefits given by the device. Having no idea of who has access to the data the user shares through a certain product could possibly impede the willingness to acquire said product. Furthermore, if people are unknowingly sharing their data and later on finds out about this, they are bound to be upset since they are likely to feel duped.

If a company like IKEA starts to collect data from their users, it would be a beneficial strategy to be transparent regarding what data is collected and why. Give the users the ability to opt out of the data gathering and rewarding those that choose to share their data could further improve IKEA's public image while still allowing for data gathering. Being proactive in this area may increase customer approval.

6.2.8 Energy consumption of standby units

Integrating smart functions into everyday objects like lamps, coffee makers and other things which usually are completely turned off cannot avoid increasing the overall energy consumption of the household. Since the receiver of the device need to be ready for incoming commands, it always need to listen to its surroundings - which requires electricity. If the device exists in a mesh network, it will also need to transmit signals which requires an even higher amount of electricity. Albeit small amounts of power, in a society where the goal is to decrease waste of our resources this can be off-putting for some people. As evidenced in the user survey where people put forward energy saving by lowering heating as desirable, saving on energy is a common goal among people.

There is however a good case to be made that connected products can easily lower the overall household energy consumption. By programming the devices to turn themselves off when the user is not at home or in the specific room could save energy in comparison with non-connected devices which have a tendency to be left on when they do not needed to be.

There is also the case with the smart thermostat which can lower the energy consumption of households by up to 10-12 % of heating usage. (Nest Labs, 2015)

For IKEA, the challenge is to create compelling user cases where they can show people how the net energy consumption can be lowered through connected devices as well as designing software that is more efficient. Having access to thermostat data is one area where IKEA could possibly benefit from data collection to improve the software.

6.2.9 Product lifetime and recycling

A new challenge arises with the introduction of smart devices concerning product lifetime and recycling. When comparing a smart device to its non-smart counterpart, the recycling is significantly more challenging due to electronic components or batteries which require special handling. For IKEA, as a furniture retailer, this raises questions regarding responsibility after a sale - how can IKEA help its customers in recycling their smart devices, as some inevitably will become defective and discarded? Does IKEA have any responsibilities when the warranty period has expired to handle defective products? These are questions essential to answer for a retailer of smart devices.

Regarding product lifetime, a different challenge rises. For example, when selling a table to a customer, the table will not require any direct service from IKEA after its been sold. Assuming that the table survives its expected lifetime, IKEA will not have anything to do with it once it has been sold. When selling smart devices, the customers expect IKEA to supply the device with updates to keep it functioning while the technology develops further. Thus a question arises - how long should IKEA provide service and updates for their smart devices?

An alternative is for IKEA to sell their smart devices with a predefined life expectancy during which they will provide adequate updates and services. Products such as lights should still function after the expiration date but the user will, upon purchase, be aware that functionality of the product may be affected after a certain amount of time. Ideally, this life expectancy would correlate well to the overall life expectancy of the product.

This alternative can be beneficial both for IKEA and for the user in the long run - IKEA will have an established timeline to work towards and the user will know that the functionality will remain supported during the predefined life expectancy.

6.2.10 The importance of feedback and visualisation

As presented in the user insights, without adequate feedback of an action, the action was less likely to occur. This was especially evident amongst the interviewees in the case of doing dishes by hand where the water wastage was often ignored. Norman (2013) states that feedback is communicating the results of an action and that feedback needs to be informative. In a smart home, sensors can play a big part in monitoring utilities but the benefit of monitoring is only present if the information is provided to the user with explanations of their actions. If a user is presented with data of how much water they used for showering during a month and how shortening their showers by a given time could impact their expenses or the environment, the user is more likely to alter their behaviour.

The visualisation of data and examples of ways to improve are thus convincing user cases. If the purchase of a smart device come with a tangible and real reward, (e.g. a lowered electrical bill) consumers will be more likely to buy a product. If long-term expenses can be lowered, users are also more likely to justify a more expensive one-time purchase.

6.2.11 Building strong user cases

From both the user insights, the literature review and information from IKEA, it became evident that strong and convincing user cases are essential when developing new smart devices for the smart home. Developing smart devices does not only need to be based in real user needs but also need to convince the user that the addition of smart functionality will increase the user value of the device. If the user can remotely start a dishwasher but still need to load it with dirty dishes, is the addition of remote control really necessary? Alternatively, if you can remotely start your coffee maker but still have to put water and coffee grounds in it, is it really more convenient than before? These are examples of questions that arises when developing smart devices and must be convincingly answered prior to moving forward with the development.

As interviewee R said: *A smart solution has to be more convenient than the dumb alternative!*

7 Discussion

This chapter describes reflections about the execution of the project and what can be done in a potential next step. Areas mentioned are the scope of the project, the research phase and further explorations.

7.1 Reflections about the process

7.1.1 Scope of the project

The scope of this thesis was consciously set wide to allow for an exploring and investigating project without many limitations. This was initially viewed as intriguing and inspiring but as the process progressed, it became evident that the width of the project also meant a struggle to decide what was important and how to move forward. In addition, as the end result of the thesis was not decided at the start of the project, it was challenging to figure out the best path.

In retrospect, having a more clearly defined scope with a narrower focus would have been advantageous as well as having a clear understanding of the end result earlier in the process. However, looking back at the process, the actual outcome is considered reasonable and suitable.

7.1.2 Interviews, observation & analysis

Despite not knowing the exact result of the thesis, it was early on decided that the research part of the project would focus on the users and that their needs would be the primary source for the project. As IKEA is a company driven by the needs of its customers and identifying the life at home as it truly is, it was decided to get into the lives of IKEA customers through interviews and observations performed in their homes. In order to facilitate this, friends and family were targeted which may be subject to scrutiny as it can be said to be a case of convenience selection where the subjects were not representative for the target groups. However, it was deemed that it was a non-significant source of error in regards to the scope of the project. Ideally, all interviews would have been held in the homes of the interviewees but this was considered undoable due to time restrictions and the scope of the project.

The authors decided to implement a more qualitative approach to user surveying since it was deemed that in-depth answers would bring better insight into the process than what a quantitative approach would do.

The interviews held with employees at IoS might be seen as contradictory when wanting to explore the views held by "the many people". However, a majority of these employees were not from the IKEA Home Smart department at IoS, but from the Lighting department and as such, they were not notably more tech savvy regarding sensors and smart homes than the general populace. The employees from the IKEA Home Smart department expressed opinions indicating greater acceptance towards smart technology inside their homes but their general needs were still equivalent to those of the other interviewees. The conclusion of the project team was that the combined views and beliefs of the interviewed employees could be considered representative of IKEA customers. It would have been beneficial to confirm this by making a survey at an IKEA store but this was not possible seen to the scope of the project.

In retrospect, the amount of interviews may have been too great for a project of this size. Although it provides a sound platform for further development, it was a time consuming process with several weeks being spent at interviews which could have been spent at other steps in the process.

Furthermore, despite a deliberate strategy in having semi-structured interviews, it was challenging creating questions which neither were too open or too targeted. Looking at the interview guide having completed the project, it is evident some questions were too targeted and some too open. This may however have been another factor influenced by a lack of a clear end goal as it was difficult knowing whether the provided answers would provide satisfactory information for the following steps of the process. Moreover, it would have been wise to attempt to ask more questions asking 'why?' as it would have provided more detailed information in some instances. For example, when asking interviewees about their attitude towards energy consumption, it would have been beneficial to have more clear answers as to why they wanted to save energy – i.e. was it for economical reasons, environmental reasons or both? This would have eliminated uncertainties occurring when clustering the data from the interviews.

During the home interviews, observations were also performed as a second method for gaining insight into the needs of users. In retrospect however, the information retrieved from the observations were limited, especially in relation to the amount of time they took. In addition, the observation would preferably have been performed with all interviewees but because of the time scope of this project it was deemed too time consuming.

7.1.3 Deciding the outcome

Initially, the outcome of the project was projected to be more product concept oriented with potential prototypes presented. However, as the user research became a larger part of the project than first expected, it was decided that creating prototypes and focusing on product development would have been too time consuming. Therefore, focus instead was targeted at analysing and presenting the insights from the interviews and combining these with examples of possible solution for implementing sensors in a smart home.

This meant that the project became slightly more user oriented than technology oriented, a shift in focus which was not initially planned.

When analysing the data from the research, deciding what method should be used posed a challenge. Using clustering and bundling of statements provided a frame of reference for the continued development but was difficult to use when some answers were considered important despite only a few interviewees providing them. Should the project be repeated, using a different method for analysing the interview answers may be advantageous.

As there is a vast amount of sensors, it was challenging trying to identify different sensor implementation alternatives. Having no restrictions when looking at different types of sensors proved difficult since there was no way of knowing whether there existed a different sensor which may have suited the implementation example better.

It would have been advantageous to narrow down the type of sensors the project would include, as it would allow for a more thorough evaluation of possible sensor implementation solutions.

7.1.4 Project management insights

This project was the first of its scope undertaken by the project team where previous larger projects were half in size seen to the amount of hours expected to be allocated for work. As such, it was hard to properly estimate the time needed for each part of the project.

For example, user surveys performed in other courses at the university have had much shorter time spans to be completed and were difficult to use as guidelines for this project since they were of such a small scope.

Despite this, the time plan has been a great tool to have an overview of what needs to be done in the project and to know how to re-allocate the time left for the things that still needed to be completed.

At the start of the project, it was decided to write the report in parallel with the work being done in the project. However, it became evident quite early on that it was difficult to keep this work up, in part because of the openness of the project. It was decided to have the report writing be offset to not risk writing a lot of text in vain.

7.2 Further explorations

The exploratory nature of this project suggests that there are areas of interest for IKEA to investigate further. As the main focus has been at finding opportunity areas and strong user cases, further work needs to be put into the technological aspect such as the appropriate sensor technology for each user case, the user interfaces and how the different products should communicate with each other.

For example, the use of ballistocardiography for measuring sleep quality is to be viewed as just one example of sensor implementation. Further research into sensors for monitoring sleep would be advantageous to identify the most appropriate technology for IKEA.

The user interface design presented for the Smart plant pot should also be further developed and tested with users to evaluate its performance. The presented design differs from the current TRÅDFRI-app as it was deemed the current version lacked the user interface to implement the desired elements of the presented implementation examples.

As this project has not focused notably at the economical aspect of the implementation, this should be examined more extensively. Although the ‘low price’ aspect of the Democratic Design principles was considered when discussing implementation possibilities, no further investigation into pricing and costs was done.

Worth noting is also that a few of the implementation examples (such as a smart oven or a smart dishwasher) presented in chapter 6 may appear as 'premium' products today. However, as the trend is moving towards more and more smart devices, it was deemed that the features of a smart oven or dishwasher would be considered standard within a not too distant future and thus the probability of IKEA offering these types of products in the future is high.

For IKEA, the presented results could be used in different ways. The examples of smart devices with different sensors implemented could be seen as inspiration for future research into areas of smart devices where IKEA could venture. The presented key findings should be used as guidance moving forward in the smart home implementation as they cover important aspects and challenges that arises when introducing monitoring devices in the homes of people.

8 Conclusions

In this chapter, the final thoughts and conclusions of the project are presented. The research questions are answered based on the presented result and discussed briefly. A short summary of the investigated topic is also presented.

8.1 Answering the research questions

I. Which needs can be satisfied by implementing sensors in the smart home?

Sensors will play a vital part in the smart homes of tomorrow and are already frequently used in smart devices. The project has identified user needs which can be solved through the implementation of sensor technology and these needs are presented in chapter 4.4, *User cases* where the underlying need has been translated into a user case for further development. Through the performed process, it became evident that needs regarding safety, convenience and comfort among other things could be solved through sensor implementation in smart devices. For example, adding flame detectors to smart smoke alarms could improve the feeling of safety as the user would be able to leave their home knowing that they would be alerted if a possible hazardous situation was present. Another example is the addition of various sensors in a smart plant pot, as it would offer the user a convenient maintenance solution.

II. How can current sensor technology be implemented in the smart home?

Available sensor technology today cover a wide area of measurable quantities and can thus be implemented in several different ways in the smart home. Examples of how current sensor technology can be implemented in a smart home environment is presented in chapter 6.1, *Examples of sensor implementation in the smart home.* These examples include currently available sensors such as temperature sensors, flame detectors, proximity sensors, pressure sensors and more.

III. What are the possibilities of upcoming sensor technology?

As the cost of sensor are steadily decreasing (see Figure 1.6), the availability increases for commercial implementation of advanced sensor technology. The size of sensors are also decreasing, allowing for implementation in products and devices where size is a limitation. This combination of advanced sensor technology being incorporated in consumer products is illustrated by e.g. the Facial Recognition Technology used by Apple as presented in chapter 1.2.3.2, *Biometric sensors*.

The development of energy harvesting will make sensors further implementable as the need for an external power source is eliminated. This will allow sensors to be placed in even more devices and their data to be used in a smart home environment, simplifying the life of is residents. In addition, as more sensors are incorporated in smart devices and made available to the public, the possibilities for AI-controlled homes increase as the AIs gain access to more data. This allows for an enhanced smart home where more and more devices will be able to share data which benefits the residents.

IV. What are the limitations of implementing sensors in the smart home?

As the functionality of sensors is based on registering an input and providing an output, they act as monitoring devices to certain extent. A sensor which simply registers when a user approaches a smart mirror to activate said mirror still monitors presence, data which can be used by the company offering the smart mirror in many different ways. The result of this project shows that users are hesitant at bringing potential monitoring devices into their homes but that it also depends on how the monitoring is performed and the purpose of it. The result also shows that if the purpose of the monitoring is beneficial enough, some users are willing to yield parts of their personal integrity, as presented in chapter 6.2, *Key findings*.

Although not exclusive to the implementation of sensors, smart devices in general need to be based on strong and convincing user cases, as they will be subject to higher demands by customers due to their often higher price than their non-smart counterparts. Creating smart devices using sensors will thus need to be based on user cases grounded in tangible user needs for the products to be commercially successful.

Even though the decreasing cost and size of sensors will lead to increased implementation possibilities, the introduction of electronic components in new devices and products leads to demands on recyclability and disassembly. Today, many smart devices uses batteries and will continue to do so in a foreseeable future, meaning that companies selling smart devices need to have a planned strategy for the recycling and handling of electrical components. This is presented in chapter 6.2, *Key findings.*

8.2 Summary

The smart home is a phenomenon that is gaining traction among the public and companies are starting to offer the smart devices required to build a smart home. Sensor technology will play a major role in the future smart home and the technology will enable solutions which will benefit its users. However, challenges are present for companies in convincing consumers of the benefit of smart devices as well as how to handle peripheral circumstances such as data collection, energy consumption and recycling. For IKEA, sensors can be used to broaden the smart home range and acquiring product usage data but the aforementioned challenges are perhaps even more present for a company proud of being associated with low price and sustainability. As IKEA also prides itself at providing products for the many people, much work need to be put into finding convincing user cases anchored in real needs before moving forward to the next step of smart devices in the IKEA Home Smart range.

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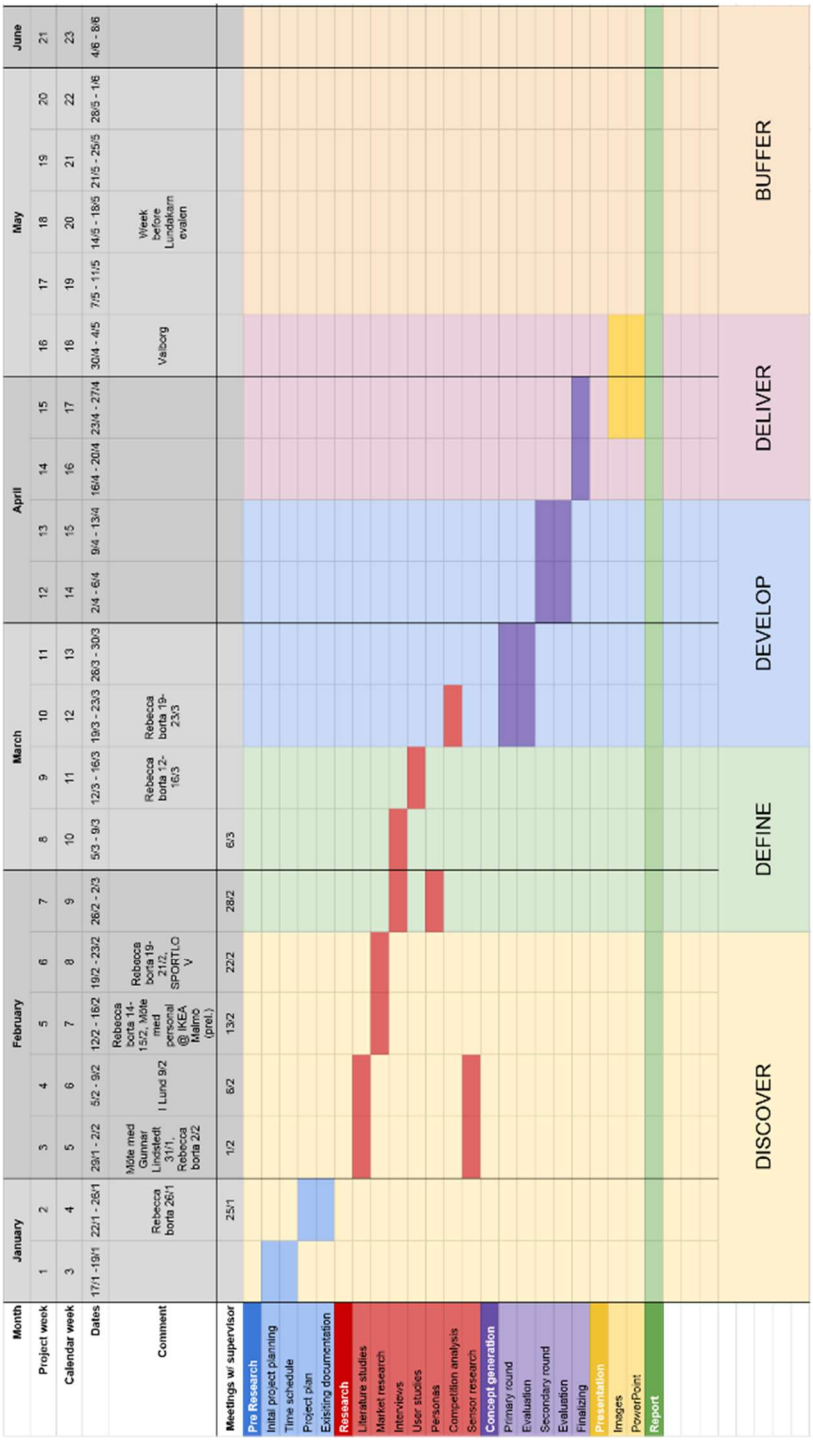
Appendix A

A.1 Work distribution

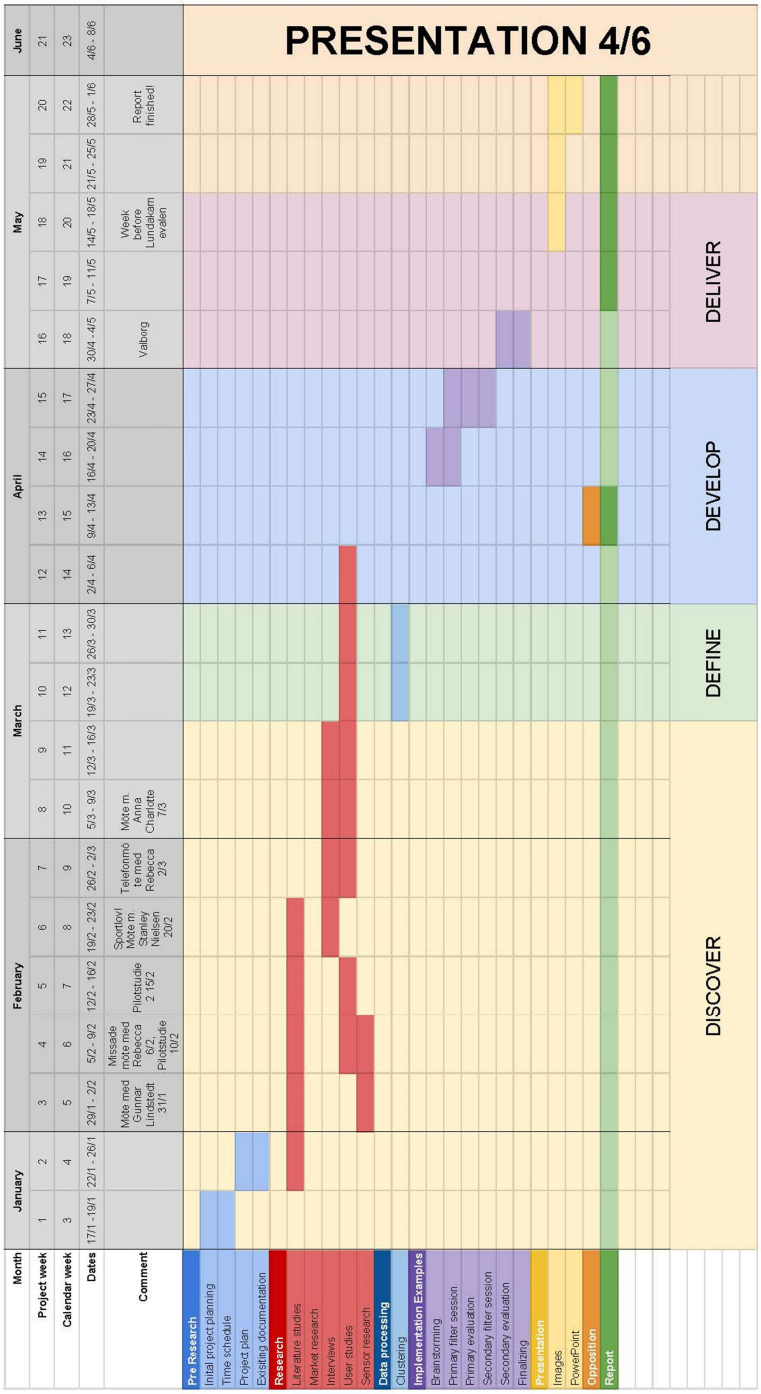
The vast majority of the project was evenly divided between team members but several steps were performed by the team members together as well. All important decisions were made together by the team members and the scope of the project was discussed and decided upon together.

Notably, all graphics which are not taken from external sources as well as the mock-up mobile application used while presenting the thesis were created by Erik Karud.

A.2 Initial time plan



A.3 Actual Time plan



Appendix B Interviews

B.1 Expert interviews

B.1.1 Stanley Nielsen

Interview 2018-02-20 at IKEA of Sweden, Älmhult

- *Sidekick till sortimentscheferna (För bedroom och bathroom)*
- *Jobba med och supportera utveckllingsteamen så att vi kommer i rätt riktning med form och funktion*
- *Lanseringskalender. Är med och koordinerar över affärsområdesgränser så det blir rätt story och uttryck.*
- *Business plan focus week. Beställare för hur sovrum och badrum under den veckan.*

- **Största behoven inom ert område? Vilka problem vill folk ha löst idag?**

  Bor på liten yta, har sjukt mycket grejer. Alla aktiviteter är samma oavsett yta. Hitta ett sätt att göra sin dagliga rutiner oavsett yta. Att saker kan ske parallellt. I badrummet vill alla komma åt vattnet så allt centreras runt vasken. Går det att hitta ett enklare flöde där man roterar runt så att alla kommer åt det de behöver? Vill bli bättre på att jobba i cross-room tänk. istället för i rum så tänker man i aktiviteter som kan ske i andra delar av hemmet. Ex. att vissa föräldrar sover i vardagsrummet för att barn(en) ska få ett eget rum. Då är aktiviteten sova inte förlagd till sovrummet.

Du behöver ta på dig kläder varje dag, oavsett hur du förvarar det så måste vi kunna lösa det problemet. (förvaring) Sakerna alla gör varje natt, om man kan få in teknik där som underlättar. I regel tar man av sig och på sig kläder i sovrummet. Att tvätta sig har alla behov av. Sen hur den runtliggande tekniken ser ut är under utveckling. Behoven är alltid desamma. Tekniken kan underlätta för hur detta behov löses.

- **Framtiden inom ert område?**

Vill gå från bara funktionsdrivna till att även vara emotionsdrivna. Förvaring är väldigt emotionellt. Tänk om det bara är kaos, då blir folk superfrustrerade. Displayskåp gör att man kan visa upp ting med en emotionell koppling. Där man sparar fina minnen exempelvis.

Brist på sömn är vanligt. I Japan sover man 5h i snitt. Stor hälsorisk. Vi vill skapa rätt atmosfär. Bra madrass är viktigt men inte allt. I sovrummet kan man få lite ro genom att stänga om sig och vila lite. Teknik kan hjälpa med att stänga ute ljus och ljud. Rensa ut dålig luft. Tänk er Mumbai. När fler och fler flyttar in till städer så lir det mer och mer intryck och hjärnan behöver stänga av. Man tar sig an problem på ett bättre sätt när man är utsövd.

Skjutdörrar på garderober är något som växer, bra på småytor. Möjligt att använda touch och elmotorer för att öppna/stänga. Behöver inte nödvändigtvis bli dyrare. Informed sleep är intressant. Sköts idag av wearables. Är man intresserad av att köpa en till "grej?"

Om man kan fokusera på mjuka behov är det lättare att få folk att ta sig till saker.

Börja fokusera på några områden, gå inte för brett. Folk kan inte ta ställning till saker förrän de kan se och ta på saker. Ta fram några få exempel som folk förstår.

- **Hur skiljer sig rummen internationellt sett? Skillnader globalt? Universala likheter?**

  När saker är väldigt etablerare så följer vi marknaden. Ex meter vs. inch. vs tatami. 7 eller 8 olika preferenser hur man bygger sin madrass. Ett område där vi börjar anpassa oss är, i våra garderober är allt öppet. I Asien så har du ofta någon som städar/hämtar tvätt etc. Då har du ofta en låda med lås så att folk kan förvara sina värdesaker.

  Olika kravställningar. Ex. lagkrav, klimatskillnader. Om vi ska ha ett helt globalt sortiment så får man gå utefter de hårdaste kraven för att det ska fungera globalt.

  Anpassa sig IKEA efter regionala/kulturella skillnader? Nja. Gällande byggstandarder måste man anpassa sig. Tänk medellängd i Kina vs. Nederländerna.

- **Smarta Hem-utvecklingen generellt i ert rum?**
  - Skjutdörrar på garderober en stor grej. Touch för att öppna/stänga. (sensor + motor?)
  - Informed sleep - mäta sömn.
  - Skjutdörr - mindre platskrävande i o m att man jobbar med små ytor.
  - Mäta vattenflöden - medvetenhet kring konsumtion.

- **Hur ser ni på att inkorporera teknik i era möbler? Risker? Exempelvis elektrisk ledning i en möbel.**

  Provat laddningspuck i sängbord, inte verkat vara nån jättesuccé. Inkorporerar du teknik måste du vara finkänslig. Om man inkorporerar det helt rigit i möbel så blir det kanske lite problem lagmässigt. Att hela soffan räknas som elektronik. Troligtvis lättare att skaffa en lite modul för att uppgradera.

Bathroom:

- **Olika IP-klassning beroende på position i rum?**

  IP-klassning är nog inga svårigheter. Oklart med IP-klassningar sett till plats i rummet.

- **Toalettstolar? Varför säljs det ej? Kommer det ev. säljas i framtiden?**

  Servicepartners är viktigt. Har vi i alla länder. Folk har i mindre utsträckning verktyg hemma för att sätta ihop saker. Folk förväntar sig att det är enkelt, att de får service. Måste ha helheten för renoveringskunderna. Om vi inte erbjuder allt så är man inte en spelare på den marknaden. Diskussion om WC har förts men har parkerats för tillfället. Vatten är viktigt i sustainability tänket. Ännu större variationer på toaletter än handfat. Generellt ganska meckigt med VVS. Vissa länder har rör ut i golvet, vissa i väggen, olika rörtjocklekar.

Bedroom:

- **Har folk med sig mobilen in i sovrummet om natten? Har de den på nattduksbordet?**

  Ja, de har med sig mobilen in i sovrummet. Aktiviteter i eller runt sängen, folk har med sig sin elektronik dit. Kanske inte det bästa att ha TV i sovrummet, men folk har det. Samma med mobiltelefon. Anpassa sig efter hur folk faktiskt beter sig, inte hur de borde bete sig.

- **'Safear' folk med att låta lampor vara tända och liknande på natten ifall att de behöver gå upp i mörkret?**

  Tror att folk famlar i mörkret när de går upp på natten. Finns det något mellanting mellan att famla i mörkret och att tända lampan? Vi vet att folk går upp på natten.

B.1.2 Nilofar Javadinejad

Interview 2018-03-02 at IKEA Malmö varuhus

- **Intresserar sig folk för TRÅDFRI?**
  En del är väldigt intresserade sedan innan, och har varit i kontakt med Philips Hue innan. Då är Ikea billigare. Vissa har ingen aning och vill ha dimbara lampor och då hänvisar vi till trådfri som kan dimra och ändra temp. Har de dimmer?Har de inbyggd dimmer så funkar inte led. Då blir det bättre med TRÅDFRI för att skapa dimmer.

- **Behöver folk hjälp att förstå TRÅDFRI?**
  Tenderar mot ja. Men efter en kort genomgång känner de sig säkra på produkten när de går därifrån.

- **Vad frågar folk om TRÅDFRI?**
  Mer inblick om vad som finns i sortimentet. Fattar inte skillnaden mellan färgade och "vita" när det är olika priser.

- **Varför köper folk TRÅDFRI? Varför köper folk inte TRÅDFRI?**
  INTE: Generellt prisskillnad. Vanliga lampor är så mycket billigare.

- **Vilka köper TRÅDFRI?**
  Flest män/killar. De som vet vad de vill ha.

- **Hur köper folk TRÅDFRI (i vilka kombinationer, i vilken ordning)?**
  Oftast köper de lampa +fjärr. Sen kommer de och kompletterar med fler lampor. Gateway? Köps mer som en rolig grej. Eller är mer insatta från början och vill ha. Inte många spontanköp. Även äldre vågar köpa när de ser hur lätt det är att använda.

- **Hur är intresset för att kunna styra ljusets värme/färg?**
  Barnfamlijer köper med flera färger. Folk har ett intresse av att ändra ljusets värme efter de får veta lite mer. Inte många som spontanköper TRÅDFRI om de är ute efter en vanligt LED-lampa.

- **Får ni frågor om IKEA har andra Smarta produkter?**
  Mer om vad som kommer i framtiden. Och vad kommer i lampsortimentet? Socklar, separat RGB-lampa.

- **Har ni någon insyn när folk återlämnar ex. TRÅDFRI? Om ja; vad ger de för anledningar?**
  I början när man inte var medveten om att de inte var kompatibla med HUE. Nu endast om det är fel sockel/för lång lampa.

- **Vad har ni för strategier när ni placerar TRÅDFRI i era utställningsrum? (om hon vet/är involverad)**
  Folk är ändå intresserade, finns inga speciella direktiv.

- **Hur är inställningen till infovideon för TRÅDFRI? Testar folk funktionerna? Finns det möjlighet att testa med appen?**
  Finns möjlighet att testa i appen om via personal.

B.2 User interview guide

MANUSCRIPT

- Students doing our masters in Mechanical Engineer with Industrial Design.
- Master's Thesis at IKEA within their IKEA Home Smart range
- Will be finished at the start of June and preliminary presentation date at IKEA is the 14th of June
- The interview is divided into two (three) parts. One part of the project aims to create an understanding of how people act inside their homes and the other one is centered around people's attitude towards technology. (Finally, we want to know a bit about your experiences of living in a different country.)
- The session is estimated to take about 45 minutes - 1 hour.
- When the study is published, it will be available to anyone. If you are interested in reading the study, you are welcome to get in touch with us and we will gladly direct you to it.
- You can abort the participation at any time and for any reason at all.
- You will be completely anonymous and it will not be possible to track any statements back to you.
- Are you OK with us recording the interview?

- Who are you?
- What is your living situation today? Family, home size, etc.
- What is your international experience?

- Which technological product in your home are you most fond of?
- Which technological product in your home are you not using as much as you thought you would do/want to do? Why?
- Can you tell us which the last time was when a technological product/solution really impressed you?
- When was the last time you got really frustrated with a technological product? For what reason?
- Do you always keep your smartphone within arms reach when you are at home? If no, do you have another connected device close by? (Smart pad, laptop, etc.)
- How do you react when getting a notification on your phone? Does it matter if it's close by or far away? Do you notice differences between notifications?
- Where do you keep your phone when leaving home? Do you notice if you get a notification at that time?

- [To parent with children still staying at home] What kind of relation do your children have to technology? What kind of relationship do you want them to have with it?

- How do you feel regarding the recent trend that more and more products are connected to the internet? Like fridges and thermostats.

- How do you feel regarding the so called 'Smart Locks' which are starting to hit the market? Would you trust it if you had it installed in your home?

- How do you feel about having products in your home which sense your movements to be able to control your products? (Motion sensors, voice assistants/smart speakers, video cameras)

- What is most important for you at home, internet connection or a sofa?

Kitchen:

- Are you mindful of closing the kitchen tap or is it often left running? (E.g. while doing the dishes)

- What is your usual procedure when doing the dishes by hand? (Wash tub? Filling the sink? Keep the tap open? Turn the tap on/off?

- What kind of oven do you have? Old or new one? Do you use any integrated functions on your oven? (e.g. timer, thermometer) Are there any functions that you are missing?

- Do you usually use a thermometer/timer when cooking/baking or do you go by your senses/experience?

- When you mess up in the kitchen, what is usually the issue?

- Do you leave the kitchen when cooking/baking?

- Do you check what you have at home before going shopping?

Bathroom:

- Are you mindful of closing the tap or is it left running? (While brushing your teeth for example)

Living room:

- What is the most important aspect in your living room? (Mood, media capabilities, furnishing, etc)

Bedroom:

- Do you keep your phone on your bedside table while sleeping?

- Do you put your phone on 'Silent' while sleeping? Do you have any prioritized notifications which override 'Silent mode'?

Hallway/Coming or going situation:

- You are leaving home to go to work/school and you are the last one leaving - what things are you mindful of before leaving?

- You arrive home after a long day at work/school, what do you do as you enter your home?

- If you forget something important when leaving home, what is it most usually?

- Does it happen that you leave home without doing something important? (check that no candles are lit, that the coffee maker is turned off)

Laundry room:

- Do you set alarms to not forget handling your laundry? (hang it out to dry, check if the dryer is finished)

General:

- Is it important for you to keep plants in your home? Do you appreciate handling your plants? Are you usually able to keep them alive?

- How often do you manage your curtains/awning/blinds?

- What do you wish would happen automatically in your home?

- Is there something in your home that you wish you could control by voice commands? That something happened when you asked for it?

- What situation that you experience often do you find hard/boring/time consuming?

- Do you wish that you could know what is happening at home when you are not there? If yes; what is that you are specifically interested in knowing?

- What would you like to control at home when you are not there? Why?

- If you had the possibility to get a quick overview of the status of your home, do you think that you would use it?

- How big is your home? [m2]

- Do you have a washing machine at home?

- Do you have a dishwasher at home?

- What kind of oven/stove do you have?

INTERNATIONAL QUESTIONS

- Regarding life at home, what would you say are the biggest differences between the countries you have lived in? Regarding social interactions? Regarding home furnishing?

- Are major appliances put in the same rooms as in Sweden? Do people usually have the same appliances as in Sweden?

- Does the way people use their phones differ compared to Sweden?

- What is the attitude towards technology and integrity/privacy? At home?

- What is the attitude towards technology in the home?

- What are people's attitude towards home safety? is it important for them to have alarm systems, locking the door while at home, etc.?

- Are the family constellations the same? Do people's parents live with you when you have started your own family?

- Is it common to have pets indoor? Outdoor?

- Do family members have separate bedrooms?

Appendix C Clustering

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	SUMMA
Tvättmaskin och diskmaskin är rätt underskattade	1																				
On-Demand TV ger hög flexibilitet	1				1	1															3
Vi kan styra vad barnen tittar på.	1																				1
Det är positivt med produkter som samlar flera funktioner.	1		1		1	1	1		1	1			1		1						9
Om en produkt är för omständig att använda används den inte (inkl. att ta fram och ta bort.)	1		1		1			1								1		1			6
Systeminteraktion på flera sätt (flera enheter, röststyrning, fysiskt, etc.) är önskvärt	1	1															1	1			4
Bara ett knapptryck så funkar det (enkelhet, smidighet, intuitivitet)	1				1	1		1	1		1							1		1	7
Det är viktigt att systemet ger förtroende till testning.		1												1							2
Det är viktigt att systemet uppfyller utlovade förväntningar.			1	1	1				1			1			1	1		1	1	1	9
Tekniken som får vardagen att gå ihop MÅSTE funka.	1	1																			2
Väl beprövad teknik förväntas fungera felfritt (ex. bluetooth).		1		1	1	1		1	1							1		1	1	1	9
När teknik strular ska det finnas ett tydligt tillvägagångssätt för att lösa det.	1					1		1				1					1		1		6
Installationsprocesser ska vara intuitiva, korta och enkla att följa.				1				1			1				1		1	1	1	1	7
Telefonen är en central del i hemmet.	1				1	1	1	1					1	1	1		1		1		10
Telefonen är smidigare än andra enheter	1	1					1		1	1		1									6
Man har inte tålamod med långsam teknik om det finns snabbare alternativ.	1								1	1		1	1					1			6
Ibland gör jag ett aktivt val att lägga ifrån mig mobilen.			1			1			1				1		1	1					6
Jag behöver inte ha med mig mobilen överallt i mitt hem.			1	1				1	1	1	1	1				1	1	1		1	10
Flexibilitet är viktigt för småbarnsföräldrar.	1								1												2
Jag kan göra skillnad på olika notifikationer.		1	1		1						1	1	1	1	1		1			1	9
Det är upp till mig att avgöra när jag ska ta in information från telefonen.		1	1			1	1			1	1								1	1	7
Det är okej att missa aviseringar för att jag kollar ofta på telefonen och noterar det då.	1		1			1															3
Jag uppfattar inte alltid aviseringar när jag går hemifrån.	1	1	1	1	1	1	1			1					1	1	1	1	1	1	13
Om det är något viktigt så ringer man.	1			1					1												3
Jag tycker det är jobbigt att få för många notifikationer			1	1			1		1		1		1		1		1			1	8
Det är viktigt att barnen använder sig av och känner sig bekväma med teknik.	1	1				1	1	1	1			1	1	1	1	1	1			1	12
Tekniken behöver inte anpassa till barn - dagens barn har en naturlig relation till tekniken.	1						1	1		1					1	1			1		7
Vi begränsar skärmtid för våra barn för att det kan vara hämmande för deras utveckling.	1	1	1			1		1	1	1		1	1	1	1	1				1	12
Jag tycker det är spännande med uppkopplade produkter.	1	1	1		1	1	1	1		1	1	1	1			1	1		1	1	14
Jag måste se nyttan med uppkopplade produkter för att det ska vara intressant.		1					1		1	1				1	1			1	1	1	8
Det är önskvärt med system som samlar styrningen för flera produkter.			1	1	1		1					1			1				1		7
Om den personliga nyttan är tillräckligt hög kan jag göra avkall på min personliga integritet.				1	1	1		1						1		1	1				7
Produkter som finns på marknaden förväntar jag mig är säkra.			1		1															1	2
När det gäller hemmets säkerhet måste jag känna att jag kan lita fullt ut på produkterna.	1	1							1			1			1	1		1			7
Jag hade litat på ett smart lås.				1	1	1	1	1					1		1		1		1	1	9

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	SUMMA
Fjärrstyrning av lås är en önskvärd funktion.		1	1	1	1	1	1	1			1			1						1	9
Det spelar roll vad det är för produkt som övervakar mig huruvida jag är bekväm med det eller ej.	1				1		1		1				1			1				1	6
Jag känner mig inte bekväm med tanken att produkter i mitt hem kan övervaka mig.	1	1	1	1					1	1	1		1	1							9
Jag har inga problem med att ha produkter i mitt hem som kan övervaka mig.	1			1		1	1	1				1					1	1	1		9
Det spelar roll ifall övervakande produkter är uppkopplade lokalt eller mot internet.					1				1						1	1				1	4
KÖK																					
Barn är ofta involverade i matlagningen.	1	1																			2
Man gör alltid en avvägning mellan insats och resultat	1																				1
Det blir äckligt vatten när man fyller upp vasken för att diska.	1			1																	2
Jag fyller upp diskhon med vatten när jag handdiskar.		1			1				1		1			1	1				1		7
Det känns ok att diska under rinnande vatten för att det är så lite vatten som slösas när man bara diskar enstaka grejer.	1	1	1	1	1	1	1	1		1	1		1		1			1			13
Det är viktigt med termometer när det är viktigt att det blir rätt temperatur.	1	1		1		1		1			1		1					1	1		9
Timer används på den enhet som gör det smidigast	1		1		1	1	1	1	1	1	1		1		1	1	1	1	1	1	15
Jag ser inte nyttan med mer avancerade funktioner än de grundläggande.				1		1	1	1				1			1			1		1	7
Det är vanligt att jag lämnar köket när jag lagar mat/bakar.			1	1		1			1	1	1	1	1	1	1	1	1	1	1		14
Jag har bra koll på vilka livsmedel som finns i mitt kök*			1			1			1	1	1	1				1	1		1		9
BADRUM																					0
Man är medveten om att stänga av kranen för att spara på vatten.	1	1	1		1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	17
Personlig bekvämlighet värderas högt i vardagen		1															1				2
VARDAGSRUM																					
Ett bra vardagsrum möjliggör umgänge	1				1	1	1									1		1	1		7
Ett bra vardagsrum möjliggör avkoppling		1	1	1		1		1		1	1	1	1	1	1		1		1	1	13
TVn är central i vardagsrummet.	1		1								1							1	1		5
Ett bra vardagsrum är inte för stökigt	1	1	1								1				1						5
Ett bra vardagsrum är inbjudande	1																				1
Musik är ett viktigt inslag i ett bra vardagsrum				1		1	1	1					1					1			6
Bra belysning är önskvärt i ett bra vardagsrum			1			1	1		1	1		1	1	1				1		1	9
Vardagsrummet är en plats för både nytta & nöje						1							1						1		3
SOVRUM																					
Barnen styr morgonrutinerna	1																				1
Jag har inte alltid med mig telefonen in i sovrummet om natten*						1				1	1		1		1			1			6
Jag har telefonen på ljudlöst om natten							1	1	1			1		1		1	1	1	1	1	9
HALL																					
Fjärrstyrning hade varit bra för att få huset att se bebott ut när ingen egentligen är hemma.				1	1																2
Hemmet känns mer välkomnande om det är lite tänt när man kommer hem och det är mörkt ute.	1		1			1					1							1			5
Man är noga med att lämna hemmet i ett skick man känner sig trygg med.	1						1		1	1			1		1	1	1		1	1	9

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	SUMMA
Man är noga med att släcka hemma när man går hemifrån.	1		1	1		1	1	1	1	1	1	1	1		1	1	1	1	1	1	16
Jag kan känna oro över att ha glömt göra något viktigt när jag gått hemifrån.		1			1								1	1							4
Jag låser dörren om mig när jag kommer hem.		1	1	1			1				1	1					1				7
Folk tycker pip-ljud från maskiner är störiga.	1			1				1					1	1	1			1			7
TVÄTTSTUGA																					
Jag ställer påminnelser för att komma ihåg tvätten (gemensam tvättstuga)			1									1					1				3
Jag ställer påminnelser för att komma ihåg tvätten (egen tvättstuga)																					0
GENERELLT																					
Växter har en viktig roll i hemmet.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Jag uppskattar inte hanteringen av växter i hemmet.	1	1		1			1		1	1	1	1		1	1	1	1				12
Omskötseln av växterna är svår	1			1			1	1	1						1	1		1	1		9
Tråkiga hushållssysslor ska helst automatiseras.	1		1	1	1			1	1	1		1	1			1		1	1	1	12
Det är önskvärt att hemmet kan känna av om någon är hemma eller ej.							1										1				2
Fjärrstyrning är bra för att det kan frigöra tid till annat.	1														1	1					3
Fjärrstyrning är bra när något är svåråtkomligt			1																		1
Röststyrning är bra när man upptagen med annat.	1							1						1		1					4
Det hade varit bra att ha möjlighet att få information om husdjurens status i hemmet	1							1											1		3
Jag hade velat få information om något händer i hemmet medan jag är borta.	1				1	1	1	1	1		1			1		1		1	1	1	11
Jag hade velat att hemmets energiförbrukning var lägre när jag inte är där.	1						1		1		1	1	1			1	1	1			9
Jag ser en nytta i att kunna fjärrstyra saker i hemmet						1	1	1	1				1	1	1	1	1	1		1	10
Man är mer mån om att spara på resurser om man vet hur mycket man förbrukar.								1	1						1						3
BARN																					
Har inte tiden att sitta ner koncentrerat en längre tid så därför vill jag ha nått som är smidigt, enkelt, litet	1																				1
Enkelt att låta barnet få leka med smartphone/surfplatta/streaming TV som distrahering när vi vill fokusera på något annat.	1																				1
Värsta jag vet är när allt ska fixas innan man ska iväg med barnen.	1																				1
Can't keep fragile things with cables out, our child will play with it		1																			1
Smartphones/surfplattor är intressanta för barn i alla åldrar - ibland måste de gömmas för att barnen inte ska interagera med dem. (Man gör alltså enheterna medvetet otillgängliga)		1								1						1					3

Appendix D First filtering session results

Outcome

Flame detector in smoke detector

- Incorporating a flame sensor in a smoke detector
- Reacts to flames - could warn if burning candles are left lit when the resident leaves their home.

Smart plant pot

- Incorporate various sensors in pot such as plant moisture sensor, humidity sensor, nutrition sensor, pH-sensor, light sensor, etc.
- Connect to other smart devices such as a motorized blind to control the light the plant receives from adjacent windows.

Smart plant sensor

- Utilizing same sensors as in the smart plant pot but incorporate in stand-alone product which can be used with external pots.

Smart irrigation system

- Complete system consisting of either smart plant pot or smart plant sensor in combination with a built in irrigation system.
- Communicates with the smart pot or the plant sensor to ensure an adequate handling of plants.
- Allows for remote controlling of watering.

Smart sensor for hydroponics

- Sensor in the water, detecting nutrients in the water and communicating to the user through their mobile device.
- Could be combined with light sources (both in product and ambient light) to optimize growing conditions.

Smart water sprinkler

- Soil moisture sensor incorporated which signals when watering is required.

- Remote control through valves, allowing water to be on constantly yet you can control it from your phone.
- Can be combined with smart plant sensor which communicates further information to the water sprinkler.

Smart refrigerator

- Include sensors for temperature monitoring, electricity monitoring (mainly to detect if the refrigerator stops working) and sensors detecting putrefactive gases.
- Could include various sensors to allow monitoring of content
- Could include sensor which detects whether the door is open or closed.

Control unit at front door

- Allows controlling of various sensors and smart devices in your home.
- Placed at a natural location - turn on or off device when coming home or leaving.
- Receive information from calendar, weather, email, etc. when leaving to make sure you are prepared for the day.
- Does not require the user to access their phones.

NFC-chip giving guests access to predetermined smart devices

- Allows guests to activate NFC in their phones and grant access to certain TRÅDFRI-products through the TRÅDFRI-app.
- Could be positioned in a guest room, giving the guest access to lights and other smart devices in that room as well as WiFi-access.
- Allows the residents to have full control of who gets what information and control.

Light sensors controlling…

- A motorized blind - adjusting the blind according to the amount of ambient light.
- Plant lighting - adjusting the lighting for growing plants according to surrounding factors and ambient light.
- Light fixtures in general.

Sleep sensor in bed

- A set of sensors to monitor sleep for the residents.
- Can be incorporated in various products to allow accurate monitoring such as pillow, mattress and duvets.
- Allows for gentle waking correlating to sleep patterns, tracking of sleep quality and possibly remote controlling (allow parents to wake their children)

Position logging in the home

- Use various sensors to track the resident in their home to optimize various tasks according to their current position.
- Can be used to turn off lights in parts where there are no residents, turn off appliances as people move throughout their house and other tracking benefits.

Connected stove

- Next level of KULINARISK stove with integrated sensors for accurately measuring the weight of the food being cooked.
- Could incorporate a camera to allow for a live feed of the inside of the oven so the user can track their cooking process.
- Could feature QR-scanner to allow for cooking instruction to incorporated on the food and then read by the oven.

Pressure sensor in bathroom mat

- Adding pressure sensor in bathroom mat to allow for weight tracking.
- Could be connected to smart mirror and use facial recognition to allow for personalized tracking and information.
- Fits in the Health-aspect of IKEA target areas.

Smart washing machine

- Remote control/remote monitoring
- Automatic dosing of detergent → More efficient chemical use
- Sensor for amount of detergent left in reservoir → Reminder to get refill
- Water hardness sensor → More efficient chemical use
- Dirt sensor for sensing which program needs to be run/for how long → Less water waste
- Water consumption sensor → More conscious water usage

Automatic sorting in clothes bin

- Sensor for amount of laundry in the bin
- Colour sorting
- Remote control/remote monitoring
- Combine with washing machine for further automation

Connected dishwasher

- Remote control/remote monitoring
    - Auto-start when electricity price is low
- Automatic dosing of washing liquid
- Sensor for amount of washing liquid left
- Water hardness → More effective chemical use

- Water consumption monitoring → More conscious water usage

Motion controlled tap

- Controlled by motion sensor → Less water waste, especially in the kitchen
- Water consumption monitoring → More conscious water usage

- Not connected → Home Smart, not Smart Home
- Motion controlled soap dispenser → More hygenic

Gas leakage sensor for stove

- Integrated into stove
- Connected to warning system i.e. smoke detector → Special alarm for gas leakage
- Warning to smartphone through app

Connected crib

- Monitoring by
    - Camera
    - Heart-beat sensor
    - Breathing pattern

Microwave with QR-scanner

- Cooperation with food suppliers → Microwave gets exact cooking instructions from the packaging

Kitchen hood with integrated sensors

- Remote temperature scanner → Able to sense temperature in cooking vessels below → Safer cooking & better cooking
- Sensors for filter cleaning → Better air quality & safety
- In cooperation with motion sensor → Auto-shutdown if no one is around and fire/smoke is detected

Integration of sensors in induction stove

- Temperature sensor in stove → More automatic cooking, easier temperature control of substances
- Boil-over sensor → Auto-shutdown/Temp. decrease if boil-over is detected

Connected delivery box

- Pressure/presence detection → Able to notice owner of delivery
- Cooling element → Able to collect food delivery when not at home

- Lock with pin-code → Only authorized personnel can access the box, safe!

Food containers with sensors
- Pressure/weight/di

Facial recognition
- Usage of facial recognition as presence and individual tracking

Smart baby monitor
- Add a baby monitor with live feed to users phones as a product in IKEAs range of child products.

Smart door lock
- Allow for remote controlling/code lock managing
- Feedback to user if door is open or closed
- Can notify if a burglary is attempted
- Can use biometrics
- Can use RFID

Smart cat/dog hatch in door
- Use different sensors to allow only the users own pets to utilize the hatch.

Integrated flow monitor in shower
- Keep track of water usage
- Incorporate timer
- Provide feedback to user of water usage
- Provide more info about shower habits in users phone

Clip-On Sensor for monitoring of power usage
- Only for monitoring
- Communication with gateway

Motion controlled switch
- Integrated in furniture or stand-alone product
- Using e.g. IR-sensor for more controlled motion tracking
- Compare to sensor controlled bathroom taps

All on/all off when coming home or leaving home
- Could be sensor controlled
- Allow for easy interaction with all connected devices in a home

Smart radiator thermostat

- Allow for remote controlling of temperature
- Incorporate temperature sensor to detect ambient temperature

Smart mirror

- Provides user with information
- Can be activated through motion sensor
- Can utilize facial recognition to provide individualized information
- Uses data from external sensors such as weather data

Open/Close sensor

- Stand alone product
- Can be position anywhere the user desires
- Can be connected to a rain sensor

Smart thermometer

- Include temperature sensors.
- Communication to mobile devices.

Smart bathtub

- Include temperature sensor, flow monitoring
- Remote controlling

Gas detector

- Smart gas sensor that communicates with user's mobile devices.

Smart air quality monitor

- Measure air quality and provides information to user
- Global perspective

Motorized blinds

- Incorporate rain sensors and light sensors