# Can Smart Homes contribute to the New Product Development (NPD) process?

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## ABSTRACT

Internet of Things (IoT) devices generate a vast amount of data which can be utilized for many commercial purposes. The Smart Home is one of the most promising application domains of IoT. Data obtained from Smart Homes (Smart Home data) can provide insights into customer behavior and product usage. Consecutively, this can be used to identify customer needs. However, firms are not actively using smart (home) data for their New Product Development (NPD) processes. Hence, this research studies to what extent data obtained by IoT devices and specifically, smart home devices, could contribute to the following key success factors of the NPD process: (1) maximized fit with customer requirements (2) minimized development cycle time (3) controlled development costs. With the help of a literature review and an expert study, this study determined that smart (home) data assists in identifying customer needs but not necessarily reduces development cycle time and costs. Through smart (home) data, the ability to identify needs and give corresponding support will be more sustainable, continuous, fast, and easy. Also, with the right algorithm and analytics, the development cycle time will be faster. The development costs will be higher at the beginning and later decrease as more data becomes available. Moreover, bottlenecks in the Smart Home field were found, due to lack of standardization of smart home systems, the data obtained is very fragmented which leaves quite a distorted picture of customer behavior. Besides, on one hand, the firms which install and support Smart Home systems like telecom companies have no intention of harvesting and exploiting its data and on the other hand, the innovative companies whom the data could be useful for, have no direct access to it. They have to go through a difficult process to procure this privacy sensitive customer data from the telecom companies.

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## Keywords

Internet of Things, Smart Homes, New Product Development process, Sensor Data, Smart Data, Success Factors



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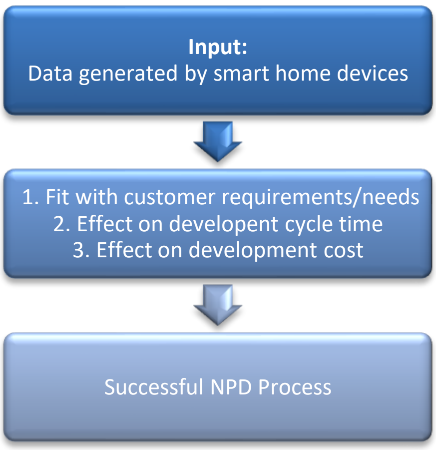
# 1. INTRODUCTION

The Internet of Things (IoT) has the potential to radically change the way we interact with our surroundings. The IoT digitizes the physical world by sensors which are embedded in everyday physical objects that are linked through wired and wireless networks. These sensors can send and receive data which allows us to monitor and manage objects in the physical world, electronically. The application of the IoT provides great opportunities for a wide variety of industries, from home automation to production optimization. It helps optimize the performance of systems and processes, save time for people and businesses, and improve the quality of life for consumers (McKinsey, 2015). Cisco estimated that more than 27 billion objects will be connected to the internet by 2021 (Cisco, 2018). One of the application domains of the IoT is the smart home, a home which has connected devices and software that can automate and control those devices (Brush et al., 2018). Smart homes typically entail smart thermostats which can automate and control the lighting and heating of the home but also other aspects as ventilation, air conditioning and security such as smart locks and cameras (Rajasekar et al., 2018). According to McKinsey (2015), the potential economic impact of the IoT on the smart home sector is estimated at around 200-350$ billion by 2025. Due to the fast-growing implications of the IoT, it is useful to gain new insights on how the data from IoT can contribute to New Product Development process.

Innovation is widely regarded as one of the key contributors to competitive advantage. It can take place as small incremental improvements to existing products or by radically developing new products and services (Veryzer, 1998). The New Product Development (NPD) process visualizes the innovation process for firms. It consists of seven steps: new product strategy development, idea generation, screening and evaluation, business analysis, development, testing and commercialization (Booz, Allen & Hamilton, 1982). Throughout the years, several NPD models and success factors have been introduced. While researchers focused on how to improve and make this process more effective and efficient, little research focused on how the growing impact of the IoT can contribute to this process. Therefore, the purpose of this research is to find out how smart (home) data can contribute to the success factors of the NPD process, which are: (1) maximized fit with customer requirements, (2) minimized development cycle time, (3) controlled development costs (Schilling, 2013). To reduce the complexity and keep it unambiguous, this research will try to focus on data from one of the application fields of the IoT, namely the smart home.

**Figure 1: Context of this paper**




As shown in figure 1, this papers' context is characterized by analyzing how and to what extent, the data that has been obtained from smart homes can contribute to the critical success factors of the New Product Development process.

## 1.1 Problem Definition

In order to identify how smart home data can contribute to the critical success factors of the NPD process, it is of utmost importance to structure this paper by dividing the main research questions into three sub-questions. The overarching research question is as follows:

***To what extent does smart home data contribute to the success factors of the NPD process?***

The sub-questions have been derived from Schilling's (2013) three critical success factors of the NPD process:

1. *What is the value of smart home data in identifying customer needs/requirements??*
2. *What is the effect of smart home data on the development cycle time?*
3. *What is the effect of smart home data on development costs?*

## 1.2 Relevance

As discussed before, the impact of the Internet of Things is growing rapidly and there are possibilities that it will disrupt the internet development. Smart homes, as one of its utilization areas, is also increasingly growing as more and more people are accepting smart devices in their homes and daily lives. According to McKinsey (2018), the US market has seen substantial year-over-year growth in the number of connected homes, and this is expected to continue in the years to come. They estimated that 17 million homes were connected in 2015 compared to the 29 million homes in 2017 (McKinsey, 2018). Given this meteoric rise of the IoT, it is valuable to gain insights for both businesses and academics to find out how to utilize the extensive amount of data that has been generated by smart homes to improve or create new products and processes. Little research has been done to find how this data can contribute to the New Development Process and its key success factors as proposed by Schilling (2013), which are (1) maximized fit with customer requirements, (2) minimized development cycle time, (3) controlled development costs. Businesses will be able to derive great value from the Internet of Things and gain the competitive advantage once they understand how smart home data can contribute to the success factors. With this paper, firms can gain a better picture of what IoT literature and experts say about the challenges and opportunities that lay for them in the NPD process.

## 1.3 Methodology

Due to the recent growth and popularity of the IoT, the literature on smart home data and IoT, in general, is scarce. Therefore, the sources used in the literature study originates mostly from consultancy firms and research departments from businesses and nonprofit organizations. Also, an empirical study is carried out in the form of expert interviews. Several IoT and Smart Home experts have been interviewed to ask for their views on how smart home data can contribute to the success factors. These interviewees consist of experts which are either business professionals, researchers or professors. The previously found results from the literature study will not be shared with them upfront on purpose, to let them form their own opinion without any background help. After this, the results will be gathered and analyzed to see whether the experts confirm the results which were found in the literature study. If not, what new and interesting views did they open up? In the end, the conclusion will contain a table with an overview of the results that are found and whether they contribute positively or negatively to the success factors. From this, a conclusion can be drawn on what effect smart home data has on the NPD's success factors.

### *1.3.1 Structure*

At the start of this paper, the reader will be provided an overview of what the concept of the Internet of Things entails to create a basic understanding of the subject in chapter 2. IoT topics such as the Radio Frequency Identification (RFID) technology, sensors, actuators and the generated smart product data will be explained. Afterward, the focus will be shifted to smart homes, one of the application areas of the Internet of Things in chapter 3. In this section, a classification of smart homes will be presented together with an explanation of the smart data which is produced by smart home devices. Chapter 4 will provide an understanding of the New Product Development process. The different NPD models will be compared alongside a deeper understanding of the three success factors. Chapter 5 will include a literature study on how smart home data can contribute to the fit with customer needs, the effect on the cycle time and the development costs. Due to the scarcity of literature on the link between (specifically) smart home data and the NPD process, in some parts, the focus will be broadened and the effect of smart product data in general on the NPD process will be reviewed. Furthermore, the expert interviews will be analyzed in chapter 6 and finally, conclusions will be drawn in chapter 7.

# 2. INTERNET OF THINGS

The Internet-of-Things (IoT) is rising as one of the remarkable trends forming the evolution of technologies and communication. Miorandi et al. (2012) discussed that there is a shift from an Internet used for connecting consumer devices to an Internet used for connecting physical objects that interact with each other or with people in order to offer a given service. This involves the urge to revise part of the traditional approaches usually used in networking, computing and service management (Miorandi et al., 2012). According to Miorandi et al. (2012) ‘’from a conceptual standpoint, the IoT builds on three pillars, related to the ability of smart objects to: (i) be identifiable, (ii) to communicate and (iii) to interact either among themselves, building networks of interconnected objects, or with end-users or other entities in the network’’ (p. 1498).

Kejriwal & Mahajan (2016) described the IoT as physical objects being able to use the Internet backbone to communicate data about their condition, position or other attributes. The title ‘Internet of Things’ typically consists out of two different terms, namely ‘Internet’ which refers to the network-oriented perspective and connectivity which the Internet provides us and the term ‘Things’ which emphasizes an ‘object’ oriented perspective and the integration of information from these everyday objects into a common and connected framework. The Internet of Things digitizes the physical world and is the proof of the fact that in the world of the Internet, data is no longer only created and distributed by humans but also by ‘things’.

The IoT connections can be classified into three sections:

- Consumer IoT: including set-top boxes, connected cars, and airport check-in kiosks: These IoT devices typically have a display and a user interface—an application framework that links consumers.
- Business IoT, encompassing vertical-market arenas such as transportation and fleet management, where the IoT devices include trucks, tractors, and railway engines: These IoT deployments have sensors throughout that generate data for analysis. Some, though not all, are equipped with their own power and connectivity to track metrics such as traffic and road conditions.
- Industrial IoT, including manufacturing, factory floor machinery equipment, smart cities, equipment used by oil and gas producers, and utility and smart-metered devices: These IoT deployments transmit data through gateways and send the information to the cloud for remote access (MIT Technology Review Insights, 2018).

Considering the functionality and identity as central, it is also reasonable to categorize the loT as "Things that have identities and virtual personalities, operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts" (Tan & Wang, 2010, p. 376). According to Aggarwal and Das (2012), The IoT can also be considered as a global network, which allows the communication between human-to-human, human-to-things, and things-to-things. Miorandi et al. (2012) noted the following ‘‘Internet-of-Things is used as an umbrella keyword for covering various aspects related to the extension of the Internet and the Web into the physical realm, by means of the widespread deployment of spatially distributed devices with embedded identification, sensing and/or actuation capabilities. Internet-of-Things envisions a future in which digital and physical entities can be linked, by means of appropriate information and communication technologies, to enable a whole new class of applications and services’’ (p. 1497).

Miorandi et al. (2012) also stated that the innovation of embedding of electronics in everyday physical objects, making them ‘smart’ and integrating them within the global cyberphysical infrastructure will give rise to new opportunities in the Information Technology sector and carves out the way to new services and applications to leverage the interconnection of physical and virtual realms.

## 2.1 Radio Frequency Identification (RFID)

At the center of the IoT, these ‘smart' products can be found. These smart products are equipped with Radio Frequency Identification (RFID) technology. RFID technology enables the design of microchips for wireless data communication (Gubbi et al., 2013). This is usually in the form of an extremely small tag or chip which is able to compute and store data. Many consider it as a replacement of the generic product bar code. However, RFID technology has many advantages compared to the conventional bar code and the most important one is that it can process real-time data, such as data about the location of a product (Tan & Wang, 2010). Radio frequency identification devices and solutions can be considered a mainstream communication technology, with a number of massive deployments, in particular in the goods management and logistics sectors. RFID plays a key role in enabling identification technology in IoT (Miorandi et al., 2012).

## 2.2 Sensors and Actuators

McKinsey (2015) emphasized the role of sensors and actuators as The Internet of Things was described as sensors and actuators connected by networks to computing systems. These systems can monitor or manage the status and actions of connected objects (‘things’) and machines. These connected sensors can also monitor the natural world, people, and animals (McKinsey, 2015).

Fell (2014) mentioned that connected objects use sensors and actuators to interact with their physical environment. Sensors measure the state of the environment and actuators change or affect the environment. For example, an iPhone 5 uses a small motor with a counterweight to vibrate when it receives a phone call - i.e. an actuator. It then uses a microphone to take the call - i.e. a sensor. Fundamentally, sensors convert mechanical, optical, magnetic or thermal signals into voltage and current. This data is then subsequently processed. On the other hand, with actuators, voltage and current induce a mechanical, optical, magnetic or thermal change resulting into a change in actions performed on the physical environment.

## 2.3 Smart Product Data

Novak and Hoffman (2018) characterized smart products as 'physical devices or assemblages of devices, such as smart lights, smart homes, robot pets and smart cars. Smart objects also include non-physical services such as those provided by the web service company IFTTT (If-This-Then-That), a virtual assistant such as Amazon Alexa, or an AI computer program such as DeepMind's AlphaGo (Silver et al., 2016, p.1).' Further, they mentioned that smart products differ from traditional products in two distinct ways. Firstly, they have their own unique capacities for interaction with other entities, not only consumers but also other objects. Secondly, through the means of the aforementioned capacities, they create and are able to express their own roles in interaction with the consumers, which they are able to perceive (Novak and Hoffman, 2018).

In essence, an IoT device is capable of communicating, sensing, actuation, data capture, data storage or data processing. Through the use of sensors, IoT devices gather different kinds of data and play it through to the information and communication networks for analyzing and processing. The devices are able to communicate with each other directly or through a communication network. These networks provide all the data which are captured by devices to various applications and other platforms. Also, it is able to transmit instructions from the application to the device itself (International Telecommunication Union, 2012).

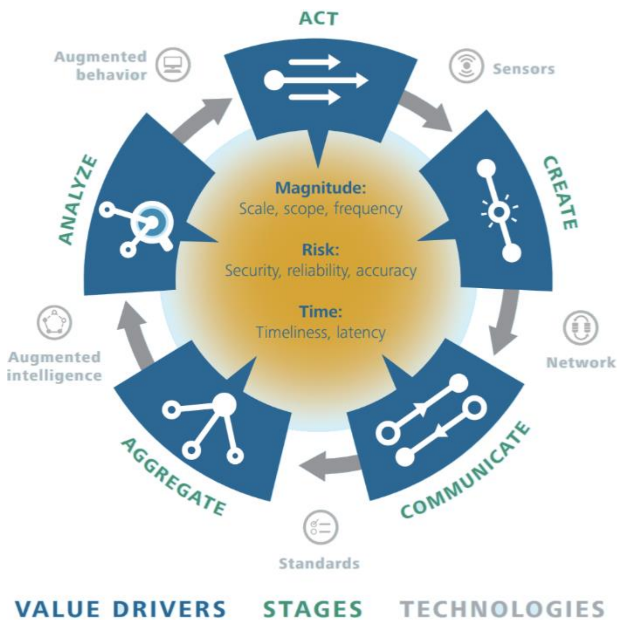
Connected devices can generate great amount and variety of data, for example, produce data on location and usage behavior. Health-related devices produce data on blood pressure and heart rates. Cars, evidently gather data such as speed, traveled distance and maintenance problems. Smart cities provide information on traffic flow, air quality, and water levels. Lastly, smart home devices capture information on heating and lighting preferences (International Telecommunication Union, 2015).

Porter and Heppelmann (2014) indicated that the strategy of a company is imperative to the type of data which the firm tries to obtain with its products. This implies that if a company's strategy is to lead in product performance or minimize service cost, it usually obtains data which has 'immediate value', which implies that this data can be leveraged in real time. Contrary, if the firm aspires a leadership position, it is astute to obtain a broad range of different types of data across various product lines and the external environment. For example, a smart, connected product system might need to capture traffic data, weather conditions, and fuel prices at different locations for an entire fleet of vehicles (Porter & Heppelmann, 2014). For instance, Nest's smart learning thermostat collects extensive data on product usage behavior and peak demand in order to adjust the temperature during to save energy (Nest, 2018).

## 2.4 Information Value Loop

In order to get a better picture of how smart data, and in particular smart home data is created and which stages it passes through, Kejriwal and Mahajan (2016) introduced the Information Value Loop. This model (figure 2) explains that data passes through the loops stages and creates value along the process. Firstly, sensors track features such as motion, pressure, and light, this creates large volumes of data about building operations and use. This information passes through a network so that it can be communicated and various parts of the building management system (BMS) are able to communicate with each other which generates new information. Standards as technical, legal, regulatory, or social then allow that information to be aggregated across time and space. Furthermore, structured and unstructured data from different systems can then be aggregated through a common platform or a set of interoperable standards, then the augmented intelligence (analytical support) analyses the information. Lastly, the loop is completed by the aggregated information which can be analyzed through different analytical tools for descriptive, prescriptive, and predictive insights for building operations. By the deep insights and advanced machine-to-machine (M2M) interfaces, building management systems are enabled to take automated and informed decisions due to enhanced intelligence, which is shaped by augmented behavior, technologies that either enable automated action or shape human decisions in a manner leading to improved action (Kejriwal & Mahajan, 2016).

**Figure 2: Information Value Loop (Kejriwal & Mahajan, 2016)**




# 3. SMART HOMES

The smart home is one of the application areas of the Internet of Things according to McKinsey (2015). Brush et al. (2018,) characterized smart homes ''as a home that has connected devices and software that can automate and control those devices, also commonly referred to as home automation. The extent to which the system observes and changes device behaviors automatically or with minimal guidance from home residents is regarded as "smart." Smart homes or home automation commonly involves the control and automation of lighting and heating (with smart thermostats), ventilation, air conditioning and security such as smart locks and cameras (Rajasekar et al., 2018).

Miorandi et al. (2012) noted that utilizing IoT can help in decreasing the consumption of resources related to homes, and in addition enhancing the satisfaction level of the people that live in the house. Advantages of utilizing IoT in homes can result in decreased operational expenses and carbon footprint. IoT-applications inside homes use sensors, which screens the cost of utilization and consumption but it also identifies current client's needs.

## 3.1 Classification of Smart Homes

According to Aldrich (2003), smart home devices hold a great potential to change the way people live with technology at home. However, he thinks that it is difficult to analyze that potential and what is genuinely new and different in the opportunities provided by smart home technology. Therefore, he presented a classification of smart homes which is still, to this date, accurate. His starting point is the distinction drawn by Gann et al. (1999) between homes which commonly include smart home appliances and those which grant interactive computing in and beyond the home. In the classification, he distinguished smart home systems which have the ability to learn and other which do not have this ability. Furthermore, he also distinguished homes which maintain constant awareness of occupants and objects, from those which do not. Also, different levels of communication of information within and outside the home have been addressed in this classification.

Aldrich (2003) presented five hierarchical classes of smart homes:

• Homes which contain intelligent objects – homes contain single, standalone appliances and objects which function in an intelligent manner.

• Homes which contain intelligent, communicating objects: homes contain appliances and objects which function intelligently in their own way and also exchange information with one another to increase functionality.

• Connected homes: homes have internal and external networks, allowing interactive and remote control of systems, as well as access to services and information.

• Learning homes: patterns of activity in the homes are recorded and the accumulated data are used to anticipate users' needs and to control the technology accordingly.

• Attentive homes: the activity and location of people and objects within the homes are constantly registered, and this information is used to control technology in anticipation of the occupants' needs (Aldrich, 2003).

## 3.2 Smart Home Data

Just as any smart object, smart home devices also produce a vast amount of data prompted by the actions and habits of the users. The data that has been obtained through the smart home devices, from now on referred to as smart home data, mostly consist of unstructured data, this is then processed to transmit it into structured data and by this giving meaning to the data from the smart home devices. Nonetheless, the challenge may depend on proper management and clever utilization of great measures of data created from IoT. Semantic reasoning and other semantic technologies will help change data into knowledge and some researchers in these areas are covering some ground (Hui et al., 2017).

Smart home data is generated in a wide variety of forms, to get a better understanding of which types of data flows exist in smart homes, Dard (1996) proposed a classification of information flows within the smart home. He focuses on the flow of information about activities and resources within the home.

He classified three information flows:

-Human flows: Supervising private and shared spaces (e.g. collecting data on the duration of stay in specific rooms)

-Energy flows: Monitoring energy consumption (e.g. collecting data on the adjustment of heating and lighting)

-Information flows: Managing transmission and reception of messages (e.g. home refrigerator sends messages when it is empty)

# 4. NEW PRODUCT DEVELOPMENT PROCESS

Radical or discontinuous new products play a very significant role in building competitive advantage and can contribute immensely to a firm's growth and profitability. Radical or discontinuous innovations refer to radically new products that involve dramatic leaps in terms of customer familiarity and use, usually these products involve new technologies such as the introduction of the airplane, automobile and personal computers (Veryzer, 1998). Incremental or continuous innovations refers to a series of small improvements to an existing product or process which helps improve its competitive position over time (Nadler & Tushman, 1986). Nadler & Tushman (1986) characterized innovation as the creation of any product, service or process which is new to a business unit. Essentially, two types of innovation exist: product innovation refers to changes in the product or service of a firm and; and process innovation, refers to changes in the way a product or service is made (Nadler & Tushman, 1986).

Nystrom (1985) defined technological innovations as the degree of novelty companies have to employ to solve the critical technical problems when developing new products. This leads us to the introduction of the New Development Process. Most innovations are brought to the market through the New Product Development Process (NPD), which is an instrument for successful innovation establishment. According to Booz, Allen & Hamilton (1982), a new product can be interpreted in various ways. They introduced six different categories of new products: (1) New-to-the-world products (2) New-to-the-firm products or new product lines (3) Additions to existing product lines (4) Improvements and revisions to existing products (5) Repositioning of an existing product(line) (6) Cost reductions through design or process innovation. After choosing which type of product businesses want to develop, it is significant to come up with a strong product strategy and facilitate effective management of the development team (Veryzer, 1998). The NPD process is commonly recognized to take place before the product lifecycle (introduction phase, growth phase, maturity phase and decline phase) which was introduced by Levitt (1965).

Various different models of the NPD process have been created over time but the stages, characteristics, and terminology remain very much the same. The traditional model was introduced by Booz, Allen & Hamilton (1982) and holds seven steps: new product strategy development, idea generation, (idea) screening and evaluation, business analysis, development, testing, and commercialization. The model is depicted in figure 3.

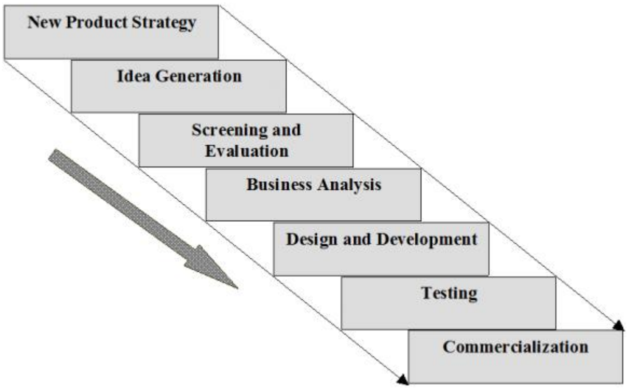



**Figure 3: The 7-step NPD process of BAH (Booz, Allen & Hamilton, 1982)**

Cooper (1990) contributed to the New Product Development research field by introducing the Stage-Gate model as a reaction to the high failure rates of new products. The model is characterized by a five-stage process with audits between them. The model has strict quality criteria's which the deliverables must meet at each stage in order to pass to the next stage. The demanding Go/No-go gates work as a funnel where the poorest ideas are eliminated and the best idea's make it to the end. The Stage-Gate model consists of the following five stages: (1) preliminary assessment (2) business case (3) development (4) testing and validation (5) full production and launch. There were some critique on this model because the model forgets about the phase before the first stage and starts with an idea but it does not say how to come up with that idea. In response to this, Cooper updated his model in 2001 by adding the discovery phase at the start of the model (Cooper, 2001).

| Author | Steps |
|---|---|
| Booz, Allen & Hamilton (1982) | **[7]** – (1) New product strategy development (2) idea generation (3) Screening and evaluation (4) Business analysis (5) Development (6) Testing (7) Commercialization |
| Cooper (1998;2001) | **[6]** – (1) Discovery phase (2) Preliminary assessment (3) Business case (4) Development (5) Testing and validation (6) Launch |
| Schilling (1998) | **[5]** – (1) Opportunity identification (2) Concept development (3) Product design (4) Process design (5) Commercial production |

**Figure 4: Comparison of different NPD models**

The last NPD model that will be introduced is that of Schilling (1998), according to her, the NPD process is not much of a sequential process with designated stages and tasks but more of a parallel process as it encourages more and better communication between the different departments. With this increased and effective communication, the plans and ideas are assessed by a variety of people from different department perspectives and ideas which are not feasible will be identified sooner. This decreases the risk of failures and shortens the time cycle of products (Schilling, 1998). Figure 4 provides an overview of the introduced NPD process models.

## 4.1 Co-creation and Traditional NPD Data Collection Methods

As mentioned in the introduction, the purpose of this paper is to identify the role which IoT data can play in the NPD process. In order to do that, it is of utmost importance to firstly determine the sources of data used in the current conventional NPD processes. Past and current data sources which are used in the NPD process include focus groups, observations, market research surveys and brainstorming. For companies to understand the need of their clients, they mainly had to rely on surveys and focus groups in the past. It is only recently that social media and online feedback mechanisms have opened up new and more accurate data sources to learn about customers' viewpoint and sentiments (Gandhi & Gervet, 2016). The significant advantage of IoT data over conventional data sources is that it allows firms to reach their customers in real-time. A connected product makes it possible to collect or interact with an object anywhere and anytime. All the data is factious and bias-free because it can be read in real-time and directly, all this is contrary to conventional data sources (Robichon, 2018).

It is evident that customer knowledge and insight are crucial to the success of new products and this is interpreted by the notion of co-creation which implies that consumers are being involved in the development and production of products or services and this subsequently adds extra value to them (Sundbo et al., 2015). Gandhi & Gervet (2016) mentioned that the extensive amount of data created by the IoT may be extremely valuable for firms as a co-creation tool due to access at any given time to information which was previously unavailable: where, how and who is using the products. Accordingly, firms analyze this data to gain insight into customer behavior to develop new product and services, through this, their customer becomes co-creators. Especially in the early stages of the NPD process where no concrete path is laid out, customer insight through co-creation innovation techniques with the help of IoT can be very treasured.

## 4.2 Fuzzy Front End

As mentioned before, all of the NPD models are construed of the same basics and steps, from idea generation to the commercialization of the product. The ideation phase is often called the Fuzzy Front End of the NPD process, it refers to the initial stage of the process where they decide to build on an idea or not (Koen et al., 2002). It is regarded as a crucial stage in the NPD process as it forms the foundation of the new product development. If the firm decides on an idea or a path which has not much potential and they are not able to execute it adequately, the firm's investments will be at risk. In the Fuzzy Front End, managers can exert the biggest influence on the process, because the process is at its initial stages and there is not much tangibility. Once the process moves to the next stages, the firm becomes path dependent and changing the course of the innovation will be very costly and difficult (Herstatt & Verworn, 2001). The Fuzzy Front End can be identified as the stages from the idea generation to the approval of development (Dewulf, 2013). To counterbalance the risk of choosing the wrong path or an idea and gain competitive advantage, firms tend to engage in customer interaction, also known as open innovation or co-creation (Lorenzo Romero et al., 2014).

## 4.3 Critical Success Factors of the NPD Process

As elaborated in chapter 4, the NPD process can be interpreted in many ways and with different steps. For the purpose of this research and in order to research how smart home data can contribute to the New Product Development process, it is recommended to narrow down the whole process and identify the key steps of the NPD process rather than analysing how smart home data can contribute in every single step of the process, which might become redundant. Therefore, in this section, the critical success factors of the NPD process will be introduced, which will, later on, be analyzed to understand how firms can contribute to these success factors using smart home data.

According to Schilling (1998), competitive advantage and successful launch of new products were previously realized by excelling in terms of quality and price. However, the increase of competitors diminishes the effect of good quality service or low pricing. Competitors with radical innovations tend to shorten product's life cycles, resulting in creative destruction. To realize a successful New Product Development Process, Schilling (2013) introduced three critical objectives which must be realized: (1) maximized fit with customer requirements, (2) minimized development cycle time, (3) controlled development costs.

The first critical success factor of the NPD process that Schilling (2013) presented is the maximized fit with customer requirements. According to her, in order to be successful in the marketplace, a product must offer more compelling features, greater quality, or more attractive pricing than competing products. This all sounds obvious to most ears but many new developments projects still fail to achieve these points. Numerous reasons could be the cause of this. Firstly, firm's might overinvest in some features at the expense of features which were valued more by the customers. This indicates that firms' interests are not aligned with the customers and that they do not have a good reliable image of what customers value. Secondly, firms may overestimate the willingness of customers to pay for particular features, this leads them to produce over expensive and feature-packed products, resulting in not gaining a significant market share. Thirdly, firms could have difficulties in resolving the heterogeneity of customer demands. Due to this, they might end up producing a product which makes compromises between conflicting demands of various customers, which will typically result into failing to be attractive to any of the customer segments (Schilling, 2013).

Minimizing the development cycle time is the second critical success factor of the NPD process as introduced by Schilling (2013). She described the development cycle time as the time which has elapsed from project initiation to product launch, usually measured in months or years. Even if the first success factor is achieved (close fit with customer requirements), products can fail if they take too long to bring to market, due to customers which are already committed to other products. A firm that is able to bring its product to the market early, contributes to a network externality effect. This effect implies that due to the early market entrance, the firm has more time to develop complementary goods themselves or encourage others to do this, these complementary goods enhance the value and attractiveness of the product. Given that the products are introduced earlier, there is a high likelihood that the product has a large installed base and availability of complementary goods over later offerings. Finally, firms with short development cycles can easily adjust or upgrade their products as design flaws are revealed or technology advances. A short development cycle time can take advantage of both first-mover and second-mover advantages (Schilling, 2013).

Another important consideration regarding development cycle time relates to the last critical success factor (controlling developments costs) which is intertwined with the cycle time and the decreasing length of product life cycles. Namely, many development costs are related to time, both costs of employees which are involved and the firms cost of capital increase as the development cycle lengthens. Furthermore, a company that is slow to market with a particular generation of technology will almost be unable to pay off the fixed costs of development before that generation becomes obsolete. A good example is the electronics industry where life cycles can be as short as 12 months (smartphones which are introduced newly each year).

However, various researchers have indicated that shortening the cycle time has its drawbacks. Dhebar (1996) noted that rapid product introductions may cause adverse consumer reactions, they may regret past purchases and be very careful with buying new products out of fear that it could rapidly become obsolete. Despite the risks, many studies have found a strong positive relationship between pace and the successful commercial deployment of new products (Schilling, 2013; Nijssen et al., 1995; Schmenner, 1988; Ali et al., 1995; Rothwell, 1992)

# 5. EFFECT OF SMART HOME DATA ON CRITICAL SUCCESS FACTORS OF THE NPD PROCESS

This section will discuss how smart home data can contribute to the subsequent critical success factors of the New Product Development process. Each critical success factor will be reviewed separately, followed by the expert insight on the contribution of each success factors.

## 5.1 Smart Home Data and Identification of Customer Needs

Various pieces of literature indicate that the data generated by smart home devices can be of great value and open possibilities for various applications. One of the benefits of smart product data is that it provides firms with concrete data for a better understanding of their clients, without client interference (Robichon, 2018).

The following sections will explain different areas of how smart home data can create a better picture of the user and identify their needs.

### *5.1.1 User expectations about Smart Homes*

A common question is, what do users want or expect to be able to do in a smart home? The answer to this question can be obtained in different ways such as questionnaires. Clark, Newman, and Dutta (2017) studied if various descriptions of smart home functionality would have an apparent effect on users' mental models of the capabilities of a smart home and the types of communication they would think to have with it. Newman and Dutta constructed four unique surveys about the exact same smart home system. The surveys differed on the point whether system competencies were defined as a list of devices such as motion, detectors or light, or data streams such as whether the lights are turned on or not. This was in combination with whether the system had a personal smart home system such as Cortana which can be found on Windows laptops and phones. The respondents consisted of more than 1500 Amazon mechanics whom all received one of the four different versions of the survey and they replied with their most favored smart home application. The definitions of the smart homes did stimulate the users with specific expectations. The device-centric definitions lead to more confined responses, while the respondents which saw data stream-based definitions were more inclined to describe high-level applications they desired (Newman and Dutta, 2017).

Another way to identify the needs and expectations of the users is to analyze the data which is generated by smart home appliances. Smart home appliances provide everyone with better information, more control, and insight into the everyday things which we need to function, both known and unknown (ISO, 2016). By unknown, it is referred to things most people do not think about until they become a problem, such as the home power grid. Furthermore, smart home data enables manufacturers the ability to track objects with real-time data, to find out how consumers are using a certain product, and to determine which features are the prominent ones. This creates a better understanding of what alterations should be made to the existing or new products to help improve adoption and purchasing rates. Being able to know what the users do with the product is something firms want to leverage and IoT makes that readily available (ISO, 2016).

A great example is Amazon's Alexa which is a voice-controlled smart home system that provides a set of built-in smart home capabilities such as controlling cameras, door locks, entertainment systems, lighting, and thermostats (Amazon, 2018). This device can be tailored to the specific needs of the user by relying on learning algorithms to absorb user's preferences and needs. Evidently, Alexa is not able to follow every command, some actions are not learned or programmed yet to the device. Nevertheless, this provides a great opportunity for developers to analyze the data generated by Alexa in order to gain insight into the interests and unfulfilled needs of customers. This data can further be used in the New Product Development process to create new products or services which produce an even better fit with customer needs and requirements.

### *5.1.2 Continuous product feedback*

Until recently, product development has typically been initiated and carried out within the boundaries of a firm, and with feedback from users collected in the early stages of the NPD process. Finally, the release to users represents the closure of the development effort and the time at which the firm instead adopts a 'maintenance mode' of the finished product. The IoT paradigm brought a change to this as it allows for completely new engagement methods with users, and rising opportunities to learn about user behavior. As products go online, firms are able to monitor them, collect data on how they perform, predict when they break, know where they are located, learn about when/how they are used or not used (Olsson, 2016).

These opportunities also affect the user feedback which is collected. Traditionally, user feedback has been collected mostly in the pre-development and during development phases by using low-tech techniques such as e.g. paper-based mock-ups, prototypes, and drawings. However, in an IoT context, the collected data from previous product development processes and real-time product feedback from products which are in use provide a valuable feedback stream. Olsson (2016) stated that user feedback gathered in the early phases of product development is now complemented with product data revealing real-time product use, and user feedback is no longer collected only in the early phases of product development, but continuously after product release and deployment. This indicates that the post-deployment phase that has been considered to mark the end of the development process now becomes the start. Instead of 'develop – deliver' we now 'deliver – develop' in the sense that IoT products allow for continuous development and improvement of products also after deployment to users (Olsson, 2016).

### *5.1.3 Differentiation and new revenue models*

Kejriwal & Mahajan (2016) studied the impact of the IoT on the Commercial Real Estate (CRE) industry, which includes the concept of smart homes and smart buildings. They stated that value created by connected systems and IoT applications can not only improve efficiency but provide new opportunities for differentiation and new revenue models.

According to Kejriwal & Mahajan (2016), through the data generated by IoT-enabled buildings, CRE owners have an opportunity to differentiate themselves through analyzing the data to identify unmet customer demands, provide more sophisticated services to their tenants and transform tenant and user experience, and contribute to a broader ecosystem. By offering services which the competition is lacking as of yet, CRE firms using IoT applications are able to charge premium prices and improve their margins. Actually, tenants will likely expect IoT features in buildings, which makes non-smart homes less attractive. The opportunities they presented are:

• **Focus on employee and occupant health and productivity:** sensors capture data on occupant health, augmented reality to guide workers, analyze data about the movement of individuals to design better tasks to boost the creativity

• **Service innovation to tenants:** use IoT data to create differentiation right from the development stage. Developers can adapt design and construction of CRE buildings to the changing consumption patterns by using tenants' and end-users' behavioral data

• **Benefits to the broader ecosystem:** sustainability analytics can help CRE companies decrease their carbon footprint, have more sustainable properties in their portfolio, and eventually differentiate themselves in the marketplace (Kejriwal & Mahajan 2016).

## 5.2 The Effect of Smart Home data on the development cycle time and costs in the NPD process

As stated in chapter 4.3, the last two critical success factors (development time and costs) are intertwined as many development costs are related to time, both costs of employees and the firms cost of capital increase as the development cycle lengthens. Therefore, in this paragraph, various pieces of literature will be introduced which explain the link between smart product data and the effect on the development cycle time and cost.

Several researchers have indicated that big data, which includes smart (sensor) product data can improve firms' NPD process in many ways (Manyika et al., 2011; Tan & Zhang, 2016; Relich & Pawlewski, 2017; Porter & Heppelman, 2014). Capgemini (2012) estimated that the process improvements which are enabled by big data may lead to an average 26% performance improvement over a 3-year period. Manyika et al. (2011) stated that predictive modelling using big data can cut 3–5 years off the nearly 13 years healthcare companies usually require to bring a new drug to market. In today's economy, development cycle time is recognized as a significant aspect of innovative firms to gain competitive advantages, especially in high-tech and fast-cycle industries where the product life cycles are often shorter than 3 years. Furthermore, big data can help firms improve the NPD process by making the development of new products faster and less costly (Tan & Zhang, 2016). Tan & Zhang (2016) have studied three firms (Xiaomi, Lenovo, and Dididache) in the Chinese industry and found out that they successfully incorporated big data to make their NPD process faster and less costly. These Chinese firms were able to launch new products in rapid succession over short periods of time due to big data activities in their NPD process. As a result of this study, Tan & Zhang (2016) introduced three principles which serve as a blueprint for managers for using big data to make NPD faster and less costly: autonomous and parallel NPD teams, customer connection, that is, a focus on building a close relationship with customers and better understand their needs via big data analytics and lastly, innovation ecosystem which represents an innovation and market-testing environment to develop new products at fast speeds and lower costs (Tan & Zhang, 2016).

Moreover, the stage of concept development in the NPD process is crucial as it precedes the more expensive and long-term development of the new products and commonly the decisions in the concept development stage is based on metrics as cost and time of the NPD project. Relich & Pawleski (2017) stated that case-based reasoning (CBR) can be used to improve this process. CBR implies using the information related to previous products by adapting a past design stored in the case base that closely matches attributes of designing a new product. This CBR approach is initiated with collecting data of a new product that can regard customer requirements for a new product or trends in the market, this data can also include smart product data. They noted that this approach enables cost estimation of much more precisely through combining the past results of existing products with modifications referring to newly designed components. The greatest benefit of it is that it can significantly reduce the need to design a new product completely from scratch and subsequently reduce the cost and time of completing an NPD project (Relich & Pawlewski, 2017). This opinion is endorsed by Xu et al. (2016), their research confirmed that smart product data contribute to big data analytics and that big data facilitates the performance and reduces the costs of NPD activities. In this study, they also mentioned that Vreeman (2014) listed some that big data analytics may help business with budget constraints to better manage their NPD processes.

However, Durmusoglu et al. (2006) objected that the time and cost will not self-evidently decrease by obtaining more data, they drew a distinction between two different teams which are vital for the process, Information Technology (IT) and NPD-teams. There must take place an effective interaction between these teams in order to realize the reduced development time and costs. If NPD teams want to utilize smart product data for the NPD process, they need more knowledge of the data and this can be obtained through increased support from IT teams, consequently, this support is paired with higher NPD costs and relatively stable increase in speed. Moreover, the results provide evidence that more IT is better for NPD flexibility (Durmusoglu et al., 2006). The lesson that can be drawn here is that there exists a bottleneck for NPD teams for realizing smart product data potential which is the lack of knowledge about the data and need of increased IT support.

# 6. EMPIRICAL RESULTS

The empirical part of this research is carried out through the means of expert interviews. The interviews include six respondents which were hand-picked from various countries such as the UK, Germany, Belgium and the Netherlands. The respondents are either a professor or an IoT professional from companies which make use of IoT and smart home applications as British Telecom, T-Mobile, and Orange. For each question which was asked, a paragraph will be dedicated to summarizing the answers and opinions of the experts on that particular question, the answers of the experts on the main questions and their descriptions can be found in Appendix A.

### *6.1.1 Identification of Customer Needs*

**What effect do you expect the data obtained from smart home to have on the ability to identify customer needs/requirements in the NPD process?** There was quite a general consensus among the experts that products and services will be more personalized and fit better with the customer demand through analyzing smart home data. Smart home devices are able to collect data that maps user behaviors. This data can further be exploited to adapt products better to the needs of the end users. The ability to identify needs and give corresponding support will be sustainable, continuous, fast, and easy. They also argued that a connected object gets a product developer closer to the end-customer. Often it creates a direct relationship that did not exist before, lots of products are sold through resellers and the developer does not have any contact with the end-customer. By collecting data from the object and therefore end-customer, the product developers can understand much better what the customer needs are, for example how often the product is used, when, where, with which kind of “profile” etc. This helps the product developers to better fit the market customer.

However, one of the experts raised a very interesting point, he mentioned that the data which is collected from smart homes are very fragmented, this implies that users have a few smart home devices from different individual brands which generate much random information and are not integrated well together due to lack of standardization. According to him, if the firms adhere to one standard for smart homes, data will become less fragmented and therefore more meaningful and provide much better insight into customer needs for product developers.

**For what type of new products could smart home data be useful? Which business models could it give rise to?** The experts noted that a distinction must be made between B2B and B2C whereas, in the B2B world, the driver to connect objects is often to be more efficient, cheaper, bring more quality and in the B2B world, the driver to connect objects is often to be more efficient, cheaper, bring more quality. So, the motive of the product developers could differ based on their customer characteristics but normally speaking, smart home data can be used to identify the needs of the inhabitants and improve their ease of life/quality of life with incremental innovations as improving other home appliances (television, fridge, furniture, tables, chairs, beds, shower, alarm systems etc.). IKEA, for example, is taking small steps in fulfilling the smart home’s potential with their ‘Home Smart’ lighting (Barrett, 2017). Anyhow, an idea which was discussed with the experts was that of embedding sensors in furniture with no extra cost for the consumer and using the data to analyze how the furniture is used and utilize the data in the NPD process of new furniture. Also, it could benefit incremental innovation in improving the energy management systems in homes including heating, lighting and water management. Furthermore, the experts mentioned that smart home data could contribute to the work of architects by giving them more insights of the motion in the home, this way they can adjust the home layout to the specification of the customer needs. In addition, smart homes will really take off when fully equipped new homes are built with already embedded and pre-wired smart home systems in them. This would have e network externalities effect where the installed base will grow and adoption rates will rise, this, in turn, will provide developers more accurate and less fragmented data. Unfortunately, fully equipped smart homes is not actively promoted yet and customers are also not passionately asking for it.

Nevertheless, the expert from British Telecom (BT) mentioned that there is a bottleneck. Namely, innovative companies which could use the smart home data for their NPD do not straightforwardly have access to this data so they need to procure this privacy sensitive data which could be really difficult. Commonly, firms like Telecom providers install and support the smart home systems and do not utilize that data, so the ones which are possessing the data are not really interested in using the data for other purposes. He found it a very interesting prospect that a firm would be built on the idea to install or support home system with the full intent to harvest the data to create new products. As of yet, no company that he knows of is doing this.

**What are the benefits of using smart product data as an innovation tool over currently used techniques (E.g. brainstorming, focus groups, observations, market research) for identifying customer needs?**
The answer to this question was quite clear and outspoken by all the experts that collecting data from end users is direct, continuous, cost-effective and easy. Moreover, instead of asking people about their needs, you can analyze their behavior through real-time data which might address latent needs, needs which the customer does not know of. In addition, the reach can spread far distances and a higher number of people than conventional techniques. Also, it gives the opportunity to analyze people based on different characteristics such as age, geography, cultures, and so on. However, in data science, more data not only means more opportunities but also more complexity. Solving that complexity will pave the way for those opportunities. In the experts' opinion, within this endeavor, observing the trends becomes continuous as well. They would say this is the most important benefit of collecting data from smart home products. By exploiting this continuity, products can be improved fast, advertisements can be highly specialized, etc.

### *6.1.2 Effect on Development Cycle Time*

**What effect do you expect the data obtained from smart home devices to have on the development cycle time of these new products/processes?**
The opinions were divided on the effect of the time element, some experts claimed that the more data you collect, the more processing power you need. This can have some impact on the performance of the systems. However, they do not think that development time will be dependent on the amount of data that will be collected. It relates more to the selection and risk of technologies, and the availability of knowledge/ resources in the company. Other experts think that the effect and acceptance of a product can be measured directly and therefore products are adapted much faster. Another expert stated that with the right algorithm and analytics the development cycle time will be faster. The drawback of large volumes of data is that there is too much data to analyze if you do not know what you are looking for, which will increase the cycle time. If the firm has experience and intelligent data analysts at its disposal who know what to look for in the sea of data, the development cycle time can dramatically be reduced.

### *6.1.3 Effect on Development Costs*

**What effect do you expect the data obtained from smart home devices to have on the development costs of these new products/processes?**
Here again, there was more or less a consensus among the experts that smart home data will not necessarily decrease the development costs and, in some cases, even increase in the short term. One expert argued, when the amount of data is higher, hardware has to be scaled accordingly and this can have some impact on operational cost. However, he did not think there is a relation with development costs of the NPD process. They mentioned that different factors play a role against each other: (1) IoT expertise such as sensors, electronics, connectivity, data platforms are often far from the core expertise of product makers, so they have to invest a lot in those new technologies. (2) New business models also mean business risks. Connecting a product and bringing a new service to market can lead to success stories but also to non-adopted services. The Vice President of Connected Home T-Mobile stated that the development costs will be higher at the beginning and later decrease as more data is available and the development team has to learn how to manage this efficiently, this implies high fixed costs and lower variable costs.

## 7. CONCLUSION AND RECOMMENDATIONS

The purpose of this research was to provide firms with some insight into how (smart) home data can contribute to a successful NPD process. The paper examined the various elements and characteristics of the Internet of Things, Smart Homes, and the NPD process. Furthermore, literature was reviewed to find whether any research has been done before on the effect of smart home data on the success factors of the NPD Process. This research also encompassed an empirical study where six IoT and Smart Home experts from different countries and recognized companies were interviewed to obtain their opinions whether smart (home) data can contribute to a successful NPD process. This was also the most interesting part of the study where very interesting points were raised and bottlenecks in the process were identified.

The literature review and empirical study answer the main research question to a great extent, namely, that smart homes can contribute to the NPD process by identifying and maximizing the fit with customer needs through analyzing smart home data. The sub-questions were based on how (smart) home data can contribute to a successful NPD process by the hand of analysing the effect of this smart data on Schillings (2013) three key success factors: (1) maximized fit with customer requirements, (2) minimized development cycle time, (3) controlled development costs.

The answer to the first research question is that both the literature and the experts agree that smart home data facilitates identifying customer needs and requirements. The literature review indicated that smart home data clearly has a positive effect on identifying customer needs, smart home data enables manufacturers the ability to track objects with real-time data, to find out how consumers are using a certain product, and to determine which features are the prominent ones. This creates a better understanding of what alterations should be made to the existing or new products to help improve adoption and purchasing rates. It also provides firms with real-time feedback which can be used for the development of new products and it could help firms differentiate their portfolio's. On the other hand, the experts all agreed on the positive effect of the first success factor that the ability to identify needs and give corresponding support will be more sustainable, continuous, fast, and easy through analyzing customer smart (home) data.

The second and third research questions which focussed on the effect of smart (home) data on the development cycle time and costs of the NPD process were also answered by literature and the experts, namely, that these two factors could be reduced but, in some instances, it would increase. Tan & Zhang (2016) showed in their research that smart product data and big data analytics can actually be utilized to decrease the cycle time and cost of the NPD process. They analyzed three Chinese firms which were successfully doing this (Xiaomi, Lenovo, and Dididache). This indicates that smart data is being used in the NPD process but by some firms but only to some extent and only a few Chinese firms are doing this as of yet. On the second and third success factor, development cycle time and costs, the experts were less outspoken if it would decrease when smart (home) data would be utilized. Some experts think it relates more to the selection and risk of technologies, and the availability of knowledge/ resources in the company whether the development cycle time would be decreased. Other experts think that the effect and acceptance of a product can be measured directly and therefore products adapted much faster. In addition, the experts think that the development costs would remain more or less unchanged, they agreed that costs will be higher at the beginning (fixed costs) to acquire the electronics and to develop expertise, later on, this would decrease as more data is available (through the already acquired machines) and the development team has learned how to manage this efficiently.

Figure 5 displays a summary of the findings and an overview of which literature and experts indicated that smart home data would either contribute (positive effects, which are marked with a plus sign '+') or withhold (negative effects, which are marked with a minus '-') each success factor of the New Product Development process. Taking into account that the realization of positive effects is dependent on certain criteria and conditions such as the availability of IoT knowledge and resources within a company, the positives can be seen as opportunities and the minuses as pitfalls for companies. It must be noted that a positive effect on development cycle time and costs means that they will decrease. Some articles did not analyze all of the three success factors, hence, that particular factor which was not discussed will be marked by '/'. Any box which contains ' + - ' indicates that the literature or expert thinks that that particular success factor would be affected in both ways and remain somewhat unchanged in some cases. A comparison of the findings between literature and experts which was explained in the previous two paragraphs can be derived from the overview below.

What can be concluded from the literature and the expert study is that there is certainly potential for firms to harvest the smart product data and use it for future NPD processes to identify customer needs and reduce the development cycle time and costs. However, some bottlenecks and useful new finding were also discovered through the empirical study. Namely, in the interviews with the experts which included three experts from renown Telecom companies who sell smart home systems, it came to light that they do not harvest the data from their customers' smart home data and reuse it for NPD purposes and no one is doing this as of yet. They merely sell the systems as products or as services and has no intention at all to use the data for other purposes. The latter indicates that firms who are innovative and use smart (home) data for NPD purposes need to firstly procure this privacy-sensitive data from telecom companies in order to use it for innovation purposes, which makes it very difficult. In addition, the data collected from smart homes is fragmented which renders it as rather meaningless. Only if smart homes become standardized and well-integrated, the data obtained from them would make more sense and give a better picture of the needs of the customers.

Moreover, it became clear that the telecom providers are currently really struggling to create a sound business case for their smart home systems as they simply sell the devices, or service and have no real value proposition. British Telecom's expert mentioned something radical must happen to create a user base for smart home systems and increase the adoption rate, this can be done by following Facebook's example to not charge people for using their smart home devices but to harvest the data and potentially using it for innovation purposes. He was very intrigued by this research and thinks that the idea for telecom companies to harvest data and use it for innovation purposes is very promising and something which he will definitely take on board and advises other firms to do so too.

This paper has examined the opportunities provided to firms. The following **recommendations** can be made to firms based on the results of this research:

• Firms are advised to install and support smart home systems with the full intent to harvest the data obtained from them and exploit the data for innovation purposes

• Home builders are recommended to build new homes with well-integrated, pre-installed and pre-wired smart home systems

• Effective communication should take place between NPD teams and IT-teams in order to realize the reduced development time and costs in the NPD process

• The smart home industry should develop one standard where all smart home systems can adhere to, in order to realize standardizations and less fragmentation

| Literature | Identifying customer needs | NPD Cycle Time | NPD Costs |
|---|---|---|---|
| ISO (2016) | + | / | / |
| Olsson (2016) | + | / | / |
| Kejriwal & Mahajan (2016) | + | + | + |
| Tan & Zhang (2016) | / | + | + |
| Durmusoglu et al. (2006) | / | + - | - |
| Manyika et al. (2011) | / | + | / |
| Relich & Pawleski (2017) | / | + | + |
| Xu et al. (2016) | / | / | + |
| **Experts** | | | |
| Gilles Robichon, IoT Solution Expert at Orange Telecom (the Netherlands) | + | + | - |
| Thomas Rockmann, CEO Smart Home at Deutsche Telecom T-Mobile (Germany) | + | + - | + - |
| Sam Lefebvre, Expert embedded systems, and IoT at Saleconix Kortrijk (Belgium) | + | + - | + - |
| Okan Türkeş, IoT expert and Applications Engineer at Universal Electronics (the Netherlands) | + | - | + - |
| Nikolas Nedkov, Senior IoT, and Smart Home specialist at British Telecom (UK) | + | - | + |
| Robin Effing, IoT expert and Assistant Professor at University of Twente (the Netherlands) | + | + - | + - |

**Figure 5: Overview of the findings**

All in all, the results suggest that smart (home) data does facilitate firms in identifying customer needs for the NPD process and that the development cycle time and costs remain somewhat unaffected although it can also decrease depending on the selection and risk of technologies, and the availability of knowledge within the company.

Evidently, obtaining customer' smart product data is paired with privacy concerns for firms. Firms should be transparent towards their customer by protecting their data but also by letting them know that it is being used for innovation purposes. The CEO of T-Mobile's Smart Home Project mentioned that in the first place it is important that there is a clear law-structure about collecting data. With GDPR steps in the good direction has already been made. Next, to it, devices need to process data and collect it to central servers. Advanced data analytics can be used to analyze that data in order to improve products, provide content suggestions, doing predictive actions.

## 8. RESEARCH LIMITATIONS AND FUTURE RESEARCH

Because of the novelty of the IoT paradigm and in specific Smart Homes, research examining smart (home) use and effects are still scarce. Hence, of this, there is little academic research that discusses smart homes in relation to the NPD process. The literature used in this research therefore mostly originates from consultancy firms or research departments from businesses. However, organizations currently use smart product data analytics to understand their customers better and to achieve optimal customer engagement (Forrester, 2011). The distinction which must be made here is that smart (home) product data cannot solely account for new idea's or products, it is merely raw data which functions as a tool to facilitate the innovation process. Managers should turn the data into insights to satisfy customer needs and create a competitive advantage. Another limitation is the small rather small sample size (n=6), one could argue the experts' opinions in this research represents only an indication of the common opinion of all IoT and Smart Home experts. Be that as it may, the experts were carefully and purposefully picked from different countries, functions, and companies to represent a better picture of the general opinion.

### *8.1.1 Future research*

As of yet it is not clearly known by the literature and the experts whether companies in Europe and the US are using smart product data for their NPD processes. As mentioned in paragraph 5.2, Tan & Zhang (2016) studied three companies in China, which were successfully doing this. Future research could be done in European and American firms where innovation is taking place based on smart product data to study what the effect is on identifying customer needs, development cycle time and costs, and whether they are successful.

Furthermore, neither literature nor the experts were certain about the effect of smart product data on the development cycle time and costs. This is another field where substantial economies and efficiency could be realized. Hence, it is recommended for future research to dig deep into the exact impact on costs and time in the development process.

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# 10. APPENDIX

**Appendix A**: Expert overview and answers

| | Expert Panel | What effect do you expect the data obtained from smart home devices in specific, to have on the ability to identify customer needs in the NPD process? | What effect do you expect the data obtained from smart home devices to have on the development cycle time of these new products/processes? | What effect do you expect the data obtained from smart home devices to have on the development costs of these new products/processes? |
|---|---|---|---|---|
| **1** | **Mr. Gilles Robichon - IoT Solution Expert at Orange (Amsterdam, Netherlands) also the author of Management book: Mastering the Internet of Things** | A connected object gets a product maker closer from the end-customer. Often it creates a direct relationship that did not exist before. By collecting data from the object and therefore end-customer, the production company can understand much better what the customer needs are, for example how often the product is used, when, where, with which kind of "profile" etc. This helps the product designer/maker/manager to better fit the market customer | Through the fact that IoT objects go from offline to online and analysis become more and more real-time, the effect and acceptance of a product can be measured directly and therefore products adapted much faster. Through functionalities such as “remote software upgrade” | Different factors playing against each other: (1) IoT expertise such as sensors, electronics, connectivity, data platforms often far from the core expertise of product makers, so they have to invest a lot in those new technologies. (2) New business models also mean business risks. Connecting a product and bringing a new service to market can lead to success stories but also to non-adopted/successful services. |
| **2** | **Mr. Thomas Rockmann - Vice President Connected Home Deutsche Telekom AG (T-Mobile, Cologne Germany) / Joint-CEO Smart Home Project** | It will increase customer experience: products and services will be more personalized and fit better with the customer demand. There will be more "moments of positive customer surprises" | With the right algorithm and analytics: faster | Higher at the beginning and later decreasing as more data is available and the development team has to learn how to manage this efficiently |
| **3** | **Mr. Sam Lefebvre – Expert embedded systems and IoT from Kortrijk, Belgium** | Smart home devices are able to collect data that maps user behaviors. This data can further be exploited to adapt products better to the needs of the end users | Research in that field is needed but, in my opinion, the more data you collect, the more processing power you need. This can have some impact on the performance of the systems. However, I don't think that development time will be dependent on the amount of data that will be collected. It relates more to the selection and risk of technologies, and the availability of knowledge/ resources in the company | When the amount of data is higher, hardware has to be scaled accordingly and this can have some impact on operational cost. I don’t think there is a relation with development cost |
| **4** | **Dr. Okan Türkeş – IoT expert and Applications Engineer of Universal Electronics (Enschede, Netherlands)** | The ability to identify needs and give corresponding support will be sustainable, continuous, fast, and easy | The most important competition remains on the data. This is also a common belief and trend in the IoT domain. The companies which can mine the data well will eventually end up with creative software solutions. They should reorganize their corresponding divisions internally well in order to support useful data mining and meaningful (and frequent) software releases. Otherwise, they will be affected dramatically with poor product qualities and longer development times | Data storage costs have always a declining trend, but companies should consider this cost. data security and privacy will need new methods while the apps/services will continue to evolve. Thus, engineering will need a budget to sustain the changes |
| **5** | **Mr. Nikolas Nedkov – Senior IoT and SmartHome specialist at British Telecom (UK)** | Although the data obtained from smart home devices is very fragmented as of yet, it can definitely identify customer needs. However, the company must have access to the data and have the intention to use it for identifying customer needs (which is not the case with Telecom companies) | The problem is that we collect large volumes of data but what do we want to get out of this data? I think it will lead to faster development if you have enough skilled data analysts which know what they are after. So, if they know what they are looking for it would be faster. | You have to look at which functions are useful if you ideally can narrow it down to the most essential features it will reduce development costs. So, based on data you can see which functions are needed and therefore the long chain and features and functions can be cut down and become cheaper. It helps you to really nail down your minimal value proposition. |
| **6** | **Mr. Robin Effing – Assistant Professor at University of Twente and IoT expert (Netherlands)** | Smart home data gives us a better picture of how people behave in their homes. All the needs in the home such as energy needs can be analyzed. Through big data analysis and predictive analysis techniques, the activity in homes can identify the need for certain new products or even existing products | IoT data enables faster and more efficient NPD processes and will speed up the development cycle time. However, we can not only rely on IoT data in the NPD process but also on other data sources, therefore, you need data triangulation | Acquiring skilled data engineers and scientists will be a vast investment for any company so it will not necessarily reduce the development costs initially (due to high fixed costs). However, the running costs for the long-term are very low which makes the business case very interesting |